Univerza v Ljubljani
Fakulteta za elektrotehniko



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University of Ljubljana, Faculty of Electrical Engineering



25. SEMINAR RADIJSKE KOMUNIKACIJE 2022

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Predgovor

Spoštovana bralka, spoštovani bralec zbornika 25. seminarja Radijske komunikacije, pred vami je zbornik prispevkov, ki obravnavajo obsežno področje radijskih komunikacij.

Od prvih ugotovitev o obstoju elektromagnetnih valov škotskega fizika Jamesa Clerka Maxwella in poznejših poskusov Heinricha Rudolfa Hertza, ki je Maxwellovo teorijo potrdil, je minilo več kot 150 let. Malo za tem, konec 19. stoletja, je Nikola Tesla izumil in patentiral prvi radio, njegovo odkritje pa je Guglielmo Marconi uporabil za prve komunikacije – prenašal je telegrafske signale v obliki Morsejeve abecede, ker prvi oddajniki še niso bili primerni za prenos govora ali zvoka. Prve radijske postaje smo dobili v dvajsetih letih 20. stoletja, razvoj pa je šel strmo navzgor po letu 1947, ko so v Bellovih laboratorijih izumili tranzistor. Radijske naprave se je dolga desetletja uporabljalo predvsem za poslušanje radia, pozneje gledanje televizije, pa tudi v vojaške in druge namene. Pravi razmah radijskih komunikacij za zasebno rabo, ki je omogočil dvosmerno komunikacijo, se je začel s pojavom mobilnih celičnih komunikacij v začetku osemdesetih let prejšnjega stoletja. Danes "živimo" generacijo pet, prvo smo ugasnili, druga, tretja in četrta pa so še vedno v uporabi. Raziskovalci že razmišljamo naprej, o šesti, sedmi in naslednjih generacijah. V slednjih naj bi bile uporabljene tehnologije, ki so danes še v fazi razvoja, čez deset ali dvajset let pa bi bile lahko povsem običajen del komunikacijskih naprav. Te, po nekaterih napovedih, naj ne bi imele več oblike in funkcionalnosti, ki jo imajo danes.

V tem zborniku boste našli veliko zanimivih tem o sodobnih in novih tehnologijah, povezanih z radijskimi komunikacijami. V prvem delu zbornika so obdelane aktivnosti, povezane z RF-spektrom avtoric Janje Varšek in Mete Pavšek Taškov, sledi prispevek o prihodnjih sistemih radijskih komunikacij za železnice, avtorjev Romana Osredkarja in Matjaža Jelena, avtor Guillaume Noel piše o omrežju generacije 0 v Sloveniji – Sigfoxu, sledi prispevek o uporabi radijskih komunikacij pri napredku športnikov avtorja Antona Kosa in prispevek Luke Snoja o komunikaciji z nevtroni. Temu sledita dva prispevka o tehnologiji WiFi, najprej avtorjev Mitje Golja in Gorazda Penka in nato Klausa Samardžića, prvi del pa zaključujeta prispevka Marjane Senčar Srdič o uvajanju video analitike v pametna mesta in Rudolfa Sušnika o testiranju omrežij 5G, ki so v uporabi v industrijskih vertikalah. Drugi del zbornika začenjata dva prispevka Matjaža Vidmarja, prvi o meritvah smernosti anten in drugi o pozabljeni anteni cigari. Temu sledi prispevek Boštjana Batagelja o sistemu satelitov Starlink, nato prispevek o komunikacijskih tehnologijah interneta stvari Boštjana Snoja, prispevek Boža Mišovića o uporabi govornih aplikacij v 4G/5G in prispevek Draga Majcna o standardizaciji na področju tehnologije DECT. Drugi del zaključujejo prispevki velikih ponudnikov telekomunikacijske opreme: Tamas Boday piše o zasebnih omrežjih 5G, Csaba Novak o časovno-kritičnih komunikacijah, Iva Lesić o odprtem radijskem dostopovnem omrežju in Marko Grebenc o nesamostojnem omrežju 5G. V zadnjem delu zbornika je šest prispevkov: Mirko Ivančič piše o sistemih za avtomatsko detekcijo radijskega prostora, Aleš Švigelj in Tomaž Javornik o uporabi mobilnega telefona za oceno odtisa radijskega okolja, Filip Turčinović o razvoju SAR platforme za avtonomno detekcijo objektov, Sanja Marković o ocenjevanju elektromagnetnih sevanj, Darko Lekić o pomembnosti sinhronizacije v TK omrežjih in Attila Hilt o gigabitnih prenosnih radijskih sistemih. Zadnji prispevek v zborniku je o razvoju in uporabi metamaterialov v radijskih komunikacijah avtorja Marka Bosiljevca.

Znanstveniki in inženirji smo vsekakor lahko ponosni na dosežke znanosti, ki je omogočila človeštvu udobno življenje in jih hkrati tudi veliko obvarovala. Po drugi strani pa moramo prevzeti del odgovornosti za to, da smo ljudje v resničnem svetu vedno bolj odtujeni drug od drugega. Množice komunikacijskih naprav, ki zmorejo skoraj vse, so nas ujele v mehurček, v virtualni svet, v katerega vstopimo, ko vzamemo v roke pametni telefon, tablico ali se usedemo pred zaslon računalnika. Seveda so vse omenjene naprave nujno povezane v svetovni splet, noč in dan, vse dni v letu. Kljub močni navezanosti nanje – ne bi se jim odrekli za nobeno ceno –, se v ljudeh vseeno rojevajo črvički dvoma o njihovi koristnosti ali škodljivosti. In prav zato moramo strokovnjaki sestopiti z naših znanstvenih "prestolov" in uporabnikom v poljudnem, vsakomur razumljivem jeziku pojasniti sicer tehnično zapletene dosežke znanosti in tehnologije. In to ponavljati znova in znova. Kot je že rekel veliki Albert Einstein: "Večina temeljnih idej znanosti je v bistvu preprosta in se praviloma lahko izrazi v vsem razumljivem jeziku".

Organizatorji seminarja se zahvaljujemo vsem predavateljem za njihov neprecenljiv prispevek, prav tako pa tudi domačim podjetjem in posameznikom za sodelovanje in pomoč pri pripravi ter izvedbi seminarja. Zahvala gre odgovornim v naših podjetij in institucijah, ki so svojim strokovnjakom omogočili udeležbo na seminarju in s tem podprli to dejavnost.

Želiva vam, da v zborniku 25. seminarja Radijske komunikacije najdete uporabne vsebine, ki vam bodo koristile vsak dan. In če končava še z eno domislico Alberta Einsteina: "Izobraževanje je tisto, kar ostane, ko človek pozabi, kaj se je učil v šoli".

Ljubljana, februarja 2022

Tomi Mlinar in Boštjan Batagelj
urednika

Foreword

Dear reader of the proceedings of the 25th seminar on Radio Communications, here is a collection of 25 papers covering diverse areas of radio communications.

More than 150 years have passed since the first description of electromagnetic waves by the Scottish physicist James Clerk Maxwell and the subsequent experiments of Heinrich Rudolf Hertz, who confirmed Maxwell's theory. Shortly afterwards, at the end of the 19th century, Nikola Tesla invented and patented the first radio. His invention was used by Guglielmo Marconi for the first communications. Marconi was experimenting with transmittion of telegraphic signals in the Morse code over the distance. Transmitters at that time were not able to transmitt speech or sound. First radio stations started to broadcast in the 1920s. After the invention of transistor in 1947 at Bell Laboratories the development of radio communications steeply increased.. For many decades, radio devices were used mainly for radio listening, watching television, and also for military and similar purposes. The real boom in radio communications for private use, which enabled two-way communication, began with the introduction of the first generation of mobile cellular communications in the 1980s. Today, we are "living" generation five, the first has been shut down, the second, third and fourth are still in use. Researchers are already considering ahead, about the sixth, seventh and next generations. The latter are supposed to use technologies that are still in the development phase today, but in ten or twenty years they could become normal part of communication devices. These, according to some predictions, are no longer supposed to have the form and functionality they have today.

In this proceedings you will find many interesting topics on modern and developing technologies related to radio communications.

The first part of the proceedings covers the following papers: Activities related to the RF spectrum by Janja Varšek and Meta Pavšek Taškov, Future radio communication systems for railways by Roman Osredkar and Matjaž Jelen, Construction of 0G network in Slovenia - Sigfox by Guillaume Noel, The use of radio communications in sports applications by Anton Kos, and Neutron communications - an alternative to radio communications by Luka Snoj. These are followed by two papers on WiFi technology, the first by Mitja Golja and Gorazd Penko and the second by Klaus Samardžić. The first part concludes with papers Introduction of video analytics in smart cities by Marjana Senčar Srdič and Testing 5G networks used in industrial verticals by Rudolf Sušnik.

The second part of the proceedings begins with two papers by Matjaž Vidmar, the first on measurements of antenna directivity and the second on the forgotten cigar antenna. These are followed by Boštjan Batagelj's paper on the Starlink satellite system, Boštjan Snoj's paper on Internet of Things communication technologies, Božo Mišović's paper on the use of 4G/5G voice applications and Drago Majcen's paper on DECT standardization. The second part concludes with contributions from telecommunications equipment providers: Tamas Boday's paper covers Private 5G networks, Csaba Novak's paper is on Time-critical communications, Iva Lesić's paper deals with Open RAN and Marko Grebenc's paper is on Non-standalone 5G network.

There are six articles in the last part of the proceedings: Mirko Ivančič's on systems for automatic detection of radio space, Aleš Švigelj's and Tomaž Javornik's on the use of mobile phones to assess the footprint of the radio environment, Filip Turčinović's on the development of SAR platform for autonomous detection of objects, Sanja Marković's on assessment of electromagnetic radiation, Darko Lekić's on the importance of synchronization in

telecommunication networks and Attila Hilt's on Gigabit radio for anyhaul. The last article in the proceedings is on the development and use of metamaterials in radio communications by Marko Bosiljevec.

Scientists and engineers can certainly be proud on the achievements of science, which have enabled humanity to live more comfortable and can sometimes even protect people's lifes. On the other hand, scientists need to take responsibility for making people increasingly alienated from each other in the real world. Crowds of communication devices, capable of almost anything, have caught us in a bubble, a virtual world we enter when we pick up a smartphone, tablet, or sit down in front of a computer screen. Of course, all these devices must be connected to the Internet, night and day, 365 days a year. Despite user's strong attachment to these devices - they would not stop using them for anything in the world - doubts about their usefulness or harmfulness are still present. And that is why experts need to step down from their scientific "thrones" and explain technically complex achievements of science and technology to users, in understandable language. And repeat this over and over again. As the great scientist Albert Einstein said: "Most of the fundamental ideas of science are essentially simple, and may, as a rule, be expressed in a language comprehensible to everyone."

The organizers of the seminar thank all the lecturers for their invaluable contribution, as well as companies and individuals for their cooperation and assistance in the preparation and implementation of the seminar. Thanks go to those responsible in our companies and institutions who enabled their experts to participate in the seminar and thus supported this activity.

We wish you to find the content of the proceedings of the 25th seminar on Radio Communications useful in your everyday life, either professional or private. Let us conclude this foreword with another quote of Albert Einstein: "Education is what remains after one has forgotten what one has learned in school."

Ljubljana, February 2021

Tomi Mlinar and Boštjan Batagelj,
editors

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I.

Aktivnosti na področju upravljanja z RF spektrom

RF spectrum management update

Janja Varšek, Meta Pavšek Taškov

Agencija za komunikacijska omrežja in storitve Republike Slovenije

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Povzetek

Agencija za komunikacijska omrežja in storitve (AKOS) upravlja z radijskim spektrom v Republiki Sloveniji na podlagi javnega pooblastila skladno z Zakonom o elektronskih komunikacijah. Poleg učinkovite izrabe radiofrekvenčnega spektra in zagotavljanja učinkovite konkurence na trgih brezžičnih storitev elektronskih komunikacij so njene prednostne naloge predvsem uporaba radiofrekvenčnega spektra za dosego največjega možnega družbeno ekonomskega napredka, zagotovitev stabilnega okolja za uporabnike radijskega spektra, vzpodbujanje naložb in razvoja ter čim hitrejše uvajanje novih tehnologij skladno z usmeritvami na EU in nacionalnemu nivoju.

V letu 2001 se je Slovenija povzpela na lestvici DESI indeksa iz 16. mesta v letu 2020 na 13. mesto predvsem zaradi uspešno izvedenega javnega razpisa z javno dražbo. S splošno oceno 53,2 za povezljivost uvršča na deveto mesto v EU in ima dodeljenih 98% spektra 5G. Agencija želi v okviru svojih pristojnosti prispevati k temu, da bi bila Slovenija med vodilnimi državami glede povezljivosti.

V osnutku Strategije upravljanja z radiofrekvenčnim spektrom 2021 - 2023, so za izboljšanje povezljivosti, zmanjšanje digitalnega razkoraka in digitalizacije slovenskega gospodarstva predvidene naslednje akcije:

A. V časovnem obdobju 2021 - 2023 spremljati razvoj na trgu MMDS/BWA in po potrebi preverjati interes za morebitni nov javni razpis nepodeljenega spektra v pasovih 10 GHz in 12 GHz za lokalno uporabo in v primeru izraženega interesa javni razpis izvesti

B. V obdobju 2021 - 2023 po sprejetju izvedbenih sklepov Evropske komisije za radijske frekvence za javno mobilno tehnologijo, ki so na voljo po WRC-19, izvesti javno povpraševanje po interesu za frekvence v pasu 40,5-43,5 GHz in za preostanek civilnega 26 GHz pasu, ter v primeru interesa začeti postopek priprave javnega razpisa

C. V obdobju 2021 - 2022 podeliti del spektra v radiofrekvenčnih pasovih 2300 MHz in 3600 MHz za lokalno uporabo, in sicer za zagotavljanje javnih komunikacijskih storitev končnim uporabnikom ali za vertikale preko javnih mobilnih ali zasebnih mobilnih omrežij

D. V primeru prejema pobude v obdobju 2021 - 2023 izvesti podelitev radijskih frekvenc v pasovih 3800 – 4200 MHz, 28 GHz in 32 GHz za vertikale oziroma za tehnološko/storitveno nevtralno podelitev za lokalno uporabo ter pri tem zaščititi ostale storitve skladno z EC/CEPT

E. V obdobju 2021 - 2022 v primeru pobude izvesti podelitev radijskih frekvenc v radiofrekvenčnem pasu 410-430 MHz za podelitev spektra za vertikale oziroma za

tehnološko/storitveno nevtralno podelitev za področje Republike Slovenije

F. V obdobju 2022 - 2023 v primeru pobude pristojnim organom pomagati pri izvedbi postopkov podelitev spektra za PPDR v 700 MHz in 450 MHz pasu (vključno z organizacijo morebitnih posvetovanj z deležniki).

G. Spremljati regulativo za cestne inteligentne transportne sisteme ITS in mestno železnico ter vključiti v Splošni akt o načrtu uporabe radijskih frekvenc

H. V obdobju do konca 2025 izvesti prehod iz uporabe frekvenc v spektru 450 MHz na uporabo harmoniziranega spektra v okviru CEPT/EU (874,4-880 MHz/919,4-925 MHz in 1900-1910 MHz) na podlagi vloge po upravnem postopku ali pa te storitve vključiti v PPDR vertikalo

I. V okviru strategije Evropa do leta 2030: Digitalni kompas za digitalno desetletje 2030 (ang. »Digital Compass: the European way for the Digital Decade"), ki temelji na štirih stebrih: 1. znanje in spretnosti, 2. varne in trajnostne digitalne infrastrukture, 3. digitalna preobrazba podjetij, 4. digitalizacija javnih storitev. Agencija želi prispevati tudi k ciljem za doseganje brezogljične družbe z že omenjenim prostim spektrom za vertikale namenjenim digitalizaciji gospodarstva, omejevanju negativnega okoljskega vpliva elektronskih komunikacijskih omrežij, na način, da spodbuja čimprejšnjo uvedbo novih okolju prijaznejših tehnologij in uvedbo novih modelov souporabe.

J. Glede frekvenčnega spektra za 5G in prihajajočega 6G ter ostale nove tehnologije Agencija na nivoju RSPG in CEPT sodeluje pri pripravi na svetovno radijsko konferenco WRC-23 ter pri pripravi regulative za uporabo teh tehnologij v na novo dodeljenih radiofrekvenčnih pasovih.

Abstract

In accordance with the Electronic Communications Act the Agency for Communications Networks and Services (AKOS) is on the basis of a public authorization, beside other activities, responsible as well for managing the radio frequency spectrum of the Republic of Slovenia. This means that in addition to frequency allocation and assignment it is responsible for the efficient use of the radio frequency spectrum and the provisions of effective competition in the markets for wireless electronic communications services. The Agency's tasks in this field are primarily the use of radio frequency spectrum to achieve the greatest possible socio-economic benefit, ensuring a stable environment for radio spectrum users, promotion of competition, investments and development, the introduction of new technologies as soon as possible.

In 2001, Slovenia rose from the 16th place in 2020 to the 13th place with regards to the DESI index benchmark, mainly due to a successfully conducted public tender with a public auction for the 5G frequency bands. With an overall score of 53.2 for connectivity, it ranks 9th in the EU as it has allocated 98% of the 5G spectrum. Within its competences, the Agency wants to contribute to the goal that Slovenia becomes one of the leading countries in the field of connectivity.

The draft Radio Spectrum Management Strategy 2021 - 2023 envisages the following actions to improve connectivity, reduce the digital divide and digitize the Slovenian economy:

A. In the time frame of 2021-2023, monitor developments in the MMDS / BWA market and, if required by stakeholders, verify interest for possible new spectrum allocations in the 10 GHz and 12 GHz bands for local use and conduct public tender with public auction in case of expressed interest,

B. In the time frame of 2021-2023, after adoption of the European Commission Implementing Decisions on the 40 GHz band for public mobile technology, which becomes available after WRC-19, conduct public enquiry for 40.5-43.5 GHz, the remainder of the civil 26 GHz band and in case of start the procedure of public tender,

C. In the time frame of 2021-2022, auction part of the spectrum in the 2300 MHz and 3600 MHz bands for local usage, namely for electronic communication services for end-users or for verticals over public mobile or private mobile networks

D. If required by stakeholders in the time frame of 2021 - 2023, conduct assignment procedure in the bands 3800 - 4200 MHz, 28 GHz and 32 GHz for verticals or for technology / service neutral local usage, while protecting other services in accordance with EC / CEPT legal framework

E. In the time frame of 2021 - 2022, if required by stakeholders allocate radio frequencies in the radio frequency band 410-430 MHz for the allocation of spectrum for verticals or for technology / service neutral allocation for the territory of the Republic of Slovenia

F. In the time frame of 2022-2023, , if required by stakeholders, assist the competent authorities in assigning procedures for allocating spectrum for PPDR in the 700 MHz and 450 MHz bands (including the organization of possible stakeholder consultations).

G. Monitor the regulations for ITS road intelligent transport systems and urban rails and implement them in the General Act on the Radio Frequency Use.

H. Till the end of 2025 make the transition of Railway Systems from frequencies in the 450 MHz spectrum to the harmonized spectrum 874.4-880 MHz / 919.4-925 MHz and 1900-1910 MHz in accordance with EC/CEPT regulatory framework on the basis of an application under the administrative procedure or by inclusion of these services in the PPDR vertical

I. In accordance with Europe to 2030 Strategy: Digital Compass: The European Way for the Digital Decade, which is based on four pillars: 1. a digitally skilled population and highly skilled digital professionals, 2. secure and sustainable digital infrastructures; 3. the digital transformation of companies, 4. digitalisation of public services. Agency wishes also to contribute to the goal of limiting negative environmental footprint of electronic communications networks by introducing new technologies as soon as possible and implementation of new sharing models.

J. In order to accommodate frequency spectrum for 5G, the upcoming 6G and other new technologies, the Agency participates in the preparation for the WRC-23 World Radio Conference at the level of RSPG and CEPT and in the preparation of regulatory framework for the use of these technologies in newly allocated radio frequency bands.

Biografije avtorjev



Meta Pavšek Taškov je diplomirala leta 1990 in magistrirala leta 1993 na Fakulteti za elektrotehniko v Ljubljani na temo Temperaturno stabilizirani napetostno kontrolirani kristalni oscilatorji. Od leta 1995 je zaposlena na Agenciji za komunikacijska omrežja in storitve RS in sicer na področju za radiokomunikacije oz. upravljanje radiofrekvenčnega spektra. Od leta 2016 na AKOSu vodi oddelek za mobilne zveze in je vodila priprave na 700 MHz javni razpis z javno dražbo in ostale dražbe ter na strani AKOS vodi projekt za podporo slovenski 5G iniciativi. Od leta 2010 predseduje skupini HCM-TWG in pripravljalni skupini v okviru CEPT ECC PT1 – DG 40 GHz. Poleg tega je aktivna članica skupin RSCom, RSPG WRC-23, ECC, CPG, ECC PT1, WGSE, SE21, HCM in članica skupin CPG-PTA, CPG-PTB, CPG-PTD, SE40.



Janja Varšek je diplomirala leta 1989 na Fakulteti za elektrotehniko v Ljubljani in magistrirala leta 2016 na Fakulteti za Organizacijske vede Univerze Maribor. Od leta 1992 je zaposlena na Agenciji za komunikacijska omrežja in storitve RS in sicer najprej na področju telekomunikacijske opreme, elektromagnetne kompatibilnosti in kasneje kot vodja sektorja za regulacijo trgov. Nato je kot inšpektorica za telekomunikacije do leta 2014 delala v sektorju za nadzor telekomunikacij. Leta 2014 je bila vodja komisije za javni razpis z javno dražbo za radiofrekvenčne pasove 800/900/1800/2100/2600 MHz in postala tudi vodja sektorja za upravljanje radiofrekvenčnega spektra. Je aktivna članica skupin RSPG in ECC ter članica RSCom in RSPG podskupin.

Authors' biographies

Meta Pavšek Taškov *received her BSEE and MSEE from University of Ljubljana, Slovenia in 1990 and 1993 respectively. Since 1995 she was employed at AKOS (Agency for communication networks and services of the Republic of Slovenia) in the RF Spectrum management department. Since 2016 she is head of Mobile department in AKOS, leading preparation for 700 MHz Auction as well as other Auctions and from AKOS site leading project to support Slovene 5G initiative. She is an active member of RSCom, RSPG WRC-23, ECC, CPG, ECC PT1, WGSE, SE21, HCM and member of CPG-PTA, CPG-PTB, CPG-PTD, SE40.*

Janja Varšek *received her BSEE in 1989 at University in Ljubljana, in Electronic Engineering and received a MSc. at the Faculty of Organizational Sciences, University of Maribor in 2016. She joined the Administration for Telecommunications of the Republic of Slovenia in 1992. She worked with telecommunications equipment, electromagnetic compatibility and market regulation. She worked as market supervisor and inspector for telecommunications for four years. She was chair of the big bang auction in 2014 and after successfully finished auction, she was appointed as head of radiofrequency spectrum management department. She is an active member of RSPG and ECC.*

AKOS

Aktivnosti na področju upravljanja z RF spektrom

SRK2022

Janja Varšek, Meta Pavšek Taškov

Ljubljana, 2. 2. 2022

AKOS

Vsebina

- Uvod
- Pretekle aktivnosti
- Strategija upravljanja z radiofrekvenčnim spektrom
- Nadaljnje aktivnosti
  - Priprava na WRC-23

AKOS

Uvod

- 5G Akcijski načrt – jeseni 2016
  - temelj za digitalno gospodarstvo in družbo,
  - odločilen dejavnik napredka
  - Akcije za usklajeno uvajanje 5G
    - Do konca 2020 vsaj eno mesto
    - Do konca 2025 vsa večja mesta
    - Osnova za določitev pionirskih pasov
      - Pod 1 GHz
      - 1 GHz – 6 GHz
      - Nad 6 GHz
- 5G pobuda
  - Testiranja 5G tehnologije

AKOS

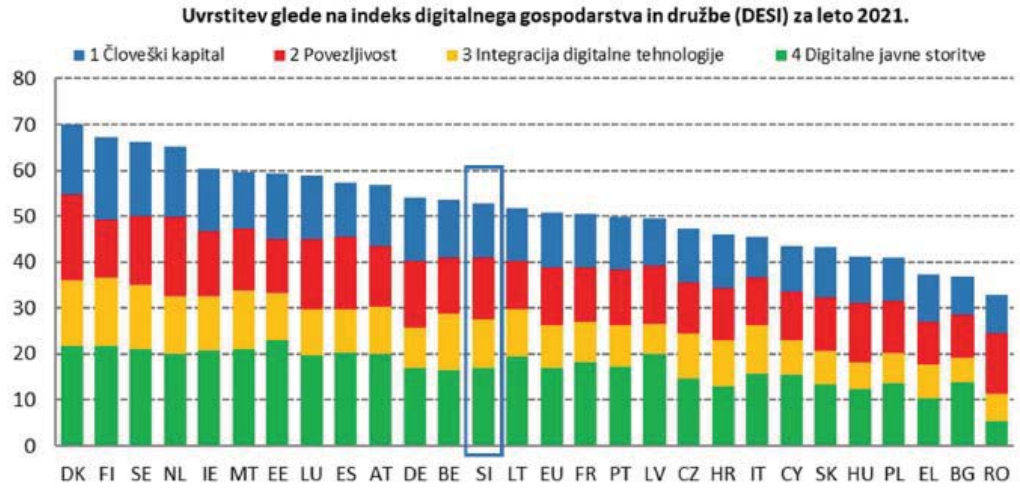
Uvod

- Strategija upravljanja z radiofrekvenčnim spektrom
- Podelitev frekvenc za poslovnokritične komunikacije M2M v pasu 700 MHz – maj 2021
- Podelitev frekvenc za zagotavljanje javnih komunikacijskih storitev v pasovih 700 MHz, 1500 MHz, 2100 MHz, 2300 MHz, 3600 MHz in 26 GHz – junij 2021

AKOS

DESI indeks

- 16. mesto v letu 2020 → 13. mesto v letu 2021.
- splošna ocena za povezljivost 53,2 → deveto mesto v EU
- dodeljeno 98% spektra 5G.



AKOS

Pretekle aktivnosti
M2M Dražba – 733-736 MHz/788 – 791 MHz

- 2 dni (10-11.2.2021), 37 krogov, 2 dražitelja: GIZ DEE and BeeIN
- Izklicna cena: 220 000 EUR,
- Končna cena: 970 000 EUR
- Zmagovalec: **BeeIN**

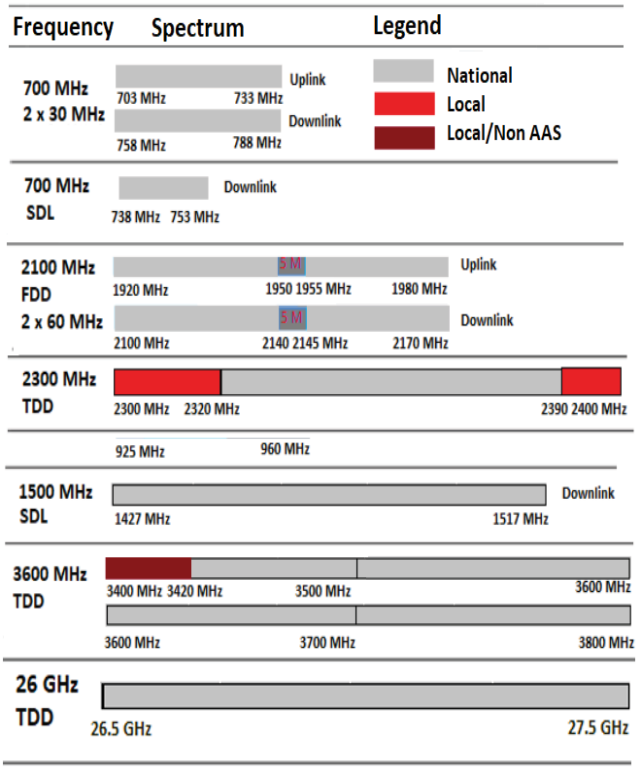
Bands	694-698	698-703	703-733	733-736	736-738	738-743	743-748	748-753	753-758	758-788	788-791
PPDR 2x3 MHz			UL MFCN Band 28							DL MFCN Band 28	
PPDR 2x5 MHz		UL PPDR							DL PPDR		
M2M 2x3 MHz				UL M2M							DL M2M
SDL 4x5 MHz						DL MFCN SDL					
PMSE	PMSE				PMSE						
Block Size [MHz]	4	5	30	3	2	5	5	5	5	30	3

- Obveznosti:
- Pokrivanje:
  - za 10% Slovenije: 1 BS do 31.12.2021, 90 % ključnih lokacij vsakega uporabnika v tej regiji do 31.12.2025
  - Za ostala področja 75% Slovenije: 90 % ključnih lokacij vsakega uporabnika v tej regiji do 31.12.2025 v skladu s pismi o nameri vendar ne kasneje kot 31.12.2030
- Zanesljivost omrežja> 99,99 %, odpravo napak, 72 h avtonomije, podpora ISO/IEC 27001 in ISO/IEC 22301 do 31.12.2024
- Varnost omrežja

AKOS

Pretekle aktivnosti
Večfrekvenčna dražba

- 700 MHz,
- 700 MHz SDL
- 1500 MHz
- 2100MHz
- Del 2300 MHz (2320 -2390 MHz)
- Del 3600 MHz (3420 – 3800 MHz)
- Del 26 GHz (26,5-27,5 GHz)



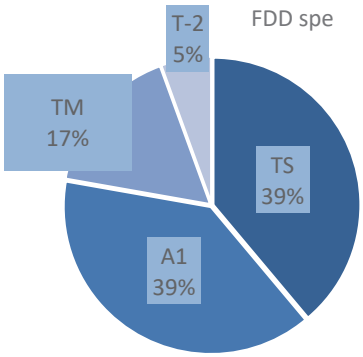
Source: https://www.akos-rs.si/fileadmin/user_upload/Razpisna_dokumentacija_za_vec__frekvenc__no_draz__bo_ANG_05022021_final.pdf

AKOS

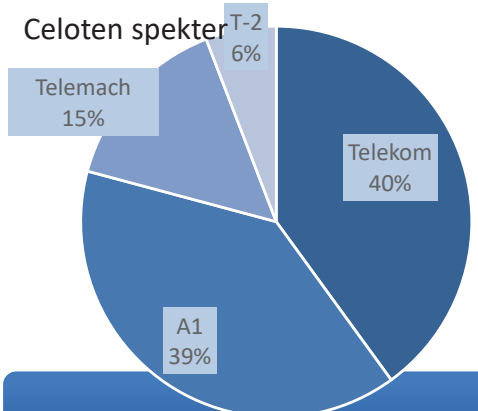
Pretekle aktivnosti
Večfrekvenčna dražba
OBSTOJEČA PORAZDELITEV SPEKTRA

Operater	Količina spektra(MHz)
Telekom	240
A1	235
Telemach	90
T-2	35

Operater	FDD (MHz)
Telekom	210
A1	210
Telemach	90
T-2	30

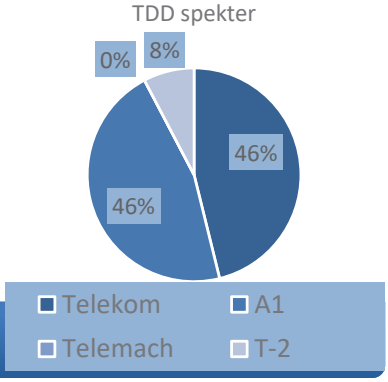


Celoten spekter



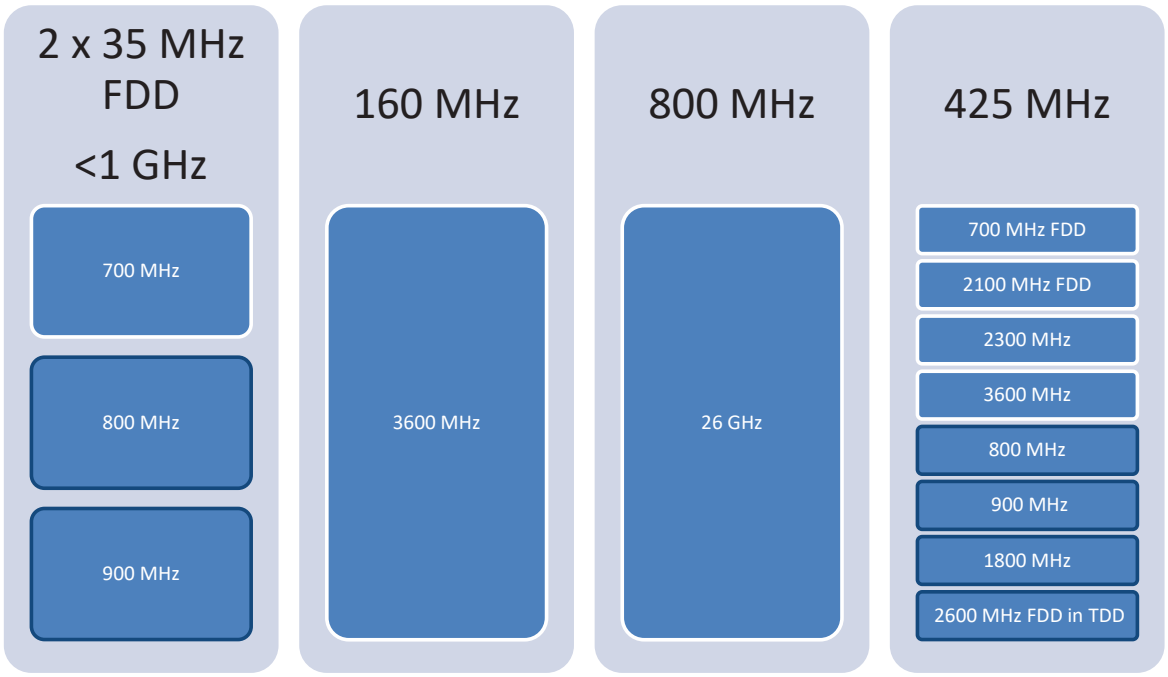
Operater	TDD (MHz)
Telekom	30
A1	30
Telemach	0
T-2	5

TDD spekter



AKOS

Pretekle aktivnosti
Večfrekvenčna dražba
SPEKTRALNE KAPE



AKOS

Pretekle aktivnosti
Večfrekvenčna dražba
SPLOŠNE OBVEZNOSTI POKRIVANJA

V vsakem radiofrekvenčnem pasu komercialno omogočati WBB TRA-ECS:

- **1 L** od razpoložljivosti pasu - uporabljati frekvence in ponujati storitve končnim uporabnikom na teh frekvencah **vsaj v 1 mestu**
- **5 L** od razpoložljivosti pasu - uporabljati vse frekvence v celotnem pasu in ponujati storitve končnim uporabnikom na vseh teh frekvencah – v **vsakem večjem mestu**

Večja mesta			
Celje	Koper	Kranj	Ljubljana
Maribor	Murska Sobota	Nova Gorica	Novo mesto
Ptuj	Slovenj Gradec	Velenje	

Za frekvence v pasovih 700 MHz SDL, 1500 MHz SDL in 26 GHz:

- **5 L** od razpoložljivosti pasu - začnejo uporabljati frekvence in ponujati storitve končnim uporabnikom na teh frekvencah **vsaj v 1 mestu**

Ponujanje storitev pomeni

- storitev je omogočena preko BS, ki pokrivajo **min 75 % prebivalstva posameznega mestnega naselja**,
- začetek uporabe in ponujanja storitev - vsaj preko 1 BS na področju posameznega mestnega naselja.

Pretekle aktivnosti
Večfrekvenčna dražba
DODATNE OBVEZNOSTI - 700 MHz FDD SPEKTER

Imetniki spektra v 700 MHz pasu FDD - z vsem radijskim spektrom, do 31. 12. 2025 komercialno omogočati WBB TRA-ECS pokrivanje:

- 99 % prebivalstva Republike Slovenije,
- 99 % avtocest (AC) in hitrih cest (HC),
- vsaj 60 % glavnih in regionalnih cest I. in II. Reda,
- vsaj 60 % aktivnih železnic s potniškim prometom, pri čemer je pokrivanje znotraj vlakov v pristojnosti železniških deležnikov.
- 30 Mb/s DL in 3Mb/s UL (vse dodeljene frekvence z RSRP signalom (v zunanjosti zgradb): -108 dBm)

Pretekle aktivnosti
Večfrekvenčna dražba
OBVEZNOSTI POKRIVANJA - »AKCIJSKI NAČRT ZA 5G«

Obveznost pokrivanja s 5G tehnologijo:

- **podpora 3GPPP Release 15 ali z novejšo izdajo specifikacij**.
- **imetnik frekvenc 700 MHz FDD, 2100 MHz, 2300 MHz ali 3600 MHz**, mora:
  - 3 mesece po izdaji ODRF začeti WBB TRA-ECS preko 5G tehnologije na vsaj 1 pasu v vsaj 1 večjem mestu,
    - začetek uporabe in ponujanja storitev - vsaj preko 1 BS na področju posameznega mestnega naselja
  - do 31. 12. 2025 WBB TRA-ECS preko 5G tehnologije in zagotavljati eMBB, če ima najmanj 70 MHz zveznega spektra, ter zagotavljati podporo množičnim IoT na pridobljenih frekvencah v vseh večjih mestu.
    - storitev je omogočena preko BS, ki pokrivajo **min 75 % prebivalstva posameznega mestnega naselja**,

Pretekle aktivnosti
Večfrekvenčna dražba
SOUPORABA

Spodbuja se naslednje možnosti souporabe z namenom učinkovite uporabe frekvenčnega spektra, izboljšanja pokritosti in zmanjšanja vpliva na okolje:

- souporaba pasivne in aktivne infrastrukture ter souporaba frekvenčnega spektra,
- poslovni dogovori o dostopu do gostovanja,
- skupna postavitev infrastrukture.

- Pri tem je souporaba aktivne opreme in frekvenčnega spektra dovoljena le na zahtevnih območjih, in sicer v okviru, ki ne omejuje infrastrukturne konkurence
  - na zahtevnih območjih Slovenije:
    - Triglavski narodni park (tabela težko dostopnih območij),
    - naselja 2. prioritete (tabela težko dostopnih območij),
    - v cestnih in železniških predorih,
    - na kritičnih odsekih cest (tabele vseh odsekov cest),
    - na območjih državne meje in v Piranskem zalivu,
    - v območjih, ki presegajo 60 % aktivnih železnic s potniškim prometom,
    - v območjih, ki presegajo 60 % pokrivanje glavnih in regionalnih cest I. in II. reda ,
    - na objektih s spomeniškim varstvom,
    - za male celice, če je omejitev posegov v prostor in
    - v notranjosti objektov.
- v primeru zgostitev omrežij za zagotavljanje zelo visokih kapacitet baznih postaj, zmožnih nudenja gigabitnih prenosnih hitrosti:
  - na cestni in mestni infrastrukturi (npr. ulične svetilke, semaforji),
  - na železniški infrastrukturi in energetskih objektih/infrastrukturi,
  - v območjih z veliko gostoto ljudi (npr. kongresni centri, koncertne dvorane, stadioni, avtobusne in železniške postaje, nakupovalna središča, tovarne, pristanišča, letališča)

V 26 GHz frekvenčnem pasu te omejitve ne veljajo - dovoljena souporaba frekvenc in aktivne opreme, vključno z dinamično souporabo spektra.

Pretekle aktivnosti
Večfrekvenčna dražba
PASIVNA INFRASTRUKTURA IN ROAMING

Obveznost souporabe pasivne infrastrukture oz. obveznost sklenitve lokaliziranih sporazumov o gostovanju:

- če drugim operaterjem ne bodo na voljo alternativni načini dostopa do končnih uporabnikov pod poštenimi in primernimi pogoji za lokalno zagotavljanje storitev
  - nepremostljive gospodarske ali
  - fizične ovire za tržno postavitev

AKOS

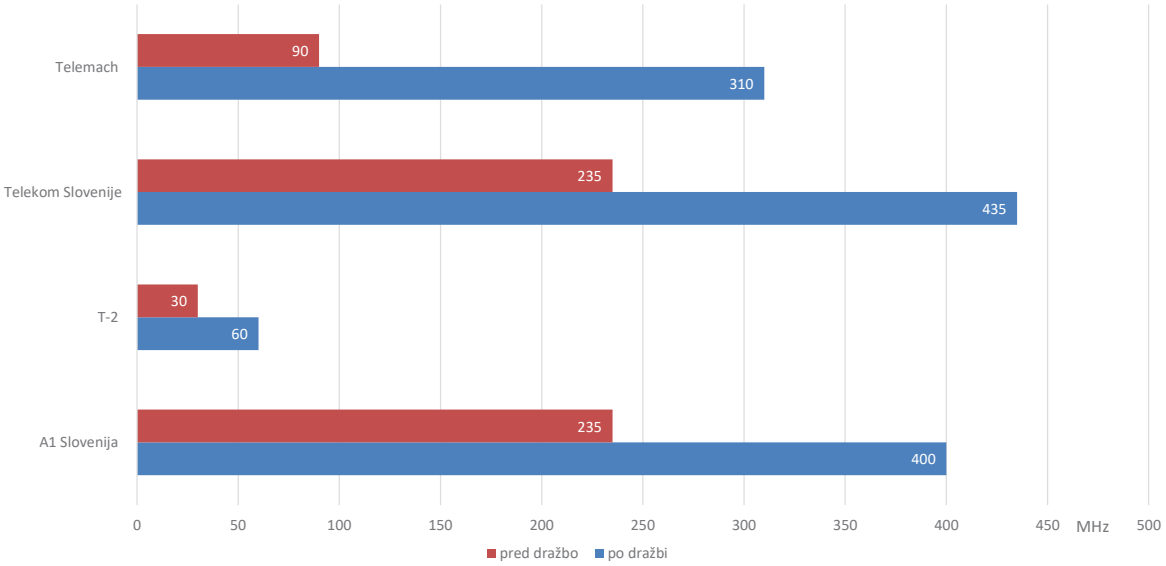
Pretekle aktivnosti
Večfrekvenčna dražba
ZAHTEVE GLEDE ZAGOTAVLJANJA VARNOSTI

Za ustrezno obvladovanje tveganj za varnost informacijskih sistemov, omrežij in storitev

- Upoštevati
  - relevantno nacionalno in evropsko zakonodajo
  - mednarodno priznane standarde in dobre prakse
    - s področja varnosti omrežij in storitev
    - neprekinjenega poslovanja
- Vzpostaviti in vzdrževati
  - Ustrezne in sorazmerne organizacijske in tehnične ukrepe

AKOS

Pretekle aktivnosti
Večfrekvenčna dražba
CELOTEN SPEKTER PRED in PO DRAŽBI



AKOS

Strategija
Javne komunikacijske storitve

- Osnutek strategije – do 2021
  - Akcija 1: Večfrekvenčna dražba700+ (700/1500/2100/2300/3600/26000)
  - Akcija 11: M2M dražba 700 MHz (733 – 736 MHz/788 – 791 MHz) za poslovno kritične storitve
- Strategija – 2021-2023
  - Akcija 1: po sprejetju ustrezne EC DEC za WRC-19 pasove – povpraševanje glede podelitve (preostanka 26 GHz in 40 GHz) (pas 57-71 GHz je na voljo brez ODRF za 5G in WiGIG)
  - Akcija 5: 2021-2021 lokalna dražba za dele pasov 2300/3600 MHz za TRA-REC ali vertikale preko javnih ali privatnih mobilnih omrežij
  - Akcija 6: 2021-2022 če bo interes dražba 2 x 5 MHz v 410-430MHz za poslovno kritične vertikale
  - Akcija 7: 2022-2023 če bo interes pomoč pri podelitvi 2 x 5 MHz in 450-470MHz za PPDR storitve
  - Akcija 8: 2021-2023 če bo interes podeliti/pripraviti lokalno dražbo za 28 GHz & 32 GHz za vertikale - storitveno/tehnološko nevtralno (BWA) – zaščita obstoječih storitev
  - Akcija 9: 2021-2023 če bo interes podeliti/pripraviti lokalno dražbo za dele pasu 3800-4200 MHz za vertikale - storitveno/tehnološko nevtralno (BWA) – zaščita obstoječih storitev

AKOS

Strategija
Javne komunikacijske storitve

- **Akcija 2**: Spremljati umik Italijanskih DTT iz pasu 700 MHz.
- **Akcija 3**: Uskladiti Metodologijo za preverjanje izpolnjevanja obveznosti ob rokih, ki so določeni v izdanih odločbah o dodelitvi radijskih frekvenc za mobilne storitve
- **Akcija 4**: Spremljati možnosti prehoda DTT na mobilno tehnologijo. Spodbujati testiranje v UHF kanalih, ki jih ima Slovenija koordinirane v skladu z GE06, za prenos avdiovizualnih vsebin in podporo mobilnim storitvam, ki potrebujejo nepretrgano pokrivanje
- **Akcija 10:** Do konca 2025 izvesti prehod iz uporabe frekvenc v spektru 450 MHz na uporabo harmoniziranega spektra v okviru CEPT/EU (874,4-880 MHz/919,4-925 MHz in 1900-1910 MHz) vloge po upravnem postopku ali pa te storitve vključiti v PPDR vertikalo.
- **Akcija 11:** V časovnem obdobju 2021 - 2023 spremljati razvoj na trgu **MMDS/BWA** in po potrebi preverjati interes za morebitni nov javni razpis nepodeljenega spektra v pasovih 10 GHz in 12 GHz za lokalno uporabo in v primeru izraženega interesa javni razpis izvesti.
- **Akcija 12:** Nezasedeni spekter dodeliti na vlogo za potrebe meritev, atestiranja in drugih preizkusov radijske opreme ter za preizkušanje novih tehnologij.

Strategija
Fiksne, satelitske zveze, PMSE

- Akcija 13: Za gigabitne P-P zveze spodbujati uporabo radiofrekvenčnih pasov od 92 do 174,8 GHz. Omogočiti širše kanale v pasovih, kjer je na voljo dovolj spektra. Spodbujati tudi prehod mikrovalovnih zvez v del 28 GHz pasu za P - P zveze in 32 GHz pas.
- Akcija 14: Glede na velike potrebe po novih kapacitetah pripraviti racionalnejši način podeljevanja frekvenc za mikrovalovne zveze.
- Akcija 15: Sodelovati v mednarodnih organizacijah (EU, CEPT, ITU) in zagovarjati tehnične specifikacije, ki omogočajo souporabo spektra za satelitske in prizemne sisteme.
- Akcija 16: Usklajevati sodelovanje med deležniki, ki uporabljajo iste radiofrekvenčne pasove za uporabo mobilnih kamer.

Strategija
Radiodifuzija

- Akcija 17: Redno izvajati JR za podelitev še prostih FM radijskih frekvenc
- Akcija 18: Koordinirati nove radijske frekvence in odgovarjati na zahtevke drugih administracij
- Akcija 19: Reševati problematiko čezmejnih motenj ma mednarodnem nivoju in sodelovati v medresorski delovni skupini ter nuditi strokovno podporo
- Akcija 20 in 21: Izvesti JR za podelitev pravic za razširjanje radijskih programov v digitalni radiodifuzni tehniki na območju Ljubljane – R3 in na območjih vzhod R2 in zahod R2.
- Akcija 22: Spodbujati operaterja omrežja, da zagotovi sprejem tudi v predorih na ključnih prometnih povezavah.
- Akcija 23: Nadaljevati z aktivnostmi na mednarodni ravni za zagotovitev dodatnih pravic za DAB omrežja.
- Akcija 24: Pospeševati uporabo DAB, ozaveščati uporabnike in prodajalce o obvezni vgradnji sprejemnikov
- Akcija 25: Spremljati interes na trgu trga in sprotno odzivanje na potrebe trga na področju DVB-T

Strategija
Klicni znaki, nelicenciran spekter

- Akcija 26: Vzpostavitev povezav z ustreznimi institucijami za lažjo izdajo dovoljenj radioamaterjem, plovilom in zrakoplovom
- Akcija 27: Predlagati spremembe in dopolnitev obstoječe zakonodaje, ki bo omogočila vzpostavitev baze podatkov o PLB/ELT.
- Akcija 28: Sodelovati na tehničnih skupinah Evropske Unije in CEPT in v čim krajšem času omogočiti uporabo novih tehnologij, ki se bodo uporabljale v prenosnih napravah.
- Akcija 29: Spremljati razvoj pravnih podlag za podporne sisteme 5G določiti najprimernejši način licenciranja za licenčni del spektra.
- Akcija 30: V podporo avtomobilski industriji slediti novostim na področju brezžičnega polnjenja in na tem področju aktivno sodelovati na mednarodnem (ITU) in evropskem (CEPT) nivoju
- Akcija 31: Sodelovati v strokovno-tehničnih skupinah v okviru CEPT, to sta SE24 in SRD/MG, kjer se novosti oziroma spremembe radijske opreme, na podlagi harmoniziranih standardov, prilagajajo uporabi radijskega spektra v RS in zagotavljati ustrezne pogoje za uporabo SRD
- Akcija 32: V sodelovanju z organi za upravljanje letalskega prometa skrbeti za interoperabilnost in usklajenost radiofrekvenčnega prostora z rabo radijskega spektra v EU za potrebe delovanja UAV naprav.
- Akcija 33: Ko bo dokončana tehnična regulativa za profesionalne UAV v pasovih 1880-1900 MHz, 1900-1920 MHz in 5000-5010 MHz.

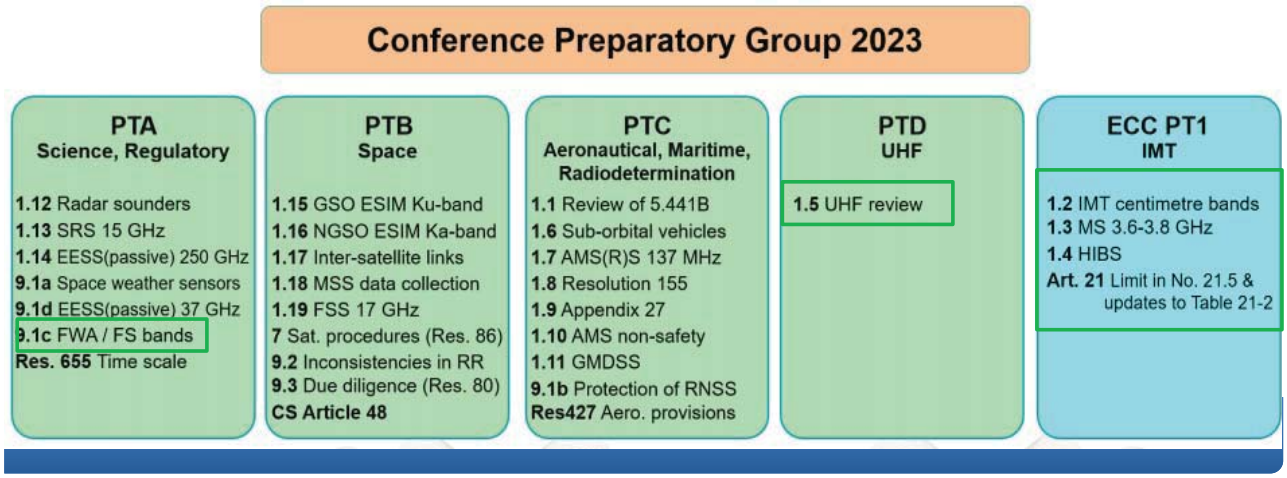
Nadaljnje aktivnosti

- Javni razpis z javno dražbo spektra za lokalno uporabo/vertikale (del 2300 MHz in del 3400 MHz)
- Spremljanje naloženih obveznosti
  - Splošne obveznosti pokrivanja
  - Dodatne obveznosti - 700 MHz FDD spekter
  - Obveznosti pokrivanja - » 5G Akcijski načrt«
- Aktivnosti v zvezi z digitalnim kompasom (Strategija Evrope do leta 2030: Digitalni kompas za digitalno desetletje 2030 (ang. »Digital Compass: the European way for the Digital Decade")
  - znanje in spretnosti,
  - digitalna preobrazba podjetij,
  - varne in trajnostne digitalne infrastrukture,
  - digitalizacija javnih storitev,
  - Za zmanjšanje okoljskega odtisa
  - Spodbujanje souporabe
    - fizične infrastrukture
    - omrežij (aktivno in/ali pasivno vključno z združevanjem spektra)
    - pasivne infrastrukture
    - lokalizirani sporazumi o gostovanju
  - Uporaba energetsko učinkovitih procesov - predlogi za učinkovito odzivanje na izzive regulacije

AKOS

Nadaljnje aktivnosti
Priprava na WRC-23

- Novi spekter za IMT: AI1.2 (6425-7125 MHz), AI1.5 (600 MHz), 9.1.c, interes tudi AI1.3, AI1.4, Art. 21
- Varnostne storitve (PTC)
- Znanstvene storitve (PTA)



AKOS

Hvala za pozornost

JANJA VARŠEK
Vodja sektorja za upravljanje z radiofrekvenčnim spektrom
Tel: +386 1 583 63 43
Fax: + 386 1 511 1101
e-mail: janja.varsek@akos-rs.si

META PAVŠEK TAKOV
Vodja oddelka za mobilne zveze
Tel: +386 1 583 63 63
Fax: + 386 1 511 1101
e-mail: meta.pavsek-taskov@akos-rs.si

?

Prihodnji sistem radijskih komunikacij za železnice

Future Railway Mobile Communication System

Roman Osredkar[1], **Matjaž Jelen**[2]

[1]SŽ – Infrastruktura, [2]Iskratel S&T

roman.osredkar@slo-zeleznice.si, m.jelen@iskratel.si

Povzetek

Prihodnji sistem radijskih komunikacij za železnice - FRMCS (Future Railway Mobile Communication System) bo nadomestil obstoječ GSM-R sistem. Temelji na peti generaciji (5G) radijskih mobilnih komunikacij. Trenutno je FRMCS v fazi definicije zahtev in usklajevanja med UIC in 3GPP. V okviru CEPT je za uporabo dodeljen razširjen obstoječ frekvenčni pas in določen nov v pasu 1900 MHz za širokopasovne komunikacije. Uporabljen bo za prenos videa, avtomatsko vožnjo in nove vrste storitev. Nekaj novih zahtev za sistem FRMCS je izpostavljenih v prispevku. V Sloveniji pripravljamo plan prehoda iz GSM-R na FRMCS, predvidevamo pa lahko, da se bo uveljavil po izteku življenjske dobe opreme GSM-R in jo postopno zamenjal z nekajletnim sobivanjem, usklajeno z načrti dobaviteljev, regulatorjev in načrti infrastrukturnih upravljalcev. Omenili bomo nekaj možnih projektov, s katerimi bi pokazali skupaj z industrijo, da smo pripravljeni na sodelovanje in iskanje rešitev v lokalnem in tudi širšem okolju.

Abstract

FRMCS (Future Railway Mobile Communication System) will replace current GSM-R system. It is based on fifth generation (5G) of mobile communications. Currently FRMCS is in phase of requirement specification and coordination between UIC (International union of railways) and 3GPP. CEPT has defined the expanded existing frequency spectrum and added additional 10 MHz bandwidth in 1900 MHz band for FRMCS broadband communication. It is planned for video, automatic train operation and other new services. Some new requirements for FRMCS are outlined in the presentation. In Slovenia the transition plan to FRMCS is in preparation. We can foresee that before end of life of GSM-R equipment, it will be gradually replaced by FRMCS, with both systems operating in parallel for some years. This should be done in coordination with solution providers, regulators and infrastructure manager plans. We will mention some of the projects where, together with the industry, we can show our readiness for cooperation and search for solutions in local and global environment.

Biografije avtorjev

Roman Osredkar je diplomiral leta 1993 in magistriral leta 2002 na Fakulteti za elektrotehniko v Ljubljani. Od leta 1992 je bil zaposlen v Iskratelu kot programer za telefonske centrale EWSD, projektni in produktni vodja za WiMAX ter GSM-R. Od leta 2016 je zaposlen v podjetju SŽ – Infrastruktura d. o. o. na področju telekomunikacij. Ukvarja se z vzdrževanjem in

nadzorom TK omrežij. Je predstavnik SŽ-I v ENIR, NMG in ERIG delovnih skupinah v UIC.

Matjaž Jelen je diplomiral iz elektrotehnike na Univerzi v Mariboru. Od leta 2000 deluje na različnih pozicijah v podjetju Iskratel, kot programer, produktni vodja ter vodja produktne linije za korporativne rešitve. Trenutno vodi oddelek Produktnega vodenja in je aktivno udeležen v pripravi Iskratelovih rešitev za naslednjo generacijo operativnih komunikacij na železnicah. Je predstavnik Iskratela v združenju evropske industrije za železnice UNIFE.

Authors' biographies

Roman Osredkar *received his BSEE and MSEE from University of Ljubljana, Slovenia in 1993 and 2002 respectively. First employment was from 1992 to 2015 as programmer for EWSD exchanges, project and product manager for WiMAX and GSM-R. Since 2016 he is employed in SŽ – Infrastruktura d. o. o. as telecommunications engineer. He is working on Telecommunications network maintenance and monitoring. He is the SŽ-I representative in UIC ENIR, NMG and ERIG working groups.*

Matjaž Jelen *received his B.Sc. degree in electrical engineering from the University of Maribor. Since 2000 he has been working in different fields in Iskratel as a developer, product manager, and product line manager for Enterprise solutions. Currently he leads Product Management team and is actively involved in the preparation of the Iskratel next-generation operational communications for railways. He is a representative of Iskratel in the European Rail Supply Industry association UNIFE.*

Infrastruktura

ISKRATEL S&T Group

FRMCS

PRIHODNJI SISTEM RADIJSKIH KOMUNIKACIJ ZA ŽELEZNICE

Future Railway Mobile Communications System

Roman Osredkar, *SŽ – Infrastruktura, d. o. o.*
Matjaž Jelen, *Iskratel S&T*

SRK 2022, 2. 2. 2022

FRMCS - Future Railway Mobile Communication System

- Nadomešča in nadgrajuje obstoječi GSM-R sistem za operativno komunikacijo
- GSM-R v uporabi že 20 let (2G)
- UIC za FRMCS določa 5G sistem (ETSI 3GPP ver. 18) in zamenjuje EIRENE (GSM-R)
- FRMCS odprt za transportna omrežja naslednjih generacij in povezavo z komplementarnimi omrežji (Wi-Fi, javni 5G ter satelitska omrežja)
- Pokriva potrebe uporabnikov po interoperabilnosti, gostovanju, zanesljivosti in pokritju vseh sistemskih potreb
- Osnova za nove storitve in funkcionalnosti:
  prenos velikih količin podatkov, video, IoT, digitalizacija železnic

GSM-R + FRMCS = **RMR** (Railway Mobile Radio)

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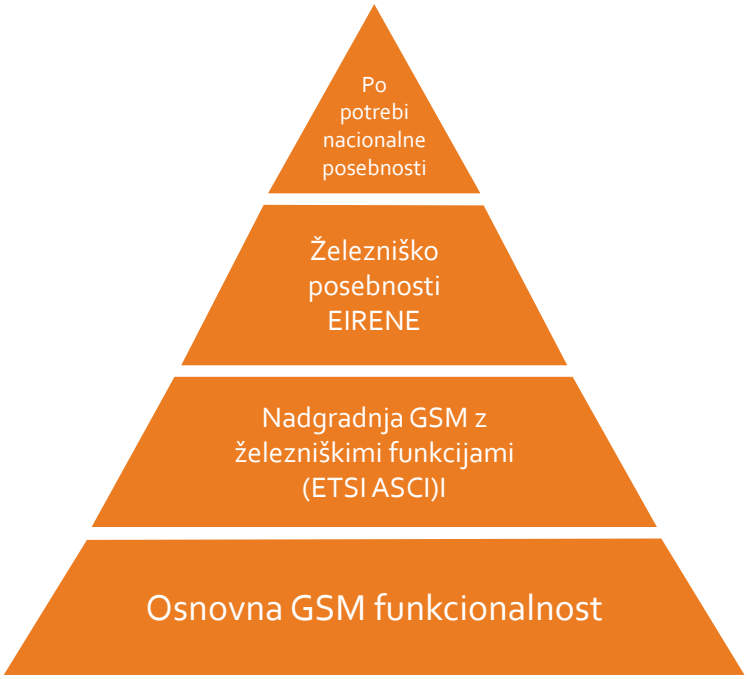
Ključni GSM-R sklopi

- Izboljšan nujni klic ali lokacijsko naslavljanje
- Lokacija vlakov ...

- Funkcijsko naslavljanje
- Lokacijsko odvisno naslavljanje
- Železniški nujni klic
- Hitrost vlakov do 500 km/h

- Skupinski govorni klic
- Razpršeni skupinski klic
- Prioritete klicev in prevzemanje klicev

- Vse GSM funkcije se lahko uporabijo tudi v GSM-R



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Razvoj je viden uporabnikom

Uporaba 15 – 30+ let



Muzejski eksponati



Uporaba 3 – 10 let





CAB (kabinski) radio GSM-R



TK pult prometnika



Telefon vzdrževalca, nadzornika

FRMCS



Pametni telefoni z aplikacijami



TK pult prometnika

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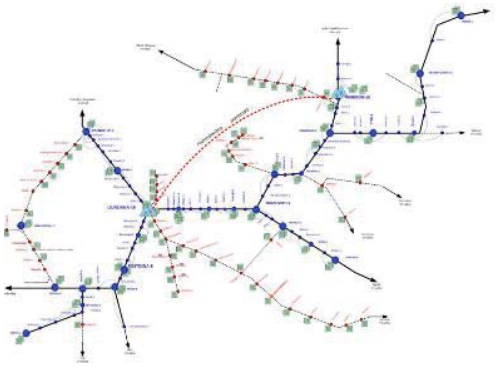
ISKRATEL S&T Group

Omrežje GSM-R SŽ

- **1207 km** prog
- **132** železniških postaj
- **244** baznih postaj- BTS (BP)
- **112** oddaljenih baznih postaj - RBP
- **2** MSC (geo redundančno)
- **3** BSC (kontrolerjev baznih postaj)
- **1** GPRS sistem
- **1** SMS center
- **1** centralni snemalnik
- **2** GSM-R klicna strežnika
- **75** kompaktnih klicnih strežnikov
- **211** TK pultov
- **372** napajalnih sistemov

oprema uporabnikov:

- **182** Kabinskih GSM-R radijev na lokomotivah + **40** na Stadler EMG in DMG
- **40** drezin z mobilnimi telefoni v držalih
- **191** mobilnih telefonov v premikalnih skupinah
- **422** mobilnih telefonov za operativne namene
- **1100** telefonov za vzdrževalce, sprevodnike, nadzornike...



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Infrastruktura GSM-R SŽ

- Optična vlakna (do 72 vlaken) – za dvakrat obkrožiti Zemljo
- 400 km napajalnih kablov
- Večina stolpov 30 m. Povprečna razdalja je ~3,3km
- Vsak temelj ima 25 m^3 betona in stolp 3,8 tone jekla
- Pomembno za pokritost FRMCS, kjer so frekvence 1,9 GHz, 2 x višje od pasu GSM-R (tu sta pasova 876 UL in 921MHz za DL po 4 MHz) z manjšim dosegom





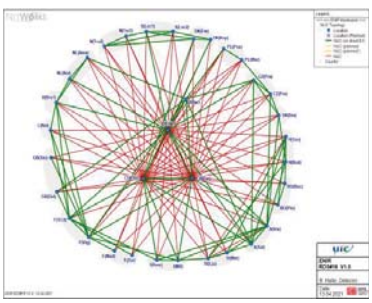






Gostovanje omogočeno:

- v Avstriji, Italiji, Nemčiji, na Madžarskem in na Češkem.
- Za ostale države se lahko gostovanje uredi s pogodbo – infrastruktura je na voljo!



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Frekvenčni spekter za RMR

Zagotovljen je frekvenčni spekter za prehodni čas, ko bosta sistema sobivala.

GSM-R

– 876 – 880 MHz za oddajo in 921 – 925 MHz za sprejem.

FRMCS

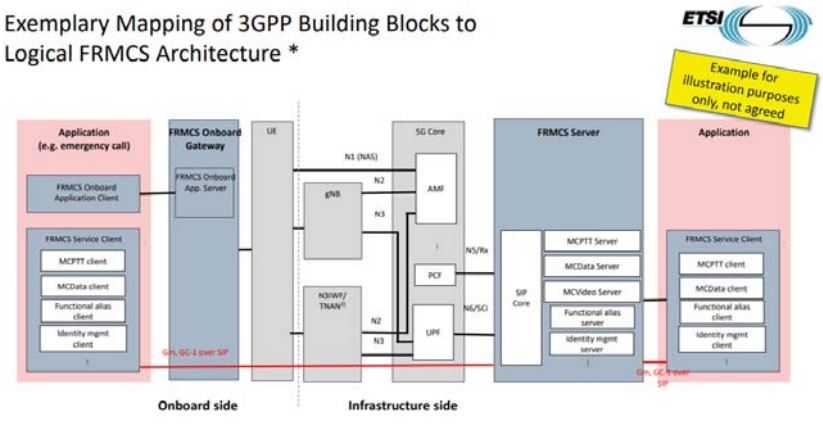
– Razširjeni pas 874.4 – 880 MHz in 919.4 – 925 MHz (FDD) za RMR.
– Možnost uporabe 200 KHz za varovalni pas glede na nacionalne potrebe.
– Za večje pasovne širine 1900 – 1910 MHz.
– Analizira se uporaba frekvenc v pasu 24.2 – 52.6 GHz za zelo hiter prenos podatkov na kratke razdalje.

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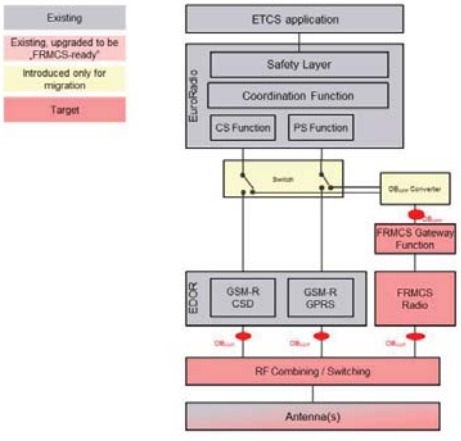
Migracija proti FRMCS (oprema v omrežju in na vlaku)

– Več načinov implementacije
– Standardizacija še ni zaključena

FRMCS gradniki v 3GPP ETSI za klic v sili



ETCS podatkovni radio na vlaku



Storitve zagotovljene s FRMCS v prvi fazi

Driver to controller
komunikacija strojevodje na vlaku s prometnikom, dispečerjem

Controller to driver
komunikacija prometnika, dispečerja s strojevodjo na vlaku

ATP (Automatic Train Protection)
kot ETCS (European Train Control System) v GSM-R

ATO (Automatic Train Operation)
pospeševanje, vožnja, ustavljanje, odpiranje vrat, vožnja v izrednih razmerah. V kombinaciji s ali brez strojevodje.

REC (Railway Emergency Calls)
železniški klic v sili, sprožen na nekem področju prejmejo vsi ostali na tem področju. Deluje z MCPTT (Mission Critical Push to Talk) storitvijo. Osnovna lastnost je prioriteta nad ostalimi klici in možnost kasnejšega vstopa v klic na lokaciji, kjer klic poteka.

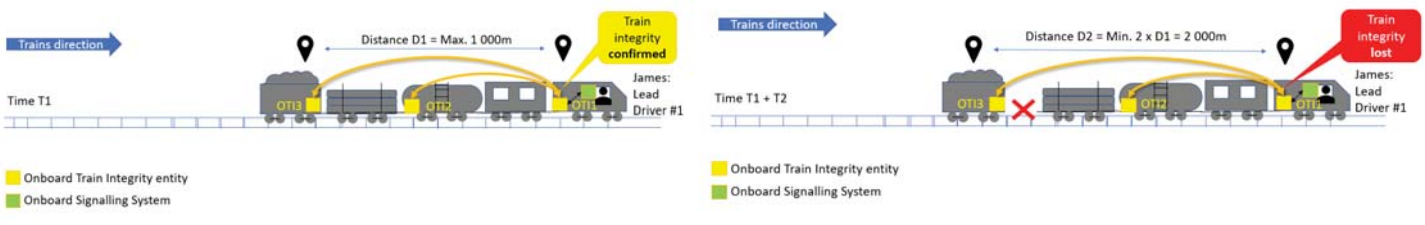
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Nove storitve | Off-Network delovanje FRMCS

- Delovanje terminala, ko ni priključen v 5G omrežje ali omrežje ni na voljo.
- Omogoča delo tam, kjer ni pokritosti s 5G signalom.
- Primer uporabe:
  za premik, opozarjanje delavcev na delo ob progi…
- Podpora MCX (Mission Critical) funkcijam:
  skupinski klici, lokacijske storitve, avtentikacija, QoS in prioriteta klicev…

- Interes v Deutsche Bahn (DB Netz) → velika možnost za nadaljevanje postopkov standardizacije

Storitev v 'off-network' načinu: Preverjanje celovitosti vlaka

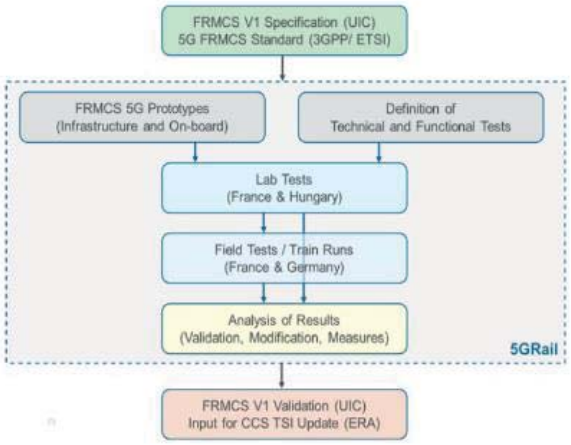


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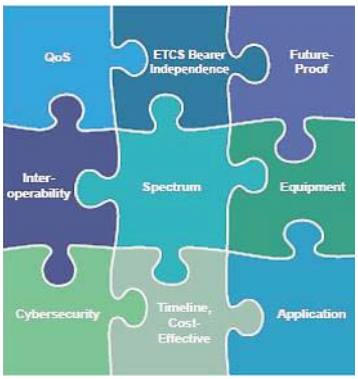
FRMCS v fazi prototipnih postavitev

5GRAIL projekt

Določa prototipe na osnovi FRMCS v1 specifikacij, vključno s telekomunikacijsko 5G infrastrukturo skladno s standardizacijskimi elementi in novo opremo na lokomotivah (TOBA, Train on Board Equipment).



izzivi



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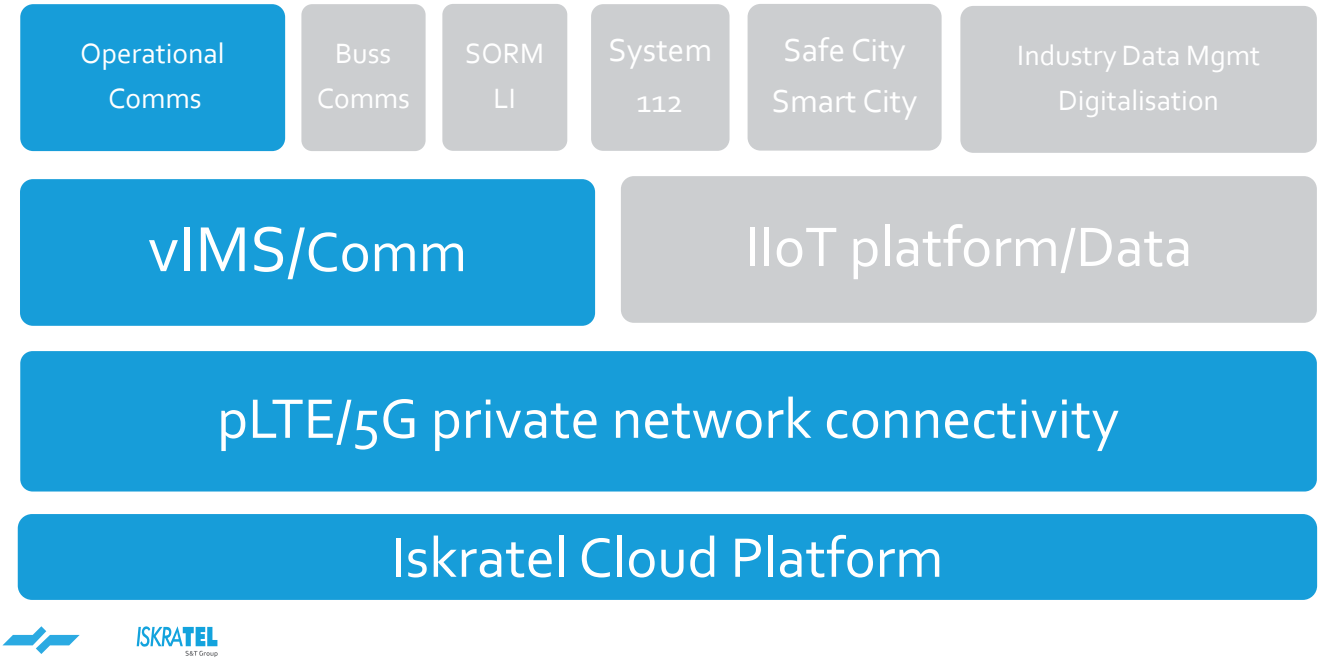
Primer načrta prehoda na FRMCS

Okvirno zaporedje faz projekta prehoda iz GSM-R, preko sobivanja, do FRMCS omrežja.

G1	End of GSM-R Nominal Support	Date of end of supplier contract nominal support
G2	Start of GSM-R Decommissioning	Date of start of GSM-R replacement, at least on a first line, by FRMCS service only
G3	End of GSM-R Service	Date at which at which no more line are providing radio service with GSM-R
F1	Start of FRMCS Preliminary Studies	Date of launch of FRMCS internal project (Resources allocated to FRMCS to produce studies)
F2	FRMCS Migration Plan Published	Date at which Infrastructure Manager is communicating to Railways Undertakings their FRMCS Migration Plan
F3	FRMCS Tendering Start	Date of publication of the FRMCS tender
F4	FRMCS Contract Award	Date at which a supplier is awarded with FRMCS contract
F5	FRMCS Pilot Line	Date at which a train is running under FRMCS radio coverage.
F6	FRMCS Start of National Deployment	Date at which FRMCS national rollout is launched and trains are starting to use FRMCS as CCS Radio.
F7	FRMCS End of National Deployment	Date at which FRMCS national rollout is completed

Year ->	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
GSM-R												G1			G1+G2	G3					
FRMCS						F1		F2		F3	F4	F5		F6		F7					

Iskratel Digital Solutions portfolio



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From GSM-R to FRMCS

- **GSM-R** is a railways success story
  - A standardized railways communications system based on 2G
  - Approaches end-of-life
  - Iskratel and other GSM-R suppliers committed to support GSM-R until 2030 and beyond 2030 on a per contract basis

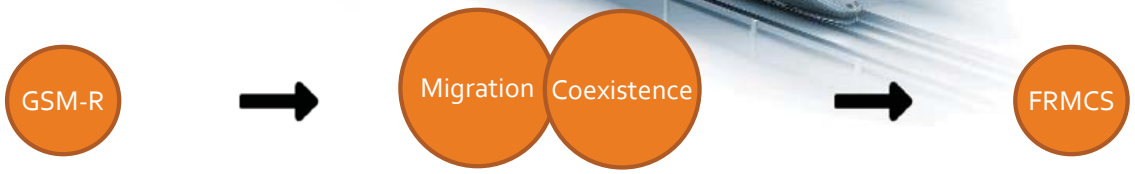
- **FRMCS** – Future Railway Mobile Communication System
  - New generation of standardized railways communication system
  - Introducing Mission critical Voice, Video and Data
  - Enabler for Railways Digitalization
  - Based on 3GPP and ETSI specifications

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Railways dedicated focus

From GSM-R to FRMCS: a full engagement in the evolution





S&T Group leading Radio spectrum management and FRMCS definition

ISKRATEL S&T Group

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Railways - Migration towards FRMCS

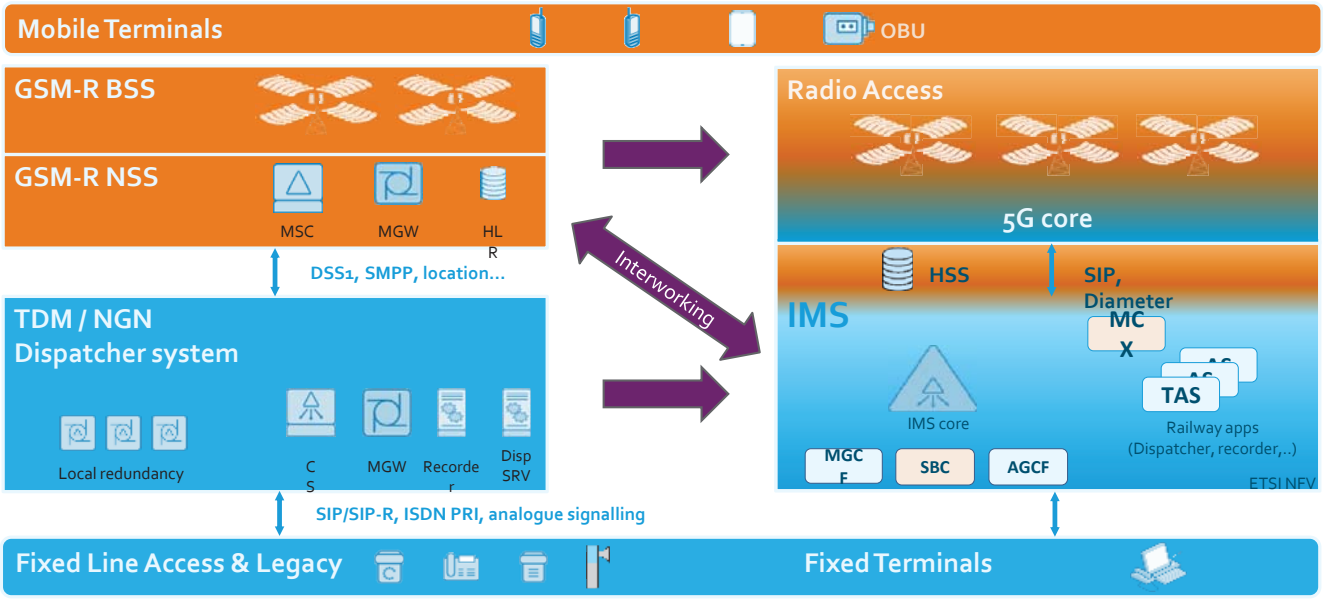
Independence from HW as an evolution → Virtualisation, vIMS, Dispatcher

- Introduction of IP technology in core, radio & transmission
- SCP and FRMCS services convergence through common Application Server
- Introduction of COTS platforms , Network Function Virtualization (NFV)
- Introduction of ETCS over GPRS. Packet Core for multi access evolution
- R4 core network for interworking capabilities with FRMCS
- Distributed BTS allowing for flexible site deployments. Multi technology option

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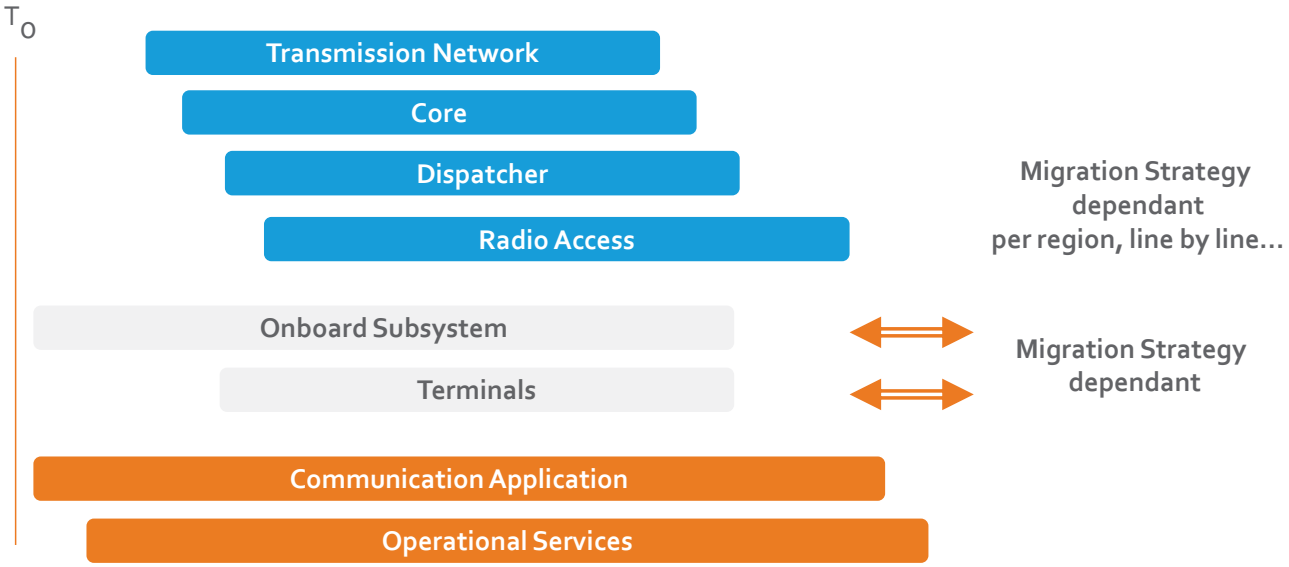
IMS – evolution towards FRMCS



Iskratel Partners

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Migration Phases



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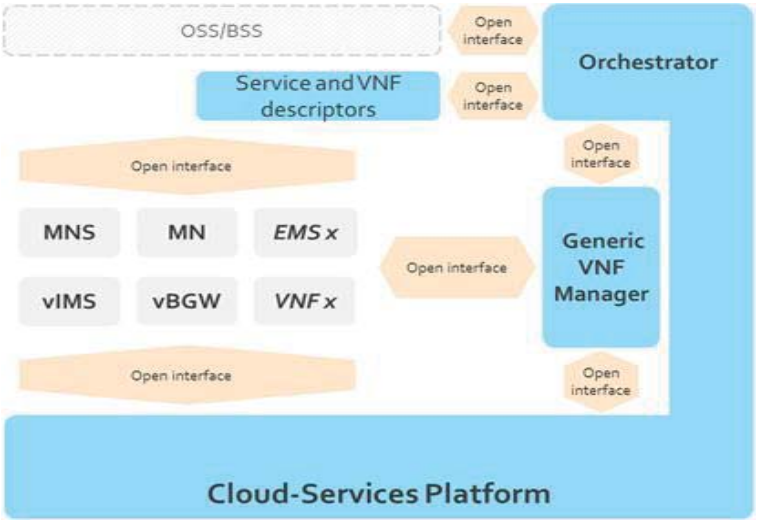
Virtualization / NFV architecture

Functionalities:

- Orchestration
- High availability
- Geo-redundancy

Enabler for:

- HW independence (COTS)
- Flexibility
- New services
- Fast exploitation



(ETSI NFV architecture)

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E2E Mission-critical solution from Iskratel and S&T Group

MCX Application Server

- providing MC Push-To-Talk voice, MC Data and MC Video services
- integration all MCX logical nodes and common services for authorisation and authentication, registration, configuration and security

IMS-based SIP core

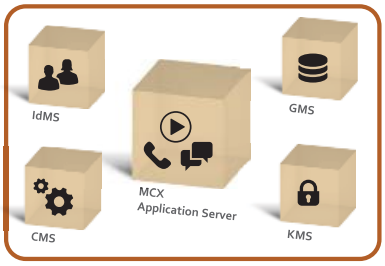
- Providing CSCFs functionality, SIP/RTP proxy, SIP registration, service selection, IWF

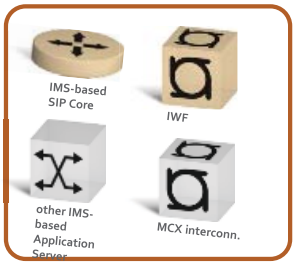
5G SA core & RAN

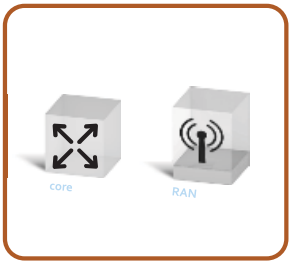
- Providing full solution for 5G SA
- Multiple RAN Options
- 5G SA Cloud Native Core Solution
- Monitoring & Measurement

MCX clients/5G UEs

- Dispatcher terminals, different UE's and Cab Options









MCX and 5G Solution ready to support Railway collaboration

5G network Railway

On-board activities

- Travel info
- Passenger commodity
- Communications
- Diagnostics



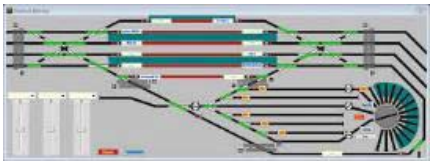


Data management

- Fleet Management
- Remote Access
- Remote Maintenance
- Early problem detection



- Wayside data evaluation for monitoring and control
- Safety critical data exchange train-land



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Pre-FRMCS / FRMCS project timeline

– Today → focus on Specification and Standards and first demonstrators

– Ongoing Pre-FRMCS project – Deutsche Bahn (DB)

– DB FRMCS Call for Research and Development Collaboration (Jan. 2021)

– First migrations to FRMCS planned for 2024-2025

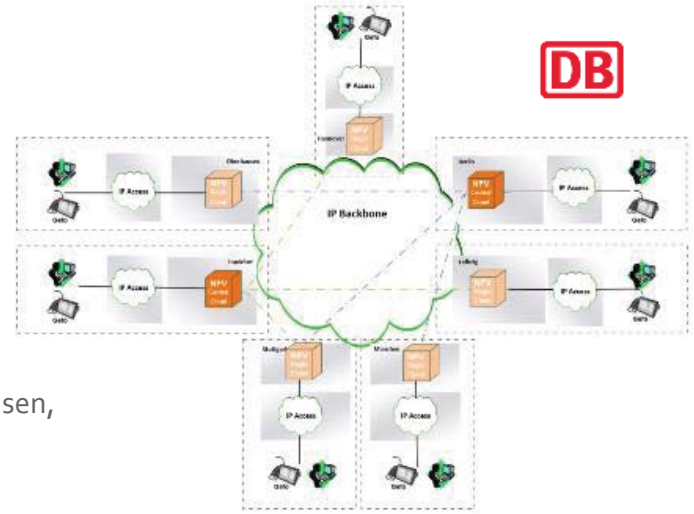
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Reference case: **Deutsche Bahn Gefo**

DB awarded S&T in January 2022 (Kontron Transportation, Iskratel)

Scope:

- Dispatchers
- Virtualization platform (ETSI NFV)
- Communications core (IMS)
- Mission Critical Communications (MCX)
- Management



2 central locations Berlin and Frankfurt

5 regional fully autonomous locations Hanover, Oberhausen, Leipzig, Stuttgart and München

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Dokumentacija o FRMCS

- UIC o FRMCS FRMCS | UIC - International union of railways
  https://uic.org/rail-system/frmcs/
- TR 103 333 - V1.1.1 - System Reference document (SRDoc); GSM-R networks evolution (etsi.org)
  https://www.etsi.org/deliver/etsi_tr/103300_103399/103333/01.01.01_60/tr_103333v010101p.pdf
- Uporabniški primeri za FRMCS: Microsoft Word - FU-7100-5.0.0 (uic.org)
  https://uic.org/IMG/pdf/frmcs_user_requirements_specification-fu_7100-v5.0.0.pdf
- 5GRail:PowerPoint Presentation (5grail.eu)
  https://5grail.eu/wp-content/uploads/2021/06/5GRAIL_IEEE_CAM21_v4.pdf
- ETSI 3GPP Release 18 (3gpp.org)
  https://www.3gpp.org/release18
- [SPEC] 3GPP TR 22.990 – Study on off-network for rail – iTecTec
  https://itectec.com/archive/3gpp-specification-tr-22-990/

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0G, a key enabler of the circular economy

Guillaume Noel

Heliot Europe

guillaume.noel@heliotgroup.com

Abstract

Misconceptions around the Internet of Things (IoT) are common, and the magnitude of the changes that the technology brings to the industrial world is both over-hyped (Goldman Sachs, 2014) and at the same time underestimated with its profound impact on the nitty-gritty part of the real world underpinning day-to-day living. Far from being limited to gadgets, smart cars, smart parking, wearables, pet trackers and "smart everything", the IoT is bringing (1) new insights to industries, utilities and logistics, (2) creating full accountability and responsibility for business transacting locally and globally, and (3) enabling new business better suited for the changing environment (sharing economy).

Nowadays, IoT coverage is readily available throughout Europe at reasonable cost through various standards (cellular or unlicensed) and business models (public or private network). Furthermore, the European union has invested more than EUR 500 mil in IoT related research, innovation and development (European Union, 2021), highlighting the strategic importance of the domain. Broadly speaking in terms of use cases, the IoT may be divided into: (1) critical IoT, which are applications requiring low latency high throughput communication (autonomous vehicles,…) and for which 5G is the standard of choice and (2) Massive IoT, which looks at connecting unpowered assets to the digital world (water meters, box and parcels,…) through very low power wireless protocols (Sigfox, LoRa, Nb-IoT,…). For massive IoT application like tracking of unpowered assets or smart metering, the TCO of the whole solution (sensor plus connectivity) may be as little as a single digit price per year per device as the life duration is commonly more than 5 years, allowing the amortization of the hardware over the years.

Within the IoT ecosystem, Sigfox 0G enjoys a unique position thanks to its ultra-low power consumption and seamless roaming. Sigfox 0G wireless sensors may last to last up to 10 years without the need to change the batteries and have proven track record of success of improving the business resilience of business operations and supply chain in the following cases:

- Use 0G to decrease CO2 footprint in road logistics (postal, automotive,..)

- Use 0G to decrease the waste of food (retails,…)

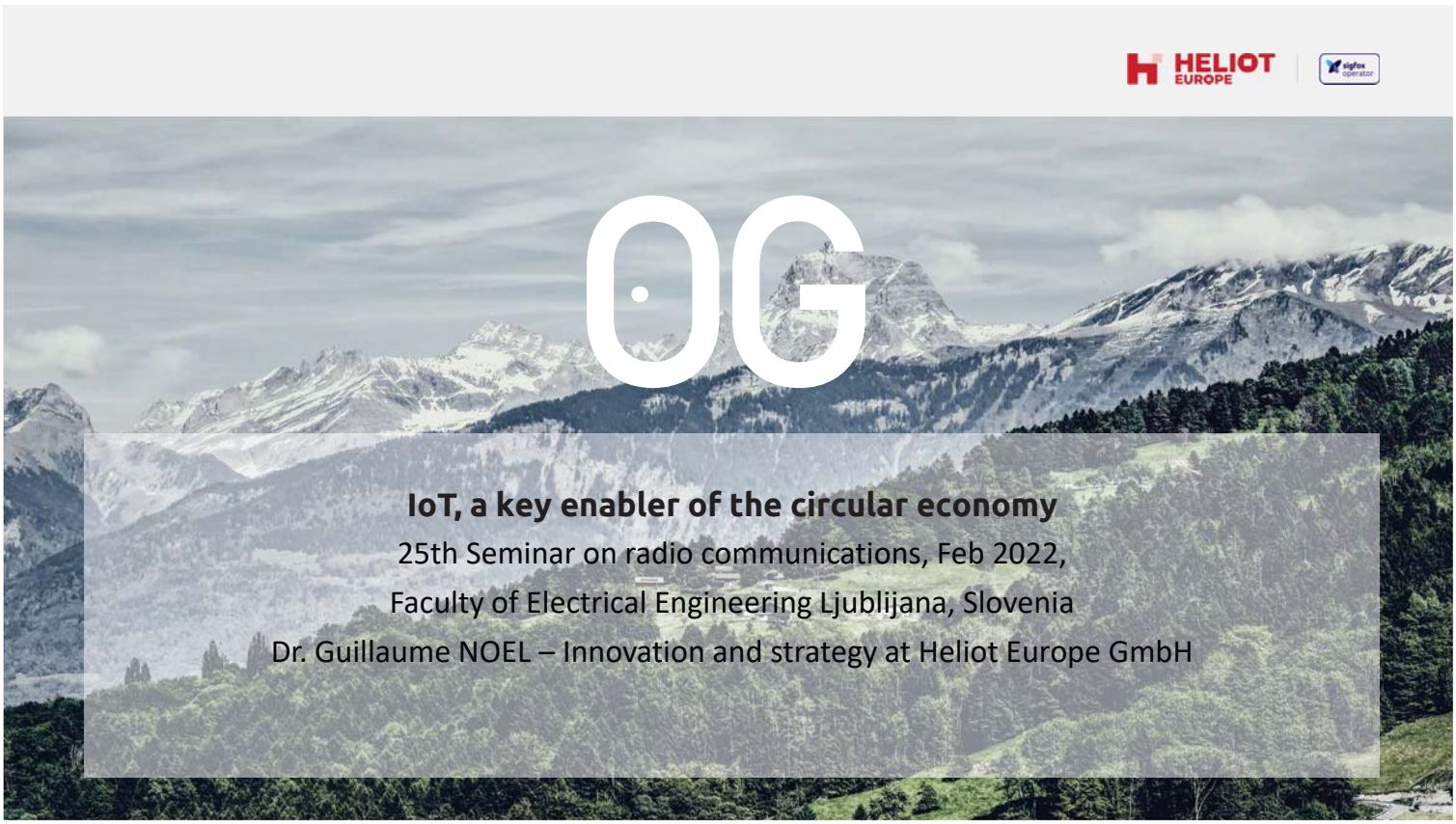
- Use 0G to improve heating and cooling efficiency (district heating,…)

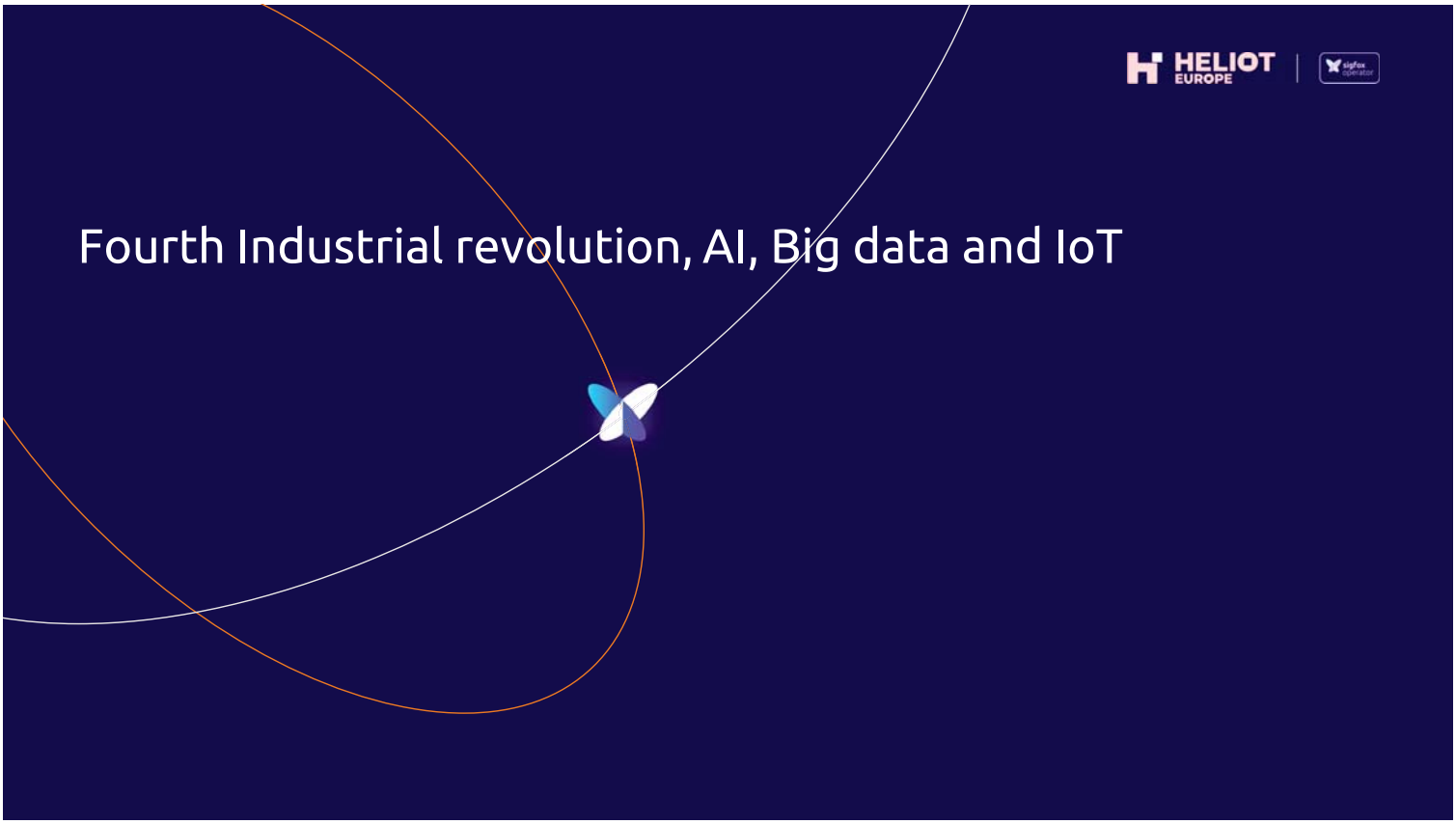
Author's biography



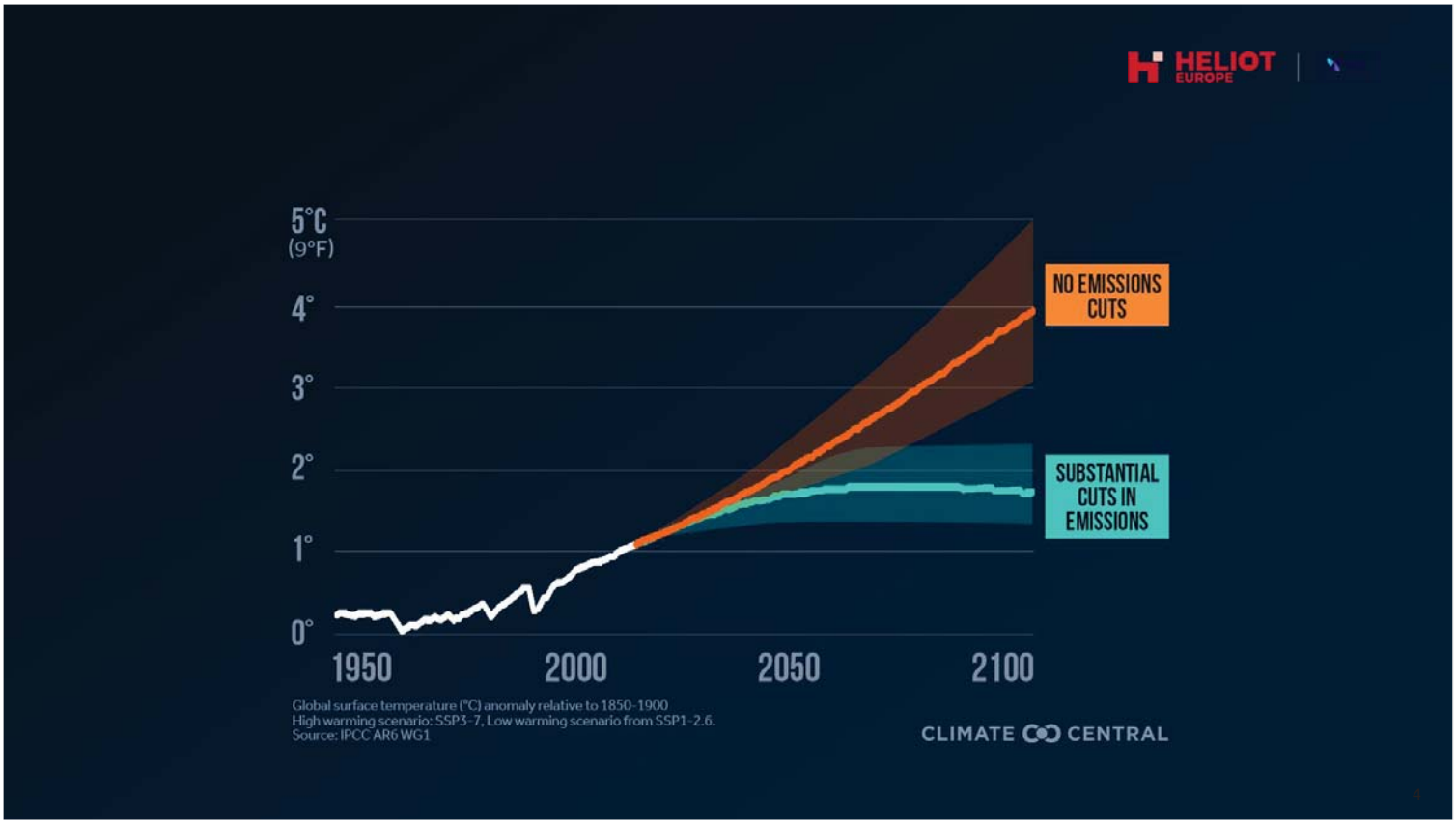
*Dr. **Guillaume Noel** is the head of strategy at Heliot Europe, the largest IoT service provider in Europe. Promoter of a very low energy wireless technology (named 0G in opposition to 5G), Heliot Europe operates more than 1 million sensors in*

Germany, Austria and Switzerland for major postal and automotive companies. Within the Heliot group, Guillaume is in charge of the innovation and technologies of the future focusing on making the sensors smaller and reducing their carbon footprint using printed batteries, energy harvesting. Previously, Guillaume worked for major telco manufacturers and operators in Europe and the USA.


0G
IoT, a key enabler of the circular economy
25th Seminar on radio communications, Feb 2022,
Faculty of Electrical Engineering Ljublijana, Slovenia
Dr. Guillaume NOEL – Innovation and strategy at Heliot Europe GmbH


Fourth Industrial revolution, AI, Big data and IoT

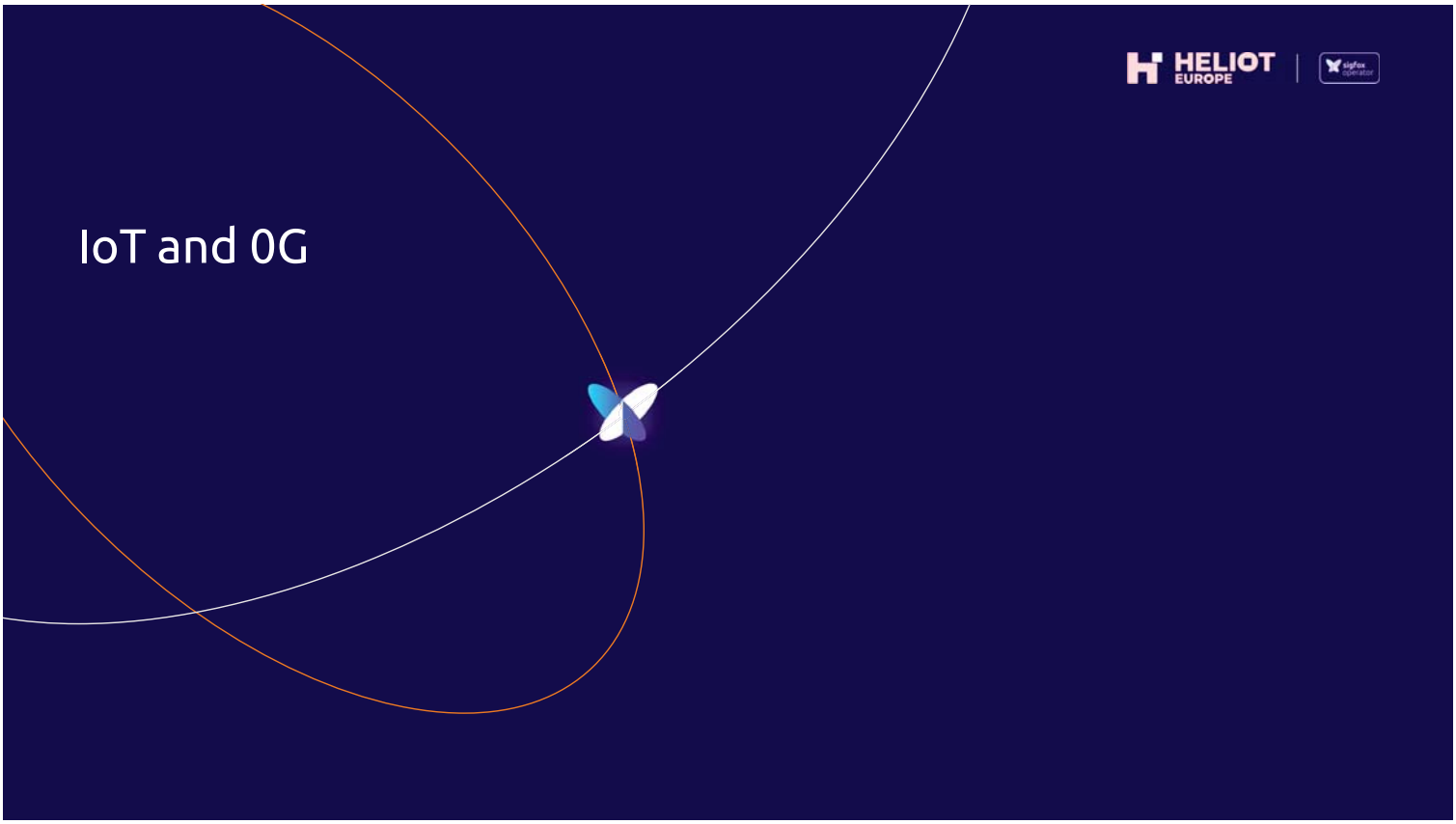

HELIOT EUROPE
The outlooks seem gloomy….


HELIOT EUROPE
5°C (9°F)
4°
3°
2°
1°
0°
1950
2000
2050
2100
NO EMISSIONS CUTS
SUBSTANTIAL CUTS IN EMISSIONS
Global surface temperature (°C) anomaly relative to 1850-1900
High warming scenario: SSP3-7, Low warming scenario from SSP1-2.6.
Source: IPCC AR6 WG1
CLIMATE CENTRAL

But there is hope as new technologies emerge…



Source: Lyivity



HELIOT EUROPE | sigfox operator

Has the delivery arrived?

Where is the tool on loan?

How can I read the consumption from a distance?

Are my goods where they should be?

Has the cold chain been maintaine

Where is the next free parking space?

Where is the stolen vehicle?



What is the current temperature?

How good is the air in the office?

Can the next construction phase start?

Has the voltage dropped below a critical value?

Is my home safe?

Is there a fire hazard due to permanently increased temperature?

What is the current fill level?

Where? What?

IoT makes your physical business processes visible

We have the answers to your questions

7

HELIOT EUROPE | sigfox operator

Pole Position: who we are

sigfox

Sigfox is the largest global 0G wireless network specifically for IoT which is designed sustainably for widespread accessibility and enables data extraction and visualization at an unbeatable low cost - it is secure, lean, cost-effective, robust and efficient. it is secure, lean, cost-effective, robust and efficient.



HELIOT EUROPE

Heliot Europe is the exclusive operator of the Sigfox 0G network in Germany, Switzerland, Austria, Slovenia and Liechtenstein. With over 3700 radio sites*, Heliot Europe is the largest Sigfox 0G network operator in Europe.

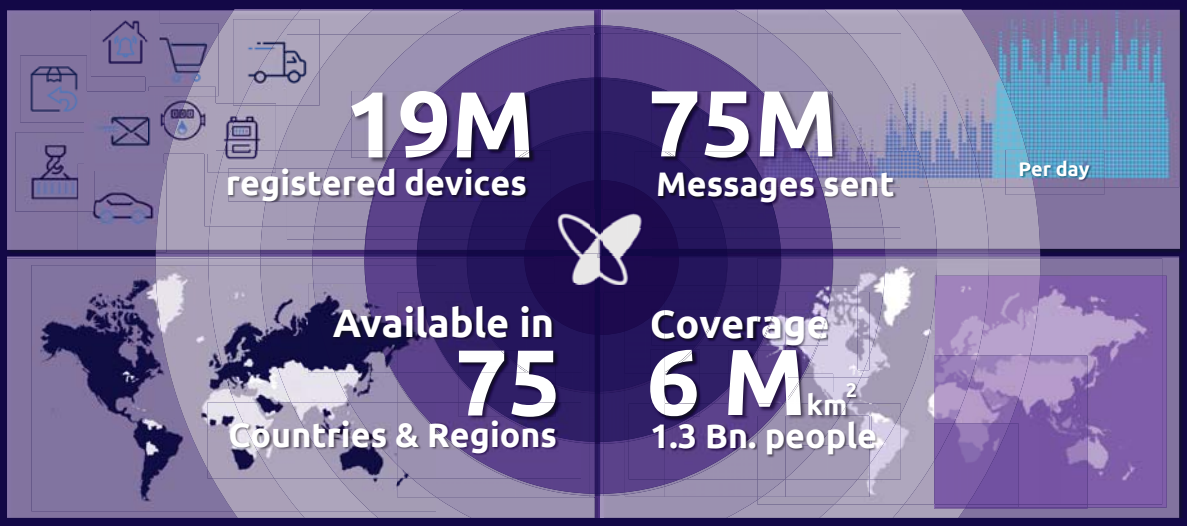
☑ Sigfox 0G Countries and Regions

(*as of 01/2021)

8

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Sigfox 0G network: exponential growth worldwide



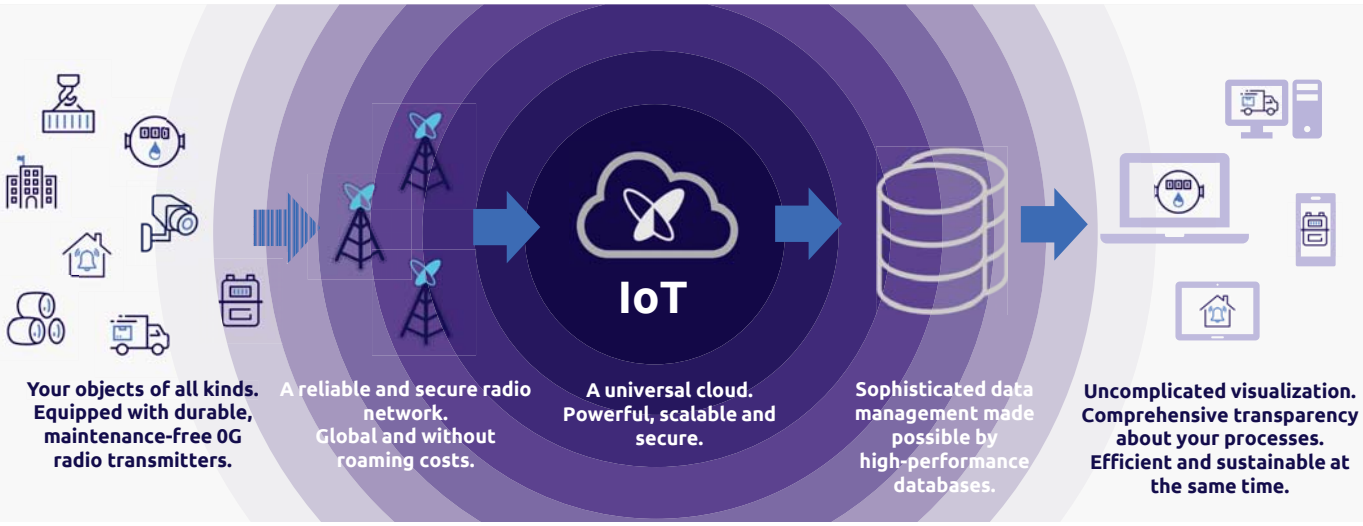
Global solutions for more sustainability

Sigfox is the largest IoT ecosystem operator in the world.

9

HELIOT EUROPE | sigfox operator

Why does your company need an "Internet of Things"?

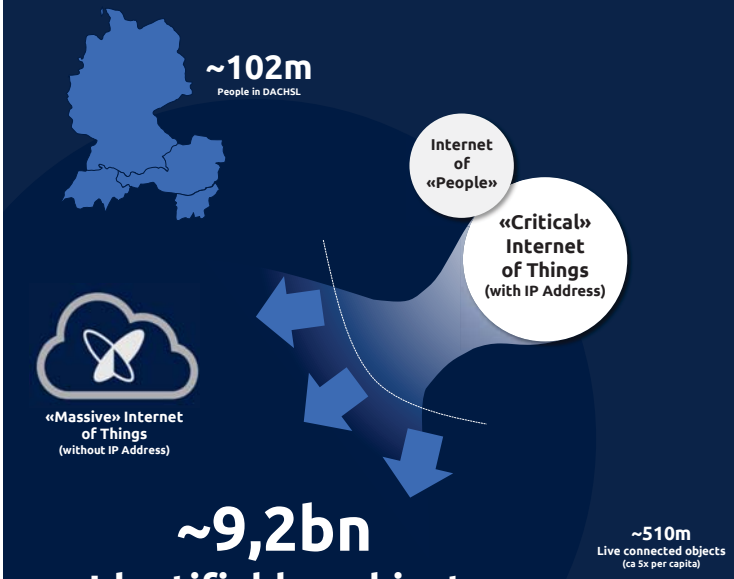


Your objects themselves provide valuable data to your IT and support your decisions

Global network for the digitalization of your physical business processes

10

IoT explained



1. The **Internet of things (IoT)** describes the network of physical objects - aka "things" - that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.
2. **Critical IoT**, connecting millions of objects, communicating high amounts of data, at a higher data rate, with low latency and high reliability, which mostly also results in higher power consumption. We find applications in transportation (connected vehicle, traffic control …), smart health (surgery, patient monitoring…), and industry (real-time applications, robots, remote manufacturing).
3. **Massive IoT**, connecting billions of objects, transmitting a low amount of data, at a low data rate, mostly battery powered, designed to optimize energy consumption and lasting up to 15 years once installed. One can find applications in many verticals such as: utilities, cities, agriculture, logistics, buildings (airports, hotels, stadiums, multi-dwelling units, home, venues…), and supply chain or transportation.

11

0G is the key to a sustainable IoT solution



0G is sustainable.

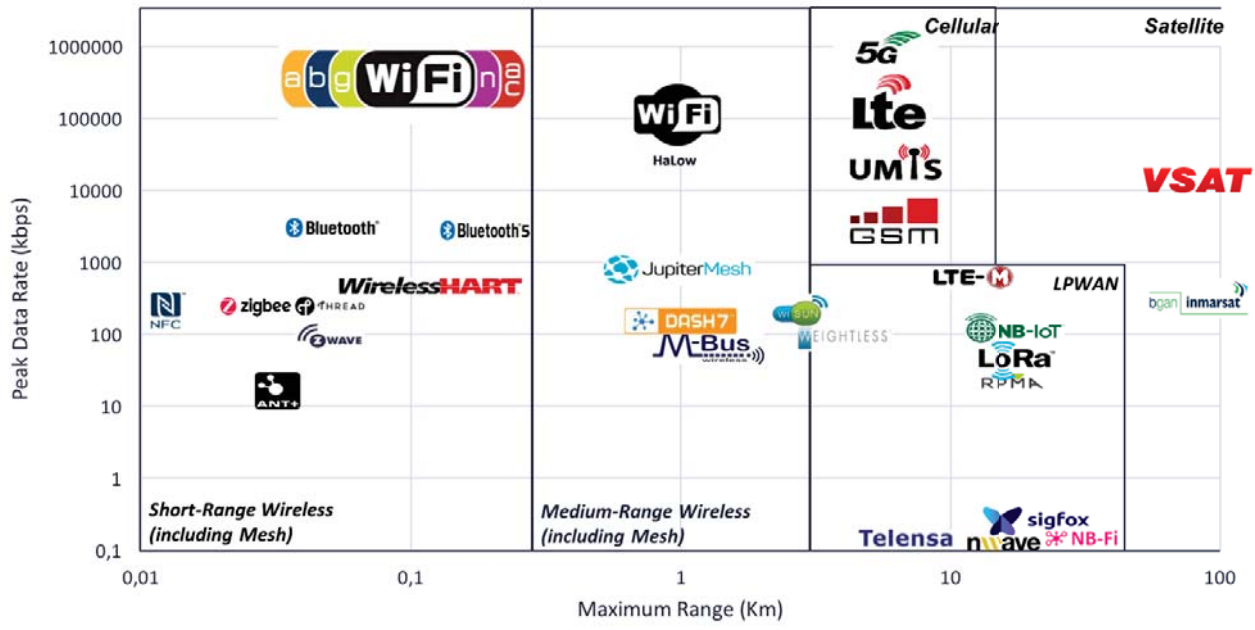
Ultra low has much more to offer.

The 0G network in Europe uses the same amount of power than 10 x 5G base stations

12

The IoT jungle

The IoT “jungle”



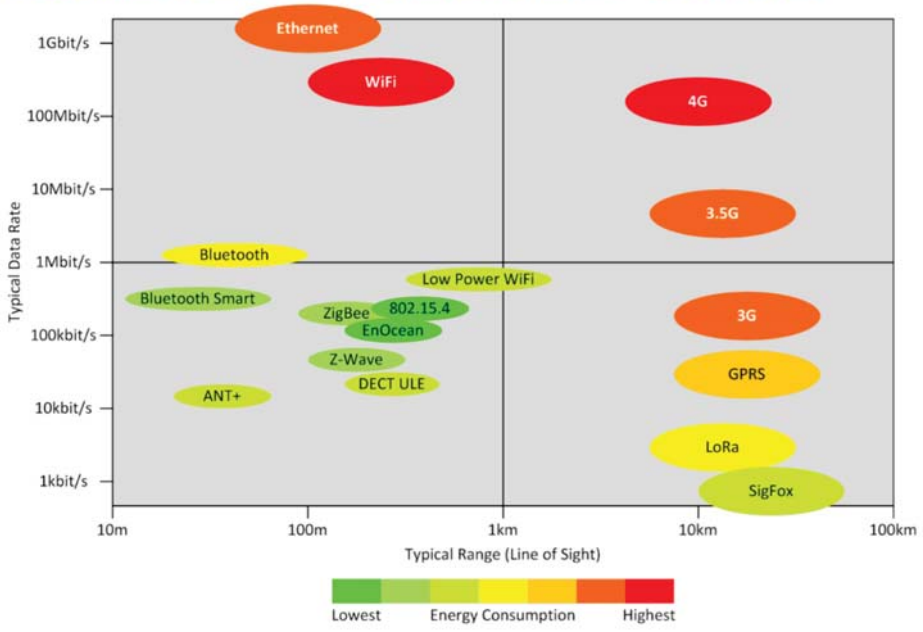
The IoT "jungle"

TABLE 1
COMPARING COMMUNICATION TECHNOLOGIES FOR IoT APPLICATION[2]

	Satellite	Cellular	LoraWAN	Sigfox	Weightless-P	Wifi	Z-Wave	Zigbee	Bluetooth	Bluetooth Low Energy
Data Rate	200 kbps	14.4 kbps (GSM); 1 Gbps (LTE)	300 bps - 50 kbps	100 bps	200 bps - 100 kbps	54 - 1300 Mbps	40 - 200 Kbps	20/40/250 Kbps	1 - 3 Mbps	1 Mbps
Frequency Band	1-2 GHz	900/1800/ 1900/2100 MHz	868/915 MHz	868/915 MHz	169/433/470/ 780/868/915/ 923 MHz	2.4/5 MHz	868/915/ 2400 MHz	868/915/ 2400 MHz	2400 MHz	2400 MHz
ISM Band	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mode of operation	Full Duplex	Full Duplex	Half Duplex	Half Duplex	Half Duplex	Half Duplex	Half Duplex	Full Duplex	Full Duplex	Full Duplex
Max. Payload size	–	–	256 Bytes	12 Bytes	10 Bytes	–	64 Bytes	127 Bytes	358 Bytes	47 Bytes
Power profile	High (weeks)	Medium (months)	Low (+years)	Low (+years)	Low (+years)	High (weeks)	Low (+years)	Low (+years)	Medium (months)	Low (+years)
Typical Range	Global	35 Km	3-15 Km	5-25 Km	2 Km urban 5 Km outdoor	15-150 m	30-100 m	30-100 m	3-30 m	5-100 m
Standard	Proprietary	GSM; GPRS; EDGE; HSPA; LTE; LTE-A	LoraWan	Sigfox Proprietary	Weightless SIG	IEE 802.11 a/b/g/n/ac	Z-wave Proprietary	Zigbee (based on IEE 802.15.4)	IEEE 802.15.1	IEEE 802.15.1

The IoT "jungle"

Figure 20: Available communication technologies for IoT applications – range vs. data rate



Use cases and verticals



Roller cage tracking

Challenge

DHL owns a fleet of roller cages that are critical to their business. They were unmanaged, resulting in losses, lack of visibility, and unoptimized usage.

Solution

- Equip roller cages with ALPS Lykaner tracker
- Using Sigfox ATLAS WiFi geolocation technology

Benefits

- Reduced number of lost roller cages means a positive impact on CAPEX
- Gain in efficiency by on-demand delivery of empty roller cages thereby reducing CO2 emissions
- Calculation of an ETA (Estimated time of availability) will be possible in the future



Public Customer case





Giving a voice to beer kegs

Kegstar

Challenge

Remove labor-intensive manual scanning bottlenecks and billing reconciliation issues to improve operational and billing efficiency across the total supply chain of the keg. For ex. 20% kegs do not get scanned every year.

Solution

A highly ruggedized, yet low cost, industrial grade multizone tracker is developed which will be fixed on the Keg dome, providing track and trace with 5 years battery autonomy. The tracker eliminates the need for manual scanning at each stage of supply chain, human errors, inventory management while monitor ambient temperature which impacts the quality of beer.

Solution is under deployment by a global Keg pooler.

Benefits

- Increase adoption - Scanless operations
- Invoice reconciliation – customer trust
- Operational efficiency to be improved by 15%
- Improve Keg rotation from 4 to 5 per annum
- Reduction of loss kegs to be reduced by 50%.

sigfox

Public Customer case



Smart metering

water-link

Challenge

Remotely monitor water consumption

Solution

Kamstrup Multical 21

Service button: The valve can be closed from a distance but can only be opened via the service button after the open command has been given from the central server.

the valve has the unique characteristic to allow a predetermined amount of liters per hour to pass.

Contains already some alarms: Leak, Burst, Dry, Fraud, Reverse flow.

Benefits

- 16 years autonomy with 1 reading per day & 1 open/close operation per month
- Remote valve control
- Flow reduction possibility
- Plug & play
- Fraud resistant
- IP 68 rating
- Cloud solution pluggable to existing ERP systems
- Central data capturing

sigfox

Public Customer case





Usage based insurance

Challenge

La Parisienne is disrupting the insurance for the mobility market with cutting edge offers that are more transparent, simple and competitive.

Solution

Individual customers or small business fleets subscribing to this offer will receive a sensor to be installed very simply on their vehicle. This object connected to Sigfox's 0G network will be equipped with an accelerometer, allowing the detection of movements and thus providing them with insurance based on their real usage (per minute, per hour or per km).

Benefits

- Increased transparency for the user
- Actual usage tracked allowing a precise billing
- Simple implementation
- Competitive advantage for La Parisienne

Public Customer case



Seniors life quality improvement

Challenge

Senior people living alone have significantly higher risks of having problems when there is nobody around that can provide help

Solution

Monitoring senior activity within their home to detect potential risk situation.

Placing several motion and door sensors in the house allow to learn the senior lifestyle. Cloud-based algorith learns senior's behavior to provide better care.

On significant lifestyle change a message is sent to the relatives.

Optional GPS-based device provides additional information of senior location when leaving home



Benefits

- Improving quality of life of Seniors
- Provides ability for seniors to stay safe longer at home
- Reduce the risks of senior citizens falling and fainting outdoor and indoor
- Help and provide peace of mind to carers
- New service being added to Vox Telecom product portfolio

MAMCO GENEVE



Giving a voice to paintings

Challenge

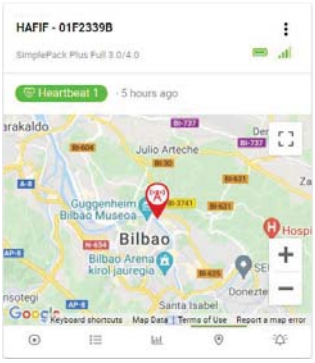
- **The MAMCO lends art pieces to other museums in Europe**
- **How to check that the transport conditions and exhibitions are not damaging the pieces?**

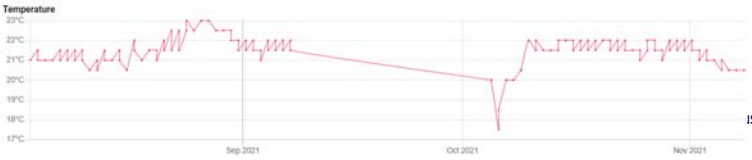
Solution

Attach a very small sensor to the paintings before shipping

The sensor reports location, humidity and temperature

When a threshold is crossed (excessive temperature or humidity), the MAMCO receives an alert.





istomer case

HELIOT EUROPE | sigfox operator

New trends

Smart label – flexible, compostable and recyclable

HELIOT EUROPE | sigfox operator

1 Scan QR code and link device ID to application



2 Cut selected temperature setting with normal scissors



3 Attach to stock (self-adhesive)



4 Receive notification if temperature is exceeded or seal is broken





Public Customer case

Track and trace with RFID plus (combined RFID & 0G)

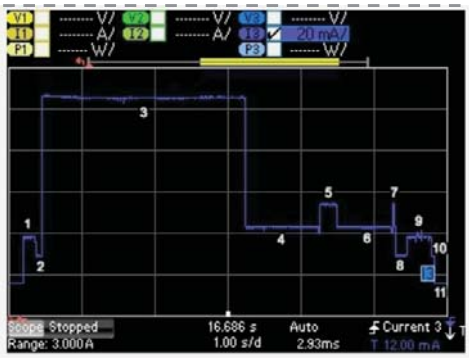
HELIOT EUROPE | sigfox operator

- Benefits:
  - Seamlessly bridges the gap between legacy indoor tracking and outdoor tracking.
  - RFID tags, events, and their environment can be monitored from the cloud (battery state, sensors, etc.).
- Cyclical uplink transmissions. Uplink only at this time (downlink as a requirement to be assessed).
- Standard battery lifetime (NXP estimate): beyond 8 years, with 6 messages per day, powered by a CR2450 battery.
- PCB dimensions: half the size of a credit card.
- Tag can be interacted with via UHF RFID.
  - Works as a regular RFID tag.
  - Can change Sigfox transmission interval, payload content, etc.
  - Can trigger Sigfox transmission.
  - Can deactivate Sigfox transmission (example: asset enters warehouse, relies only on RFID to save on battery consumption for a few hours/days/weeks. Sigfox communication is reactivated when device is scanned, leaving the premises).



26

Printed batteries



State Number	Description	Duration		Current Consumption	
		Variable	Value (ms)	Variable	Value (mA)
1	wake up	T_{wu}	168.2	I_{wu}	22.1
2	radio preparation	T_{pre}	83.8	I_{pre}	13.3
3	Transmission	T_{tx}	(see Table 6)	I_{tx}	83.0
4	wait 1st window	T_{w1w}	983.3	I_{w1w}	27.0
5	1st receive window	T_{rx1w}	(see Table 6)	I_{1w}	38.1
6	wait 2nd window	T_{w2w}	Equation (4)	I_{w2w}	27.1
7	2nd receive window	T_{rx2w}	33.0	I_{2w}	35.0
8	radio off	T_{off}	147.4	I_{off}	13.2
9	Postprocessing	T_{post}	268.0	I_{post}	21.0
10	turn off sequence	T_{seq}	38.6	I_{seq}	13.3
11	Sleep	T_{sleep}	Equation (2)	I_{sleep}	45×10^{-3}

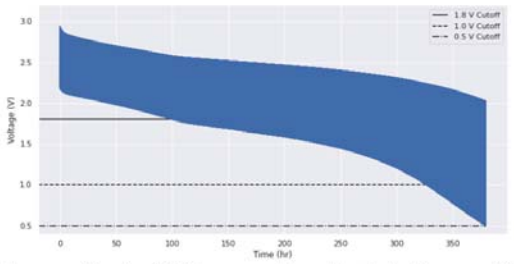


Figure 1. Voltage profile of an 8349 battery subjected to the LoRa test at 23°C, 45%RH.

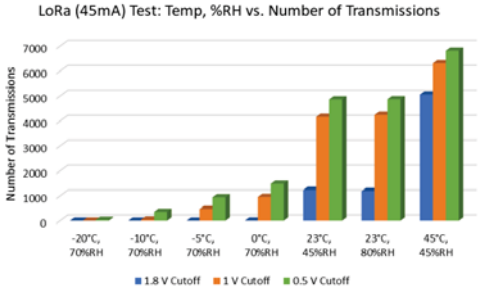
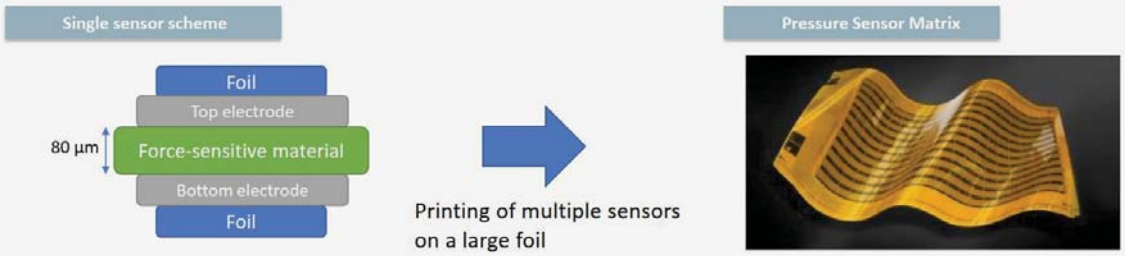
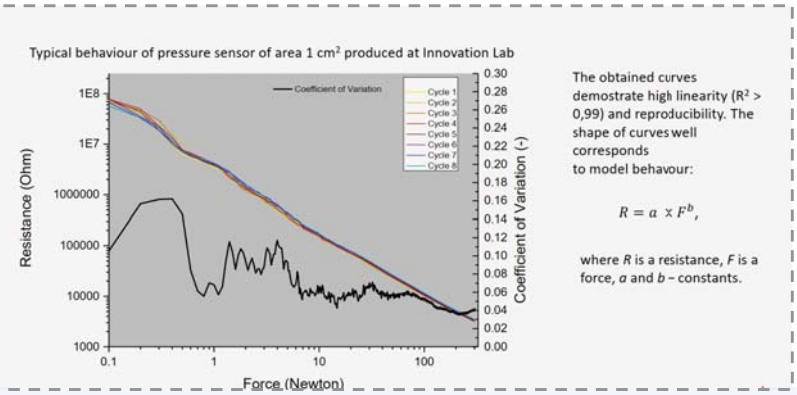


Figure 4. Number of transmissions (45 mA, 0.4 sec pulses) over a wide temperature range and different voltage cutoffs.

Printed sensors





The obtained curves demostrate high linearity ($R^2 > 0,99$) and reproducibility. The shape of curves well corresponds to model behavour:

$$R = a \times F^b,$$

where R is a resistance, F is a force, a and b – constants.



The software is capable to detect changes in passenger's position.

Any questions?

Please contact us.

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Uporaba radijskih komunikacij v športnih aplikacijah

The use of radio communications in sports applications

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Univerza v Ljubljani, Fakulteta za elektrotehniko
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Povzetek

Senzorji, nosljive naprave, brezžične in druge tehnologije so vse bolj prisotne v našem vsakdanjem življenju. Preučujemo njihovo izvedljivost in uporabo v sistemih in aplikacijah z biološko povratno vezavo v športu. Ti so pomembni pri motoričnem učenju in spremljanju športnega treninga. Senzorji, aktuatorji in brezžične tehnologije so glede na njihove lastnosti zelo raznolike. Opisujemo najpogostejše skupine senzorjev in aktuatorjev, ki se uporabljajo v športu, ter podajamo pregled komercialno dostopnih brezžičnih tehnologij. Predstavljamo najpomembnejše omejitve delovanja sistema z biološko povratno vezavo in predstavljamo različne scenarije njihove uporabe v športu. Scenarije povežemo z najprimernejšo obstoječo brezžično tehnologijo, za katero se pričakuje, da bo vzdrževala razširljivost v številu vozlišč ali povečane hitrosti prenosa podatkov v pričakovani življenjski dobi aplikacije.

Abstract

Sensors, wearable devices, wireless and other technologies are ever more present in our daily life. We study their applicability and use in biofeedback systems and applications in sport. Biofeedback systems are important in motor learning and monitoring in sports training. Sensors, actuators, and wireless technologies come in great varieties regarding their properties. We describe the most common groups of sensors and actuators that are used in sport and review commercially available wireless technologies. We present the most important constraints of a biofeedback system operation and present a number of different biofeedback application scenarios in sports. We match the scenarios to the most appropriate existing wireless technology that is expected to sustain scalability in the number of nodes or increased data rates for the expected application lifetime.



Biografija avtorja

Anton Kos je doktoriral leta 2006 na Fakulteti za elektrotehniko, Univerze v Ljubljani. Zaposlen je kot izredni profesor na Fakulteti za elektrotehniko, Univerze v Ljubljani. Je član laboratorija za informacijske tehnologije na katedri za Informacijsko komunikacijske tehnologije. Njegovo pedagoško in raziskovalno delo obsega področja komunikacijskih omrežij in protokolov, kakovosti storitve, pretočno podatkovnega računalništva in aplikacij, uporabe senzorjev gibanja v sistemih in aplikacijah z biološko povratno vezavo, obdelave signalov in informacijskih sistemov. Je (so)avtor več kot 50 člankov objavljenih v mednarodnih revijah s področja tehnike in več kot 80 člankov predstavljenih na mednarodnih konferencah.

Author's biography

Anton Kos *received his Ph.D. in electrical engineering from University of Ljubljana, Slovenia, in 2006. He is an associate professor at the Faculty of Electrical Engineering, University of Ljubljana. He is a member of the Laboratory of Information Technologies at the Department of Communication and Information Technologies. His teaching and research work includes communication networks and protocols, quality of service, dataflow computing and applications, usage of inertial sensors in biofeedback systems and applications, signal processing, and information systems. He is the (co)author of a scientific monograph, more than fifty papers published in international engineering journals, more than eighty papers presented at international conferences, and two patents.*

LaiT Laboratorij za informacijske tehnologije



Uporaba radijskih komunikacij v športnih aplikacijah

Anton Kos in Anton Umek

Univerza v Ljubljani, Fakulteta za elektrotehniko

Vsebina

- Sistemi in naprave z brezžično komunikacijo v športu
- Sistemi z biološko povratno vezavo v športu
  - Osnove delovanja in uporaba
  - Arhitekture
  - Funkcionalnost
  - Časovnost
- Senzorji
- Aktuatorji
- Brezžične tehnologije
- Scenariji uporabe v športu
- Najprimernejša obstoječa brezžična tehnologija

Brezžični sistemi v športu

- Senzorji, nosljive naprave, brezžične in druge tehnologije so vse bolj prisotne v našem vsakdanjem življenju.
- Preučujemo njihovo izvedljivost in uporabo v sistemih in aplikacijah z biološko povratno vezavo v športu.
- Ti so pomembni pri motoričnem učenju in spremljanju športnega treninga.
- Senzorji, aktuatorji in brezžične tehnologije so glede na njihove lastnosti zelo raznolike.
- Opisujemo najpogostejše skupine senzorjev in aktuatorjev, ki se uporabljajo v športu, ter podajamo pregled komercialno dostopnih brezžičnih tehnologij.
- Predstavljamo najpomembnejše omejitve delovanja sistema z biološko povratno vezavo in predstavljamo različne scenarije njihove uporabe v športu.
- Scenarije povežemo z najprimernejšo obstoječo brezžično tehnologijo, za katero se pričakuje, da bo vzdrževala razširljivost v številu vozlišč ali povečane hitrosti prenosa podatkov v pričakovani življenjski dobi aplikacije.

Kaj je biološka povratna vezava?

V sistemu z biološko povratno vezavo ima oseba pritrjene senzorje za merjenje telesnih funkcij in parametrov (**bio**).

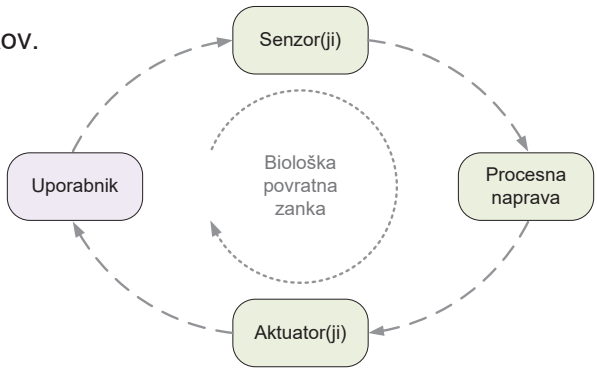
Senzorji so povezani z napravo za obdelavo in analizo podatkov.

Rezultati obdelave se sporočajo osebi (**povratna vezava**) preko enega od človeških čutov (tj. vida, sluha, dotika).

Oseba poskuša ukrepati glede na prejeto informacijo in spremeniti neko funkcijo telesa ali parameter na želeni način.

Izraz ***biološka povratna vezava*** se najpogosteje opisuje v povezavi s fiziološkimi procesi.

V zadnjem času se vedno bolj uporablja tudi v povezavi s telesno aktivnostjo v smislu **fizičnega gibanja**.



Uporaba biološke povratne vezave

Področja uporabe sistemov z biološko povratno vezavo so raznolika in številna.

Šport
- Pohitritev učenja novih gibov (motorično učenje).
- Preverjanje kakovosti in natančnosti izvedbe športnih elementov.
- Preprečevanje poškodb.
- Zaznavanje skoraj neopaznih razlik v izvedbi.

Zdravstvo
- Hitrejša in bolj varna fizična rehabilitacija.
- Cenejša avtonomna rehabilitacija.

Drugo
- Kibernetsko-fizični sistemi kjer je človek del zanke.

Sistemi z biološko povratno vezavo

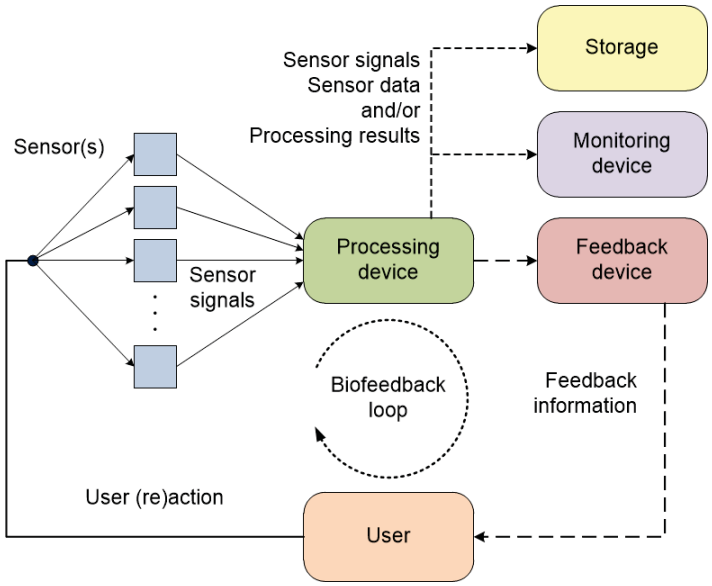
Splošna arhitektura sistema

Senzorji zaznavajo aktivnost in njihovi signali se prenašajo v procesno napravo,
ki poskrbi za njihovo obdelavo in analizo.

Rezultati obdelave krmilijo delovanje naprave za podajanje povratne informacije.

Odziv uporabnika spremeni signale senzorjev in tako sklene povratno zanko sistema.

Signali in rezultati se lahko spremljajo z nadzorno napravo in shranijo v podatkovno shrambo za morebitno kasnejšo uporabo.

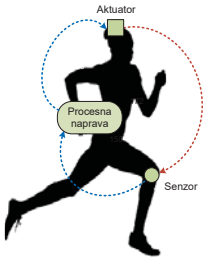


Izvedbene arhitekture

Strnjen sistem

Vsi elementi sistema so na uporabniku
- združeni v eni napravi
- ali zelo blizu eden drugemu.

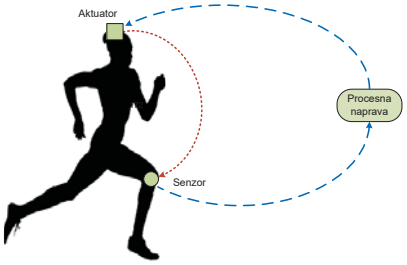
Komunikacije je navadno brezžična, lahko pa tudi žična.
Sistem je avtonomen.
Kompromis med
- procesno močjo
- časom delovanja.



Porazdeljen sistem

Senzorji in aktuatorji so navadno na uporabniku.
Procesna naprava je na oddaljeni lokaciji.
Komunikacija je brezžična.
Kompromis med:
- dosegom
- bitno hitrostjo
- zakasnitvijo

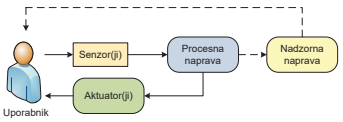
Procesna moč ni problem.



Funkcionalnost

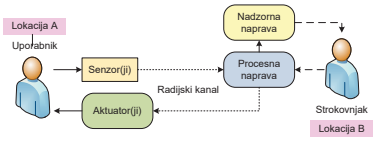
Uporabnik (športnik)

Sistem je v celoti pod nadzorom uporabnika.
- Nosljive naprave kot so:
  - pametne ure,
  - pametni telefoni,
  - namenske naprave z biološko povratno vezavo.



Strokovnjak (trener)

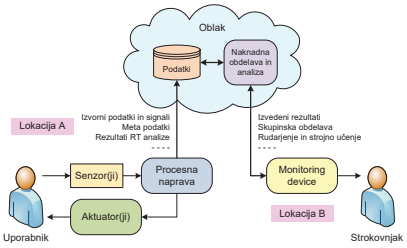
Sistem nadzoruje strokovnjak, ki spremlja uporabnika.
- analizira izvedene akcije,
- podaja povratno informacijo uporabniku
- spremlja statistične in druge parametre izvedbe in uporabnika.



Oblak

Obdelava in/ali shranjevanje podatkov v oblaku
- izvorni podatki,
- izvedeni parametri,
- statistične analize…

Dosegljivo preko spleta vsem z ustreznimi pravicami.



Časovnost

Glede na čas podajanja povratne informacije, ločimo dva osnovna načina delovanja

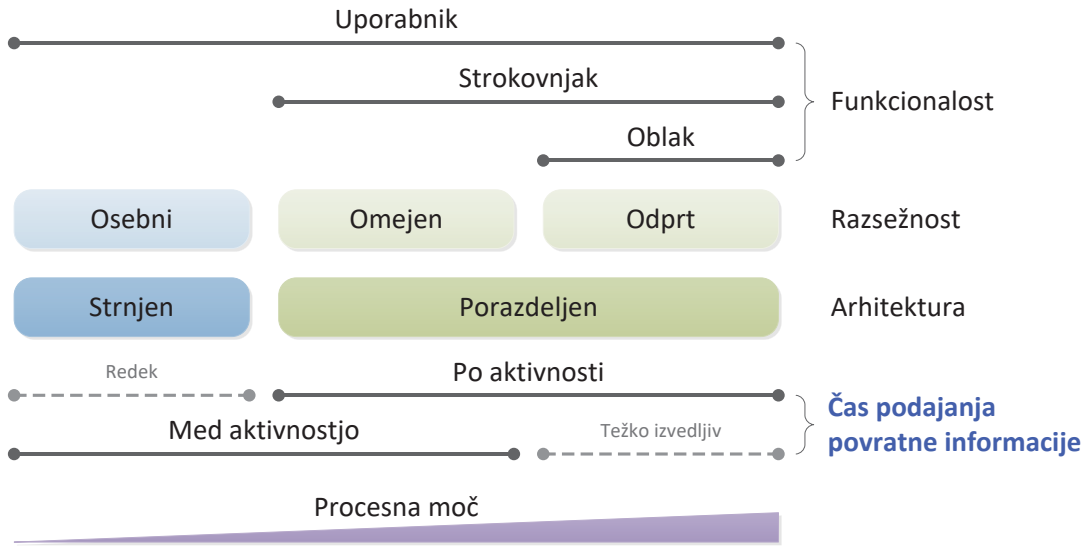
Po aktivnosti (*terminal feedback*)

kjer se signali senzorjev,
pridobljeni med aktivnostjo,
obdelujejo po končani aktivnosti
(post-processing)

Med aktivnostjo (*concurrent feedback*)

kjer se signali senzorjev
obdelujejo sočasno z izvajanjem aktivnosti
(real time processing)

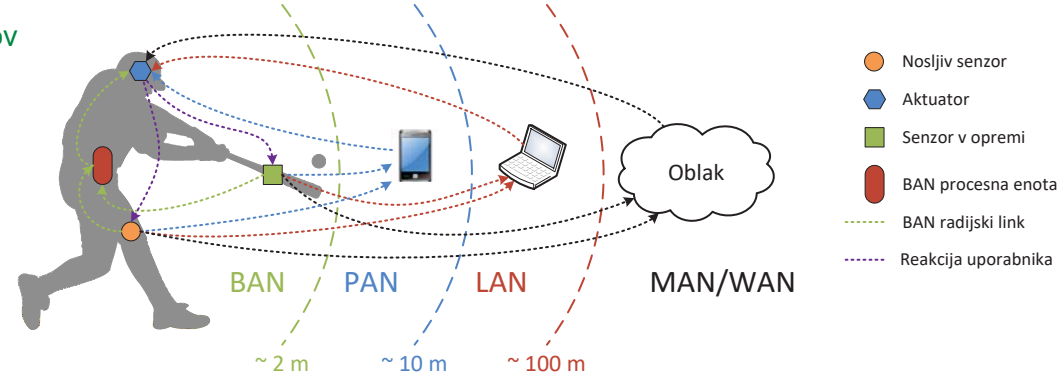
Kategorizacija sistemov z BPV



Potrebe sistemov z BPV

Potrebe po procesnih in komunikacijskih virih so odvisne od številnih dejavnikov:

- komunikacijske tehnologije
- razdalje med elementi sistema
- razpoložljive moči baterije
- števila senzorjev
- frekvence vzorčenja
- bitne hitrosti
- protokolnih skladov
- …



Senzorji in aktuatorji

Senzorji in aktuatorji v športu, so zelo **heterogeni**.

Lahko jih razvrstimo po več kriterijih

- izmerjena fizikalna veličina,
- zahteve glede zakasnitve,
- bitne hitrosti,
- …

V tabeli so navedeni najpogosteje uporabljeni senzorji in aktuatorji z:

- razponi bitne hitrosti in
- omejitvami zakasnitve.

Senzor/Aktuator	Bitna hitrost	Zakasnitev
Temperature	< 100 bit/s	Not critical
Heart rate	< 100 bit/s	Seconds
Oximeter	< 100 bit/s	Seconds
CO_2	< 100 bit/s	Seconds
Blood sugar	< 100 bit/s	Not critical
Blood pressure	< 100 bit/s	Not critical
ECG	20-100 kbit/s	< 1 s
Accelerometer	1-200 kbit/s	< 50 ms
Gyroscope	1-200 kbit/s	< 50 ms
Magnetometer	1-200 kbit/s	< 50 ms
Altimeter	< 1 kbit/s	Not critical
Strain-gauge	1-50 kbit/s	< 50 ms
Tactile actuator	< 100 bit/s	< 50 ms
Voice	50-100 kbit/s	< 50 ms
Audio	<1 Mbit/s	< 50 ms
Video	< 10 Mbit/s	< 50 ms

Brezžične tehnologije

Brezžične tehnologije so, tako kot senzorji in aktuatorji, zelo **heterogene**.

V tabeli so navedene najbolj razširjene brezžične tehnologije za BAN, PAN, LAN in MAN .

Tehnologija	Frekvenca	Doseg	Bitna hitrost	Oddajna moč
Bluetooth 2.1 + EDR	2.4 GHz	10 - 100 m	1 - 3 Mbit/s	2.5 - 100 mW
Bluetooth 4.0 + LE	2.4 GHz	10 m	1 Mbit/s	2.5 mW
ZigBee	868 MHz and 2.4 GHz	10 - 100 m	20 - 250 kbit/s	1 - 100 mW
IEEE 802.11n	2.4 and 5 GHz	70 m	600 Mbit/s	100 mW
IEEE 802.11ac	5 GHz	35 m	6.93 Gbit/s	160 mW
IEEE 802.11ad	60 GHz	10 m	6.76 Gbit/s	10 mW
IEEE 802.11ah	900 MHz	1 km	40 Mbit/s	100 mW
IEEE 802.11af	54 - 790 MHz	>1 km	1.8 - 26.7 Mbit/s	100 mW
LoRaWAN	868 - 928 MHz	up to 100 km	250 - 5470 bit/s	1.5 - 100 mW

Brezžične tehnologije

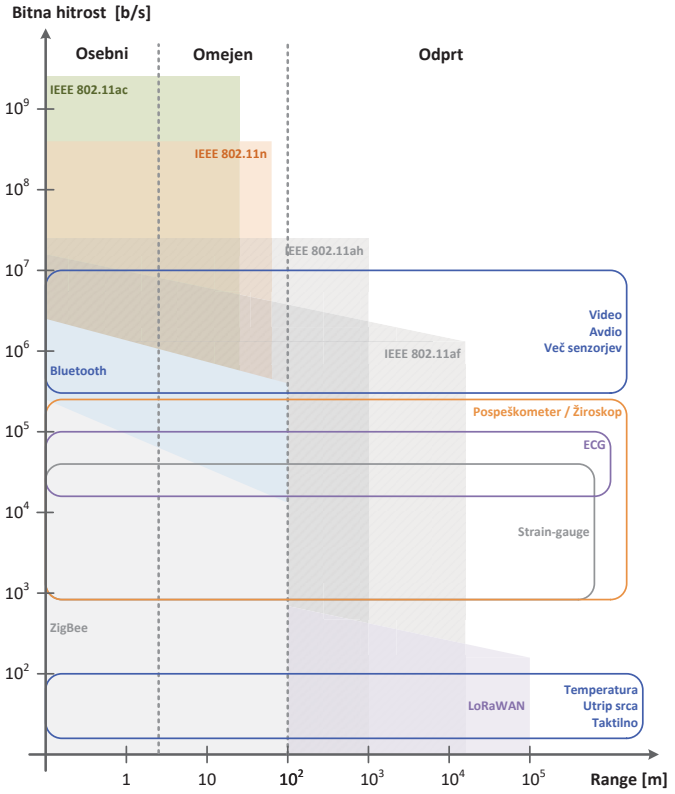
Dva glavna parametra, ki se navadno upoštevata, sta
- doseg in
- bitna hitrost.

Oboje je močno odvisno od izbrane različice sistema z biološko povratno vezavo ter obsega, načina in mesta obdelave podatkov.

Nekaj primerov možne uporabe in omejitev:
- Za pošiljanje podatkov senzorja iz sistema odprtega prostora sta potrebna različica LoRaWAN ali IEEE 802.11ah.
- ZigBee in LoRaWAN nista primerna za prenos visoko dinamičnih signalov IMU.
- Bluetooth je primeren za osebne aplikacije biološke povratne informacije, ne pa za aplikacije z biološko povratno vezavo v omejenem in odprtem prostoru.

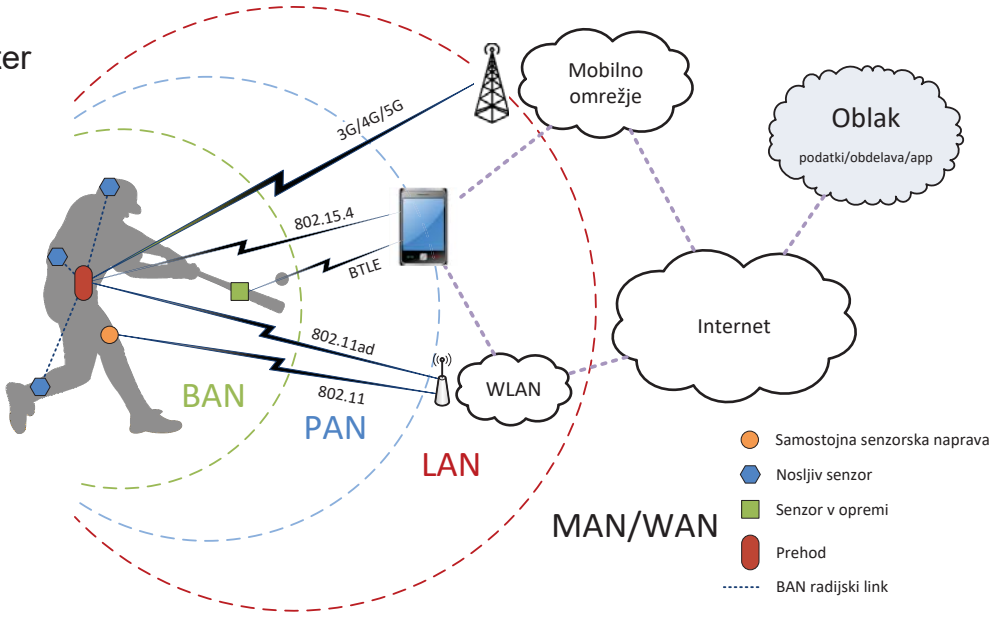
Senzorji in tehnologije

Prikaz razpoložljivih bitnih hitrosti in dosegov brezžičnih tehnologij iz tabele 2, skupaj z zahtevanimi razponi bitnih hitrosti različnih senzorjev in aktuatorjev iz tabele 1, ki pomagajo pri izbiri ustreznih elementov sistema z biološko povratno vezavo.



Primeri izvedbenih scenarijev

Glede na heterogenost senzorjev in aktuatorjev ter brezžičnih tehnologij je možnih mnogo različnih scenarijev.



Scenarij uporabe - 1

Aplikacija z biološko povratno vezavo,
ki uporablja signale nizko-dinamičnih fizioloških senzorjev,
ni komunikacijsko zahtevna:

- bitne hitrosti ne presegajo 1 kbit/s,
- lahko se izvaja v kateri koli obravnavani tehnologiji.

Na primer:

- osebna različica je izvedena z Bluetooth LE,
- različica za omejen prostor z IEEE 802.11af in
- različica odprtega prostora z LoRaWAN.

Primer uporabe v športu je spremljanje fizioloških parametrov športnika med tekom na tekalni stezi v fitnesu, na stezi ali v naravi.

Scenarij uporabe - 2

Aplikacija z biološko povratno vezavo,
ki uporablja signale iz visoko dinamičnega IMU,
je bolj zahtevna

- Bitne hitrosti zlahka dosežejo nekaj sto kbit/s,
  ko se hkrati uporablja več IMU naprav celo več Mbit/s.
- Za različico odprtega prostora je možen le prek prehoda ali mobilne naprave,
  če je na voljo dovolj visoka bitna hitrost

Primer uporabe v športu je podajanje slušne povratne informacije telovadcu,
ki izvaja vadbo na skakalnem konju.

Scenarij uporabe - 3

Aplikacija z biološko povratno vezavo,
ki uporablja signale iz kombinacije visoko dinamičnega IMU,
senzorjev športne opreme
in aktuatorjev z video povratnimi informacijami,
je lahko zelo zahtevna.

- Bitne hitrosti lahko presegajo 10 Mbit/s.
- Različice z omejenim prostorom so omejene na različne obsege, odvisno od uporabljene tehnologije LAN.
- Različice odprtega prostora niso izvedljive.

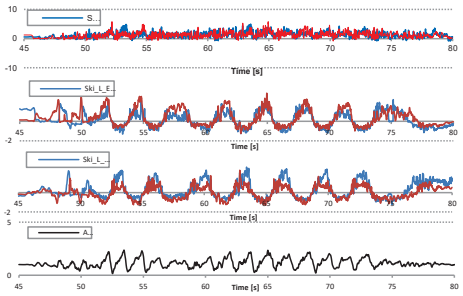
Primer uporabe v športu je podajanje video povratnih informacij v realnem času smučarju z osebno različico sistema.

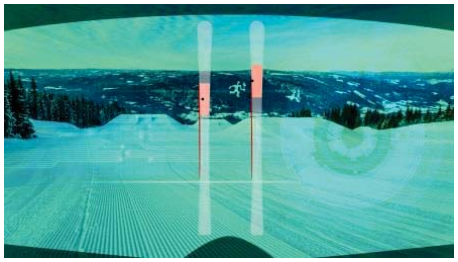
Pri uporabi aplikacij z BPV v skupinskih športih so možni še bolj zahtevni scenariji.

Primeri sistemov in aplikacij

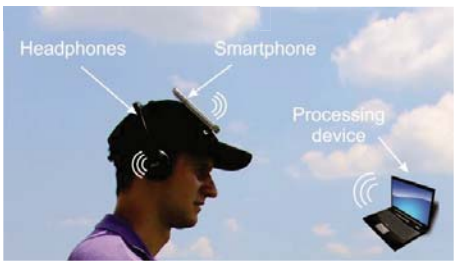
SmartSKI

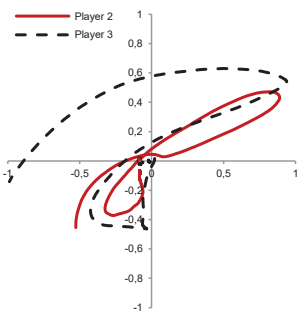






Golf trainer

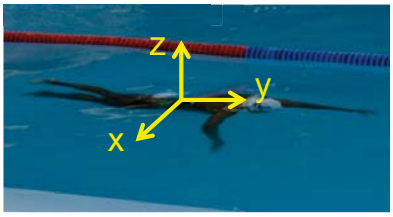


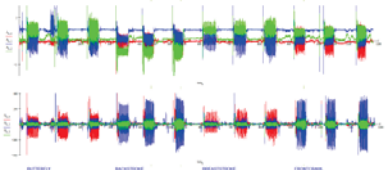




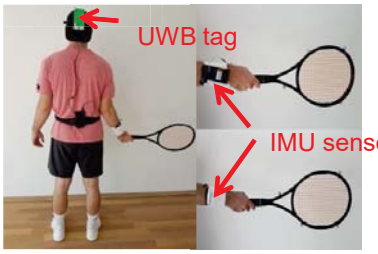
Primeri sistemov in aplikacij

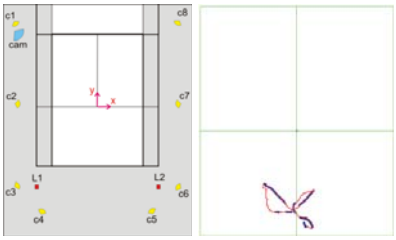
Plavanje





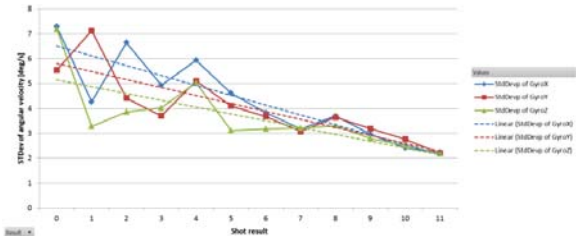
Tenis





Streljanje



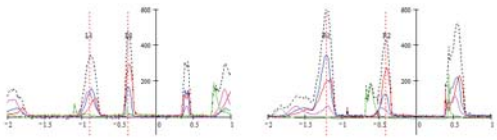


Primeri sistemov in aplikacij

Odbojka



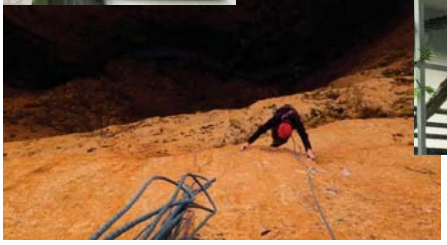




Plezanje

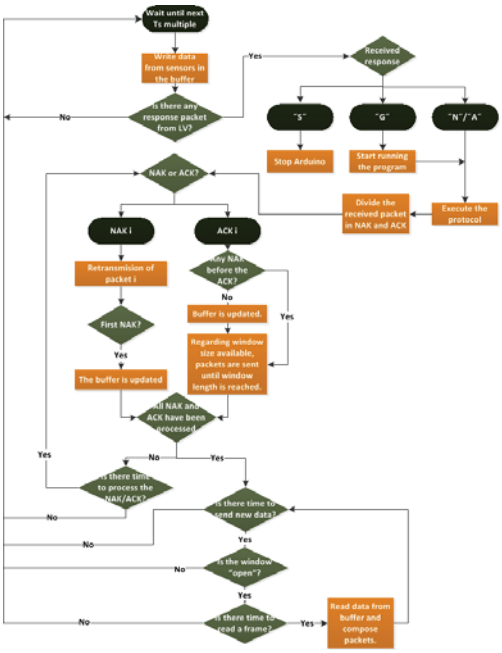






Primeri sistemov in aplikacij

Protokoli za prenos podatkov pod vodo →



Karate

Kajak in kanu

Sabljanje

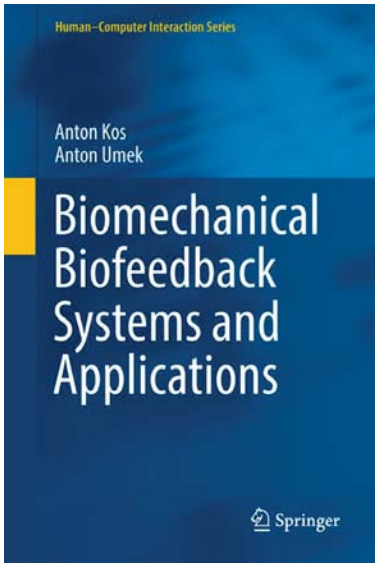
Meritve gibalnih sposobnosti

- **otrok**
- **športnikov**

…….

Nadaljnje branje

Biomechanical Biofeedback Systems and Applications



Avtorja: ***Anton Kos in Anton Umek***

Prva knjiga o interdisciplinarni temi sistemov in aplikacij z biomehaniko biološko povratno vezavo, s poudarkom na senzorskih sistemih za pospešeno motorično učenje in preprečevanje poškodb v športu in rehabilitaciji.

Knjiga celovito pokriva naslovno tematiko, ki jo podprta tudi s študijami specifičnih primerov uporabe biološke povratne vezave v različnih športih.

Podrobna študija omejitev sistemov in razpoložljivih tehnologij za njihovo izvedbo.

Študije primerov vključujejo poskuse s profesionalnimi in amaterskimi športniki.

Eksperimentalni rezultati kažejo koristi sistemov in aplikacij z biološko povratno vezavo, ki delujejo v realnem času, za pospešeno motorično učenje.

Več izvodov knjige je na voljo v knjižnici FE in v LaiT.

LaiT Laboratorij za informacijske tehnologije

Anton Kos

anton.kos@fe.uni-lj.si

Anton Umek

anton.umek@fe.uni-lj.si



Komunikacije z nevtroni - alternativa radijskim komunikacijam?

The use of radio communications in sports applications

Luka Snoj, Aljaž Čufar, Klemen Ambrožič

Institut »Jožef Stefan«, Odsek za reaktorsko fiziko

luka.snoj@ijs.si

Povzetek

Nevtroni so nevtralni delci, ki imajo popolnoma drugačne lastnosti širjenja in interakcije z medijem kot elektromagnetno valovanje, na katerem temelji današnja brezžična komunikacija. Za razliko od elektromagnetnega valovanja so praktično neobčutljivi na elektromagnetne motnje ter lahko prodrejo skozi goste in kovinske materiale. Zaradi svojih lastnosti se nevtronska komunikacija lahko uporablja tam, kjer običajne metode odpovedo, npr. komunikacija skozi debele tlačne posode, med rovi v rudniku, v vesolju, skozi Faradayevo kletko ali v primeru intenzivnih vesoljsko vremenskih pojavov. Nevtronska komunikacija je primerna za sisteme, ki potrebujejo visoko stopnjo odpornosti in zanesljivosti kot so npr. komunikacije v kritični infrastrukturi. Poleti 2021 smo izvedli eksperiment, s katerim smo prvi na svetu dokazali, da je komunikacija z nevtroni mogoča. Trenutno raziskujemo omejitve nevtronske komunikacije glede pasovne širine, propagacijo in možnosti za ojačenje signala.

Abstract

Unlike radio waves, which are absorbed by high-density materials, fast neutrons offer significant advantages where communication needs to penetrate high-Z materials or porous aggregates, potentially complementing or replacing radio communications according to neutrons' unique properties. Neutrons offers advantages for two-way communication where radio waves do not reach, e.g. deep mines, thick pressure vessels, Faraday cages or during/after severe space weather events. Neutron communication is well suited to systems requiring large degree of resiliency and reliability such as communications in critical infrastructure. In summer 2021 an experiment was performed in which the concept was demonstrated. Currently we research limitations of neutron communications regarding the bandwidth, signal propagation and possibilities for signal amplification.

Biografija avtorja



Dr. **Luka Snoj** je od leta 2005 zaposlen kot raziskovalec na odseku za reaktorsko fiziko na Institutu Jožef Stefan. Njegovo raziskovalno področje so teoretične in eksperimentalna reaktorska fizika povezana z uporabo na močnostnih in raziskovalnih jedrskih reaktorjih. Še posebej se posveča Monte Carlo transportu nevtronov in fotonov v jedrskih napravah. Leta 2005 je diplomiral na oddelku za fiziko Fakulteta za matematiko in fiziko Univerze v Ljubljani in se takoj zaposlil na Institutu Jožef Stefan.. Leta 2009 je na FMF UL doktoriral s področja fizike jedrskih reaktorjev. V letih 2010 in 2013 je bil na podoktorskem usposabljanju na centru za fuzijsko energijo v Culhamu v Veliki Britaniji, s katerim sodeluje še danes. Leta

2010 je bil imenovan za vodjo raziskovalnega reaktorja TRIGA na IJS. Od leta 2014 je vodja odseka za reaktorsko fiziko na IJS. Je izredni profesor za področje radiacijske in reaktorske fizike Na Fakulteti za matematiko in fiziko Univerze v Ljubljani ter gostujoči profesor na Virginia University of technology.

Author's biography

Luka Snoj *received the Diploma and PhD thesis in Physics from the Faculty of Mathematics and Physics, University of Ljubljana, Slovenia in 2005 and 2009, respectively. His research interest is mainly theoretical reactor physics related to practical applications in power and research reactors, in particular: Monte Carlo transport of neutrons and photons in fission and fusion nuclear reactors, integral reactor experiments, criticality experiments and calculations. In 2010 has been appointed head of TRIGA reactor at the Jozef Stefan Institute (JSI). Since 2014 he has been head of reactor physics division at the Jozef Stefan Institute. He is very active in teaching; reactor and radiation physics, experimental reactor physics at the Faculty of mathematics and physics where in 2019 he was elected associate professor. He is also an adjunct professor at the Virginia University of technology.*

Institut "Jožef Stefan", Ljubljana, Slovenija

Komunikacije z nevtroni - alternativa radijskim komunikacijam?

Luka Snoj, Aljaž Čufar, Klemen Ambrožič

Vsebina

Institut "Jožef Stefan", Ljubljana, Slovenija

- Motivacija
- O nevtronih
- Viri nevtronov
- Komunikacija z nevtroni
- Uporaba
- Demonstracija
- Simulacije
- Ojačenje
- Izzivi za prihodnost
- Zaključek

Nevtroni

Institut "Jožef Stefan", Ljubljana, Slovenija

	masa [g]	atomska masa, m.e.*	naboj	magnetni moment	spin	razpolovni čas za razpad β
proton	1.672×10^{-24}	1.00728	$+e_0$	2.79 μ_j**	½ ħ	stabilen
nevtron	1.674×10^{-24}	1.00866	0	-1.91 μ_j	½ ħ	10.2 min

- Nevtroni – delci brez električneganaboja, ki sestavljajo jedra atomov
- Interakcija s snovjo preko jedrskih reakcij – sipanje, absorpcija
- Močna jedrska sila
- Neobčutljivi na električno ter malo občutljivi na magnetno polje
- Ionizirajoče sevanje

*m.e. = masna enota = m (C^{12})/12 =1.660×10^{-24} g = 931.5 MeV/c^2
**μ_j = jedrski magneton = $e_0\hbar/2m_p$ = 3.2×10^{-8} eV/T

Viri nevtronov

Institut "Jožef Stefan", Ljubljana, Slovenija

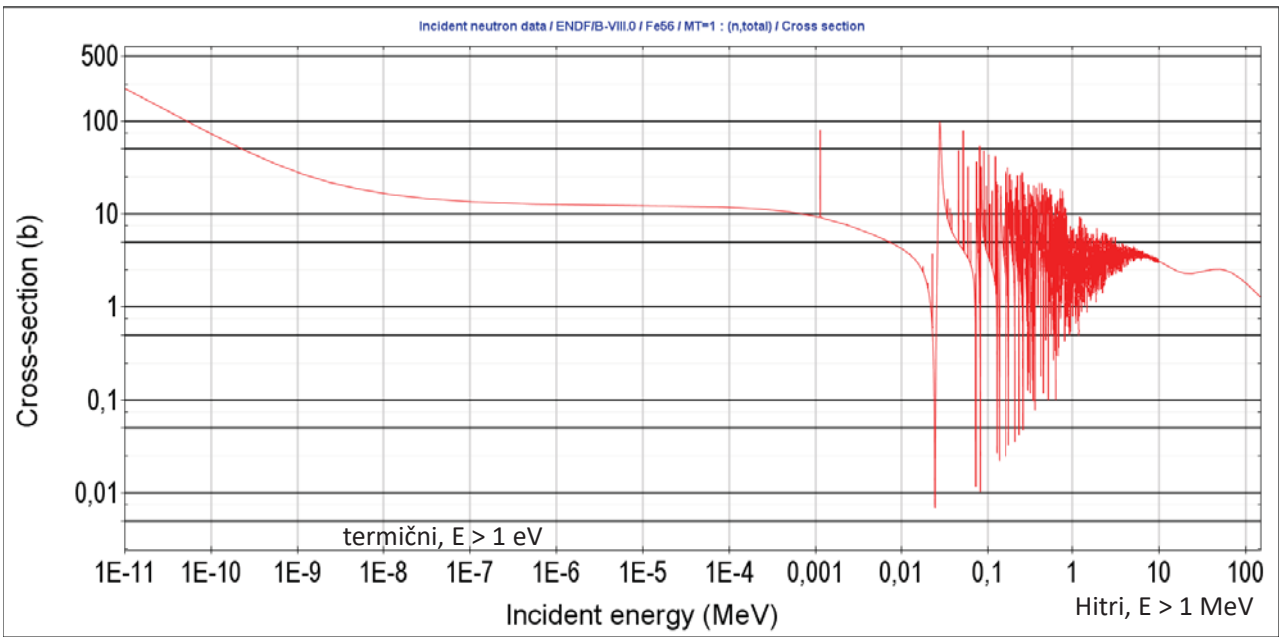
- Viri nevtronov:
  - Radioaktivni (^{252}Cf, Am-Be, Ra-Be, Pu-Be)
  - Jedrski reaktor (^{235}U, ^{239}Pu) E ϵ (2 meV - 2 MeV)
  - Pospeševalniški (DT, DD, pn) E ϵ (2 MeV - 20 MeV)
- Modulacija:
  - Mehansko: zaslonka iz absorberja nevtronov (B,Cd, In, Au,…)
  - Električno: pulzni pospeševalniki





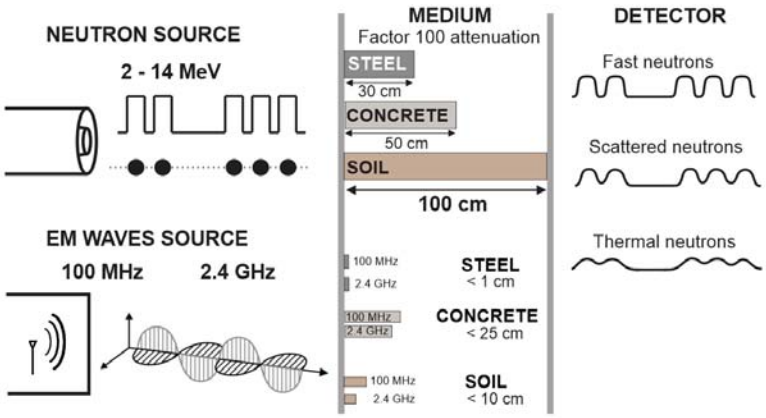


Interakcija nevtronov s snovjo



Komunikacija z nevtroni

- Majhna atenuacija pri prehodu skozi goste materiale zemlja, beton, kovine.
- Odpornost na EM motnje
- Pasivno ojačenje – repetitorji



Uporaba

Institut "Jožef Stefan", Ljubljana, Slovenija

- Preko betonskih in kovinskih struktur brez penetracij
- Faradayeva kletka
- Potreba po raznolikosti
- Kritična infrastruktura
- Odpornost na EM motnje - Carrington event, 1.-2. september 1859 – najintenzivnejša geomagnetna nevihta v znani zgodovini – električni mrk, znatne poškdobe telegrafskih sistemov, električnih omrežij,…
- Komunikacija v primeru nesreč, npr. rudarske nesreče
- Komunikacija v jedrskih elektrarnah, bunkerjih, trezorih,…

Demonstracija

Institut "Jožef Stefan", Ljubljana, Slovenija

Nuclear Inst. and Methods in Physics Research, A 1021 (2022) 165946

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima



Wireless information transfer with fast neutrons

Malcolm J. Joyce [a,*], Michael D. Aspinall [a], Mackenzie Clark [a], Edward Dale [a], Hamish Nye [a], Andrew Parker [a], Luka Snoj [b], Joe Spires [a]

[a] Department of Engineering, Lancaster University, Lancaster, United Kingdom
[b] Reactor Centre, Jožef Stefan Institute, Slovenia

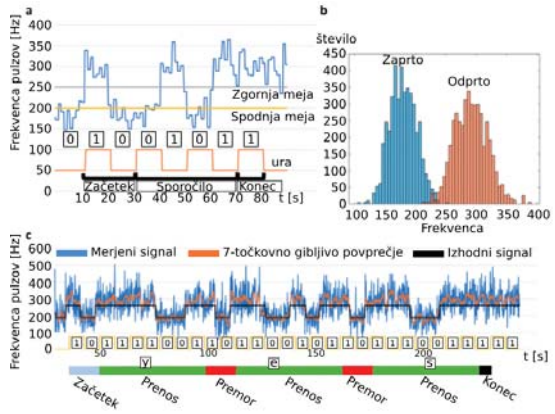
ABSTRACT

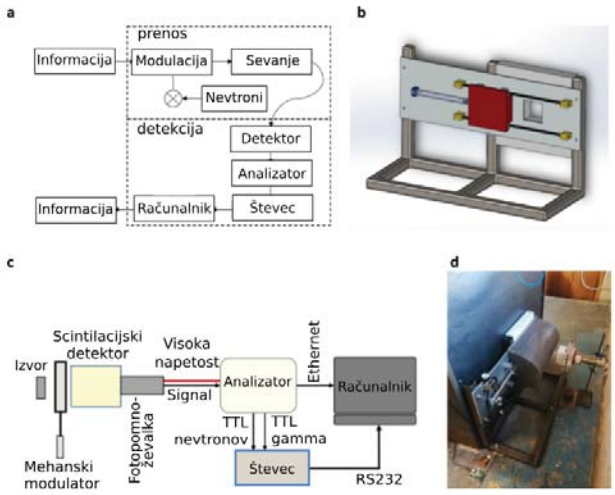
Fast neutrons propagate significantly in free space with interaction properties that contrast markedly with those of electromagnetic radiation, the latter being fundamental to most wireless communications. Here, we report on the configuration and operation of a nuclear instrumentation set-up designed to transmit digitally encoded information using fast neutrons. We demonstrate the potential of fast neutron radiation as a medium for wireless communications for applications where conventional electromagnetic transmission is either not feasible or is inherently limited.

Demonstracija

Institut "Jožef Stefan", Ljubljana, Slovenija

- Mehanska modulacija nevtronov iz ^{252}Cf.
- Hiter, scintilacijski detektor nevtronov
- Vzpostavitev komunikacijskega protokola
- 100% uspešen prenos ASCII znakov v zraku





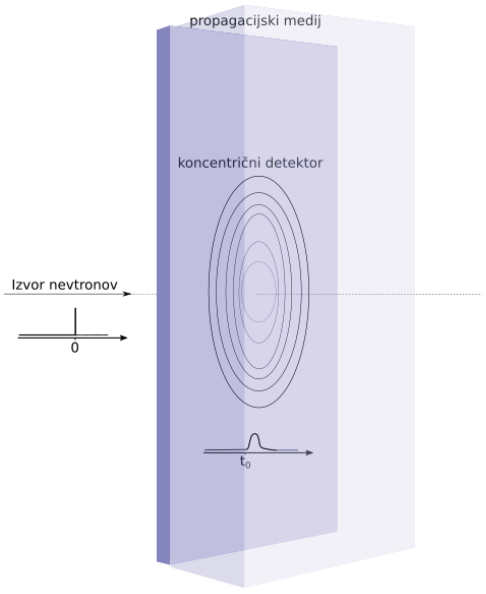
Joyce, et al. NIMA 1021, 165946, (2022)

Raziskave na področju

Institut "Jožef Stefan", Ljubljana, Slovenija

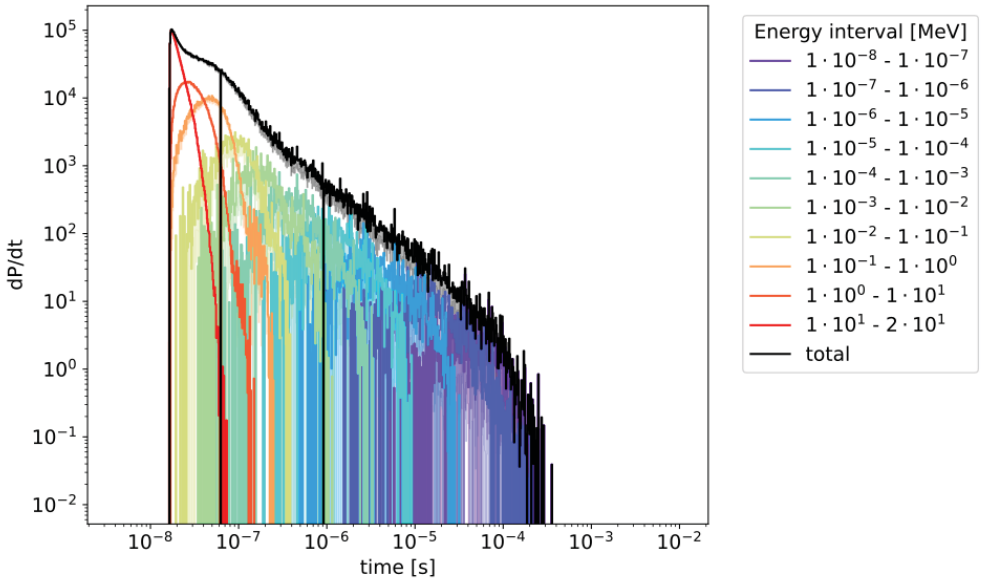
Simulacija propagacije nevtronskega pulza preko različnih medijev:

- Jeklo, aluminij, beton, grafit, voda, granit, apnenec, svinec, volfram.
- Študij atenuacije in razširitve pulza:
  - Potrebna jakost signala in občutljivost detektorja.
  - Ocena FWHM → Hitrost prenosa podatkov.
  - Sprememba v energiji nevtronov



Raziskave na področju: Računski rezultati

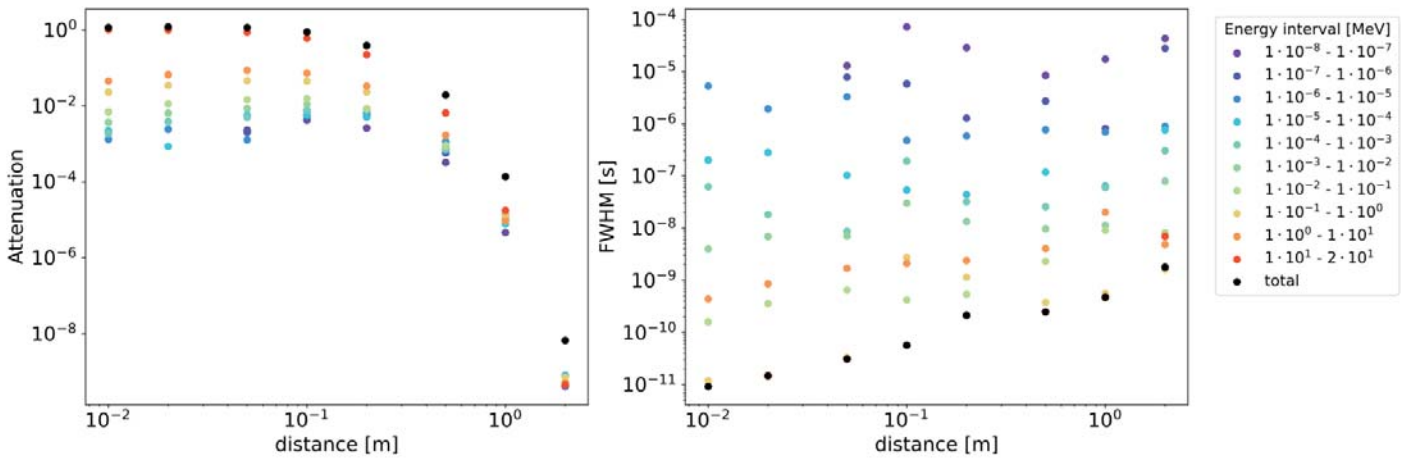
Institut "Jožef Stefan", Ljubljana, Slovenija



Razširitev idealnega pulza (δ(t)) 20 MeV nevtronov v 1 m baritnega betona

Raziskave na področju: Računski rezultati

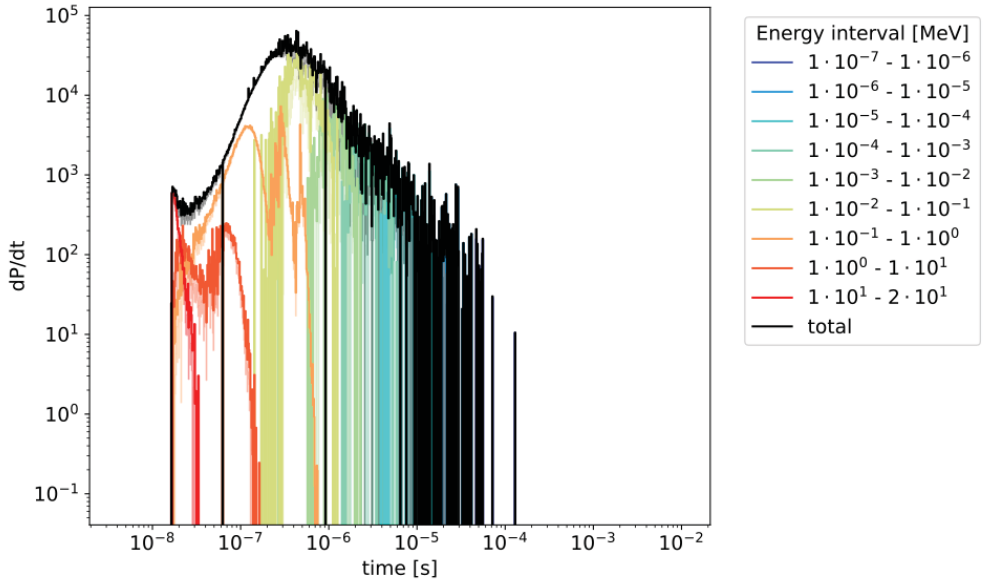
Institut "Jožef Stefan", Ljubljana, Slovenija



FWHM in atenuacija pulza nevtronov v baritnem betonu.

Raziskave na področju: Računski rezultati

Institut "Jožef Stefan", Ljubljana, Slovenija

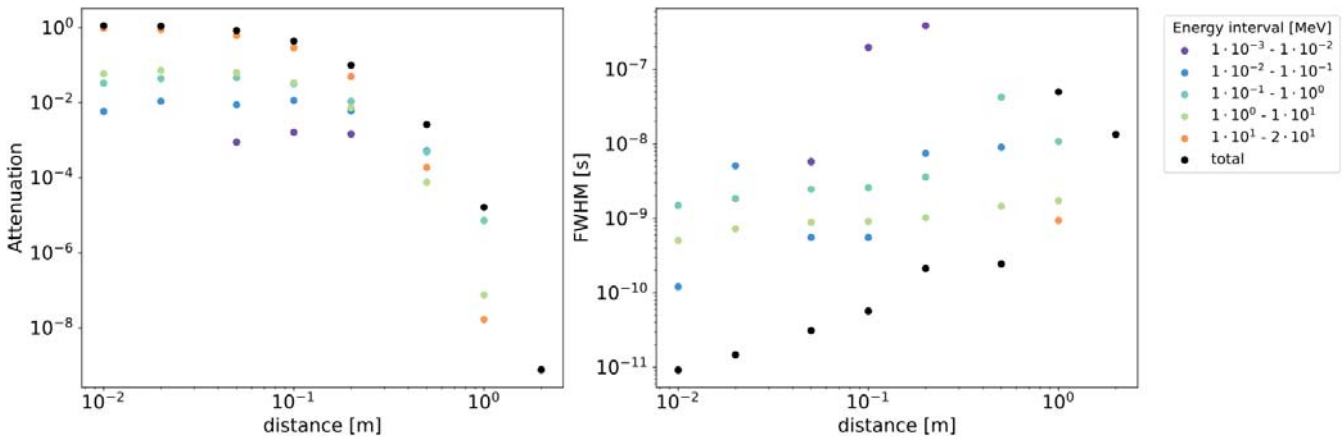


Razširitev idealnega pulza 20 MeV nevtronov v 1 m nerjavnega jekla 304.



Raziskave na področju: Računski rezultati

Institut "Jožef Stefan", Ljubljana, Slovenija



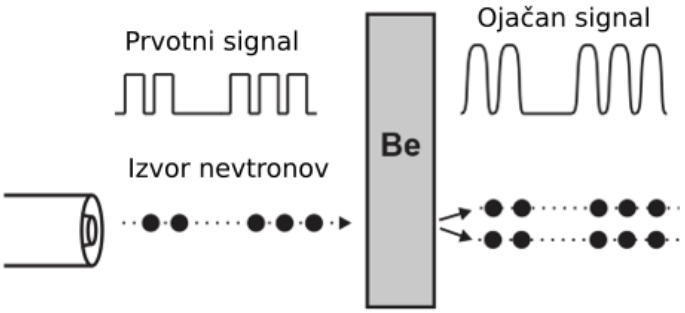
FWHM in atenuacija pulza nevtronov v nerjavnem jeklu SS304.

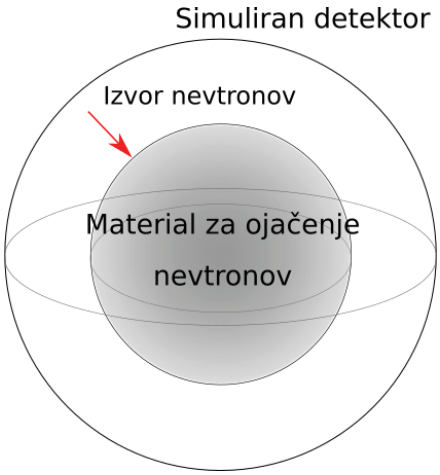


Ojačanje

Institut "Jožef Stefan", Ljubljana, Slovenija

- Kako ojačati signal?
  - Nekateri materiali imajo visoko verjetnost za pomnoževanje nevtronov (n,2n), (n,f)
  - Ojačenje preko podkritične fisijske reakcije?

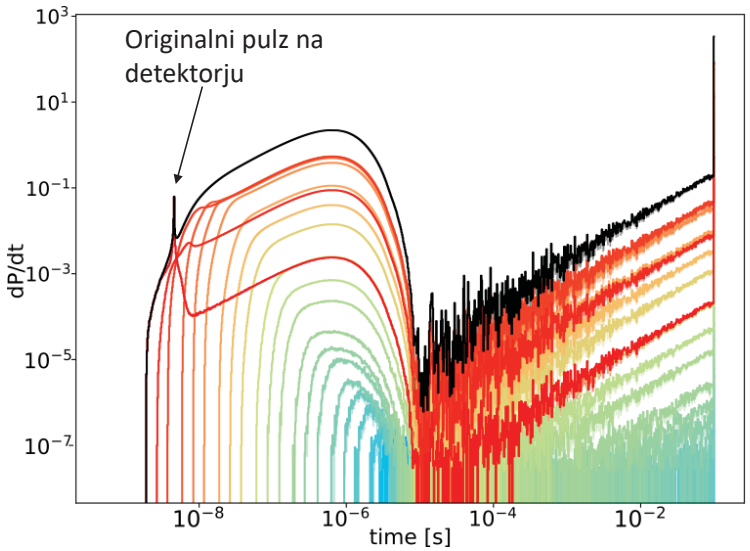


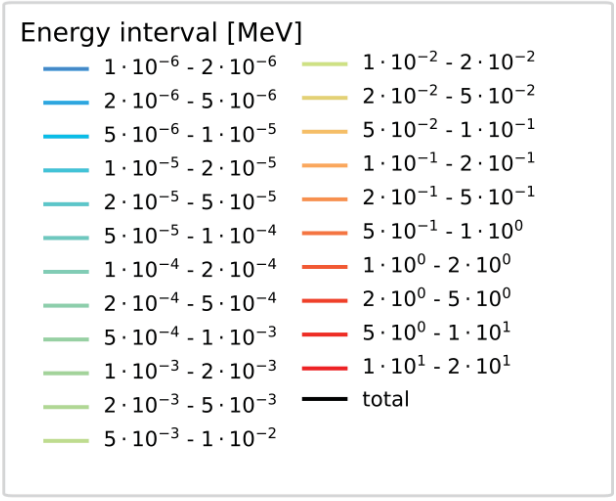


Simuliran ojačevalnik

Ojačenje: rezultati

Institut "Jožef Stefan", Ljubljana, Slovenija





Faktor ojačitve 668 na pokritični krogli ^{235}U (k_{eff}=0.999, E_n= 20 MeV). Problem zakasnelih nevtronov!

Izzivi za prihodnost

Institut "Jožef Stefan", Ljubljana, Slovenija

- Optimizacija izvorov & detektorjev
- Zaščita pred sevanjem
- Nevtronski vodniki
- Diode & tranzistorji
- Sklopitev z optičnimi elementi
  - Jedrsko gnani polprevodniški laser
  - Lasersko gnani izvori nevtronov

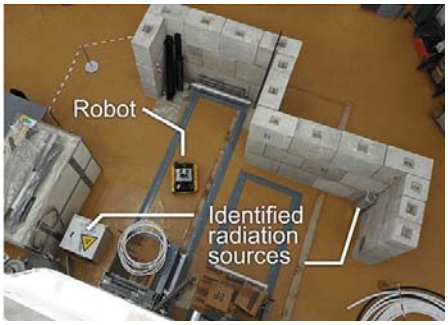
Zaključek

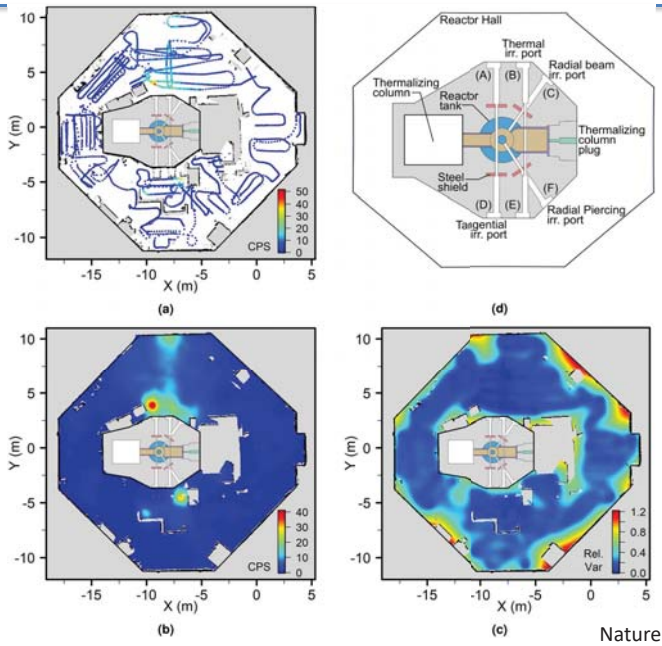
Institut "Jožef Stefan", Ljubljana, Slovenija

- Nevtronska komunikacija ne bo izpodrinila klasične
- Ponuja pa:
  - raznovrstnost,
  - robustnost za specifične potrebe
  - Prodornost
  - Svež pogled

Radiation mapping of a nuclear reactor with a mobile robot







Nature Scientific Reports , July 2021

Tehnologija Wi-Fi6 / Wi-Fi6 Mesh od razvoja proizvajalca in prenosa v realno okolje s komercialnim zagonom operaterja

WiFi6 / WiFi6 Mesh technology from manufacturer development and transfer to real environment with commercial operator launch

Mitja Golja[1], **Gorazd Penko**[2]

[1]Iskratel S&T, [2]T-2

golja@iskratel.si, gorazd.penko@t-2.com

Povzetek

V prispevku so predstavljene tehnične značilnosti, t.i. tehnološke rešitve WiFi 6 in Wifi 6 Mesh. Podana je dobra praksa sodelovanja med ponudnikom novih tehnoloških rešitev in ponudnikom telekomunikacijskih storitev. Opisan je tudi empirični postopek končnih predprodukcijskih performančnih meritev v realnem okolju operaterja.

Abstract

The technical characteristics of the WiFi 6 and Wifi 6 Mesh technological solution is presented in this article. Good practice of cooperation between the provider of new technological solutions and the provider of telecommunications services is provided. The empirical process of final pre-production performance measurements in the real environment of the operator are also described.

Biografije avtorjev

Dr. **Mitja Golja** je zaposlen v podjetju Iskratel kot direktor razvoja poslov v poslovni enoti dostop. Odgovoren je za pripravo tržnih strategij in razvoja poslov novih tehnologij. Ima več kot 15 let izkušenj s širokopasovnimi tehnologijami in se strastno ukvarja z razvojem širokopasovnih produktov, poslovnih modelov in strategij. Pred vodenjem razvoja poslov je delal na več vodilnih pozicijah v Iskratelu, med drugimi je bil odgovoren za vodenje produktne linije in razvoja. Njegovo raziskovalno delo je osredotočeno na izboljšave uporabniške izkušnje in iskanje novih načinov uporabe IoT tehnologij.

Gorazd Penko je vodja oddelka Referenčnnega laboratorija telekomunikacijskega operaterja T-2 d.o.o, pristojnega za tehnološki razvoj fiksnih dostopovnih omrežij P2P/FTTH, xDSL in P2MP/FTTH, ter CPE IAD naročniških naprav. Diplomiral je na Univerzi v Ljubljani, Fakulteti za elektrotehniko. V letu 1998 se je iz področja vzdrževanja podatkovnih omrežij preselil v razvojni oddelek Telekoma Slovenije. Leta 2006 se je pridružil podjetju T-2 d.o.o. Od leta 2007 do 2010 je bil vodja oddelka xDSL, kjer je sodeloval pri razvoju, načrtovanju in upravljanju omrežij xDSL. Pred tem (2006-2007) je delal kot operater omrežja. Njegova naloga je bila razvoj, nadzor, upravljanje in uvajanje novih širokopasovnih tehnologij VDSL1 in VDSL2. Sodeluje na številnih mednarodnih konferencah na področju telekomunikacij, kot so Broadband World Forum, FTTH Council, Smart Home konferencah itd. Bil je in je še vedno projektni vodja številnih projektov, vključno z dostopovnimi omrežji GPON, XGS-PON in dostopovnimi tehnologijami naslednjih generacij.

Authors' biographies

*Dr. **Mitja Golja** is a Business Development Director at Iskratel's Business Unit Broadband. He is responsible for new market strategies and go-to-market initiatives for new technologies. He brings 15+ years of global*

operating experience in the broadband-networking industry and a deep passion for product business development and strategy to Iskratel. Prior to heading business development, Mitja held various management positions within Iskratel. Amongst others he was in charge for broadband product line management and R&D. He's research work is focused on user experience improvements and search for new IoT technology applications..

***Gorazd Penko** is curently working as Head Of Reference Laboratory for development P2P/FTTH, xDSL, P2MP/FTTH, xDSL and CPE IAD at T-2 telecommunication company. He graduated at University of Ljubljana, Faculty of electrical engineering. His work in telecommunications development department area started in 1998 at Telekom Slovenije with the development and commercial introduction of ADSL technolog. In 2006 he joined T-2. From 2007 to 2010 he was Head of xDSL department, where he has been involved in development, planning and management of xDSL networks. Before that (2006-2007) he worked as a Network operator; his task included development, supervision, management and introduction of new VDSL1 and VDSL2 broadband technology (among the first ones in Europe). He participates in many International Conferences in the field of telecommunications, such as Broadband World Forum Europe, FTTH Council, Smart Home conferences etc. He was and still is a project manager of many projects, including GPON, XGS-PON and next generation access networks.*

Tehnologija Wi-Fi6/Wi-Fi6 Mesh od razvoja proizvajalca in prenosa v realno okolje s komercialnim zagonom operaterja

Dr. Mitja Golja, Iskratel d.o.o.
Gorazd Penko, T-2 d.o.o.

Agenda

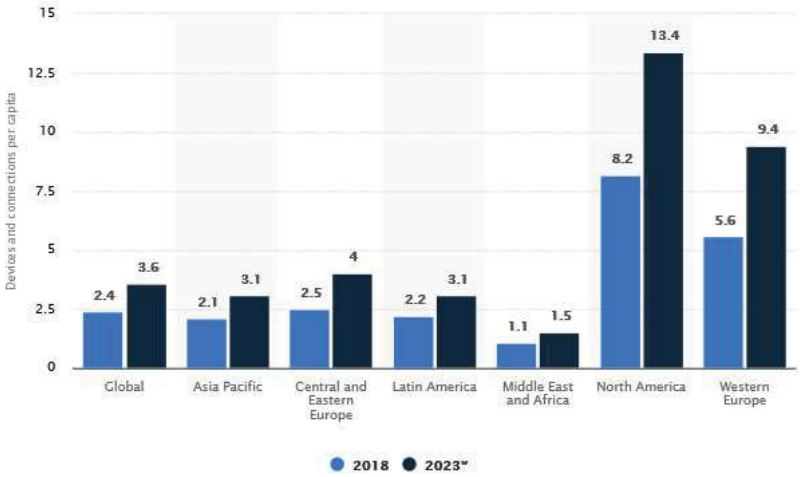
- Motivacija za Wi-Fi 6
- Tehnološko ozadje in standardizacija
- Princip vpeljave novega CPE produkta v operatersko okolje
- Opis metodologije primerjalnih meritev Wi-Fi / Mesh Wi-Fi
- Rezultati primerjalnih „meritev" Wi-Fi 5 in Wi-Fi 6
- Rezultati primerjalnih „meritev" Wi-Fi 5 Mesh in Wi-Fi 6 Mesh v več različnih konfiguracijah
- Zaključek

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Zakaj Wi-Fi 6 / Wi-Fi 6 Mesh ?

- „Eksplozija" brezžičnih naprav,
- Pametne naprave:
  - Telefoni, tablice, kamere, senzorji, IoT,...
- Vsebina na zahtevo:
  - Časovni zamik (time shift)
  - YouTube, Netflix,...
  - Aplikacije in storitve v oblaku
- Zahteve uporabnikov po Wi-Fi:
  - Mobilnosti,
  - stabilnosti,
  - zanesljivosti

Povprečno število naprav in povezav na osebo po svetu leta 2018 in 2023

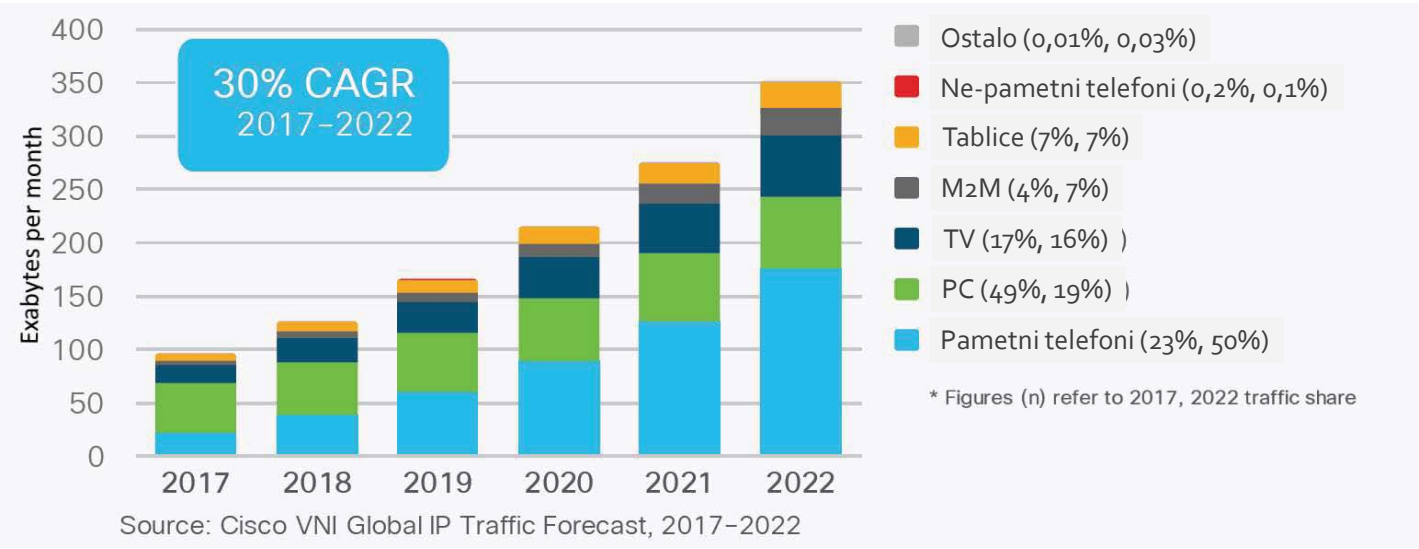


Vir: https://www.statista.com

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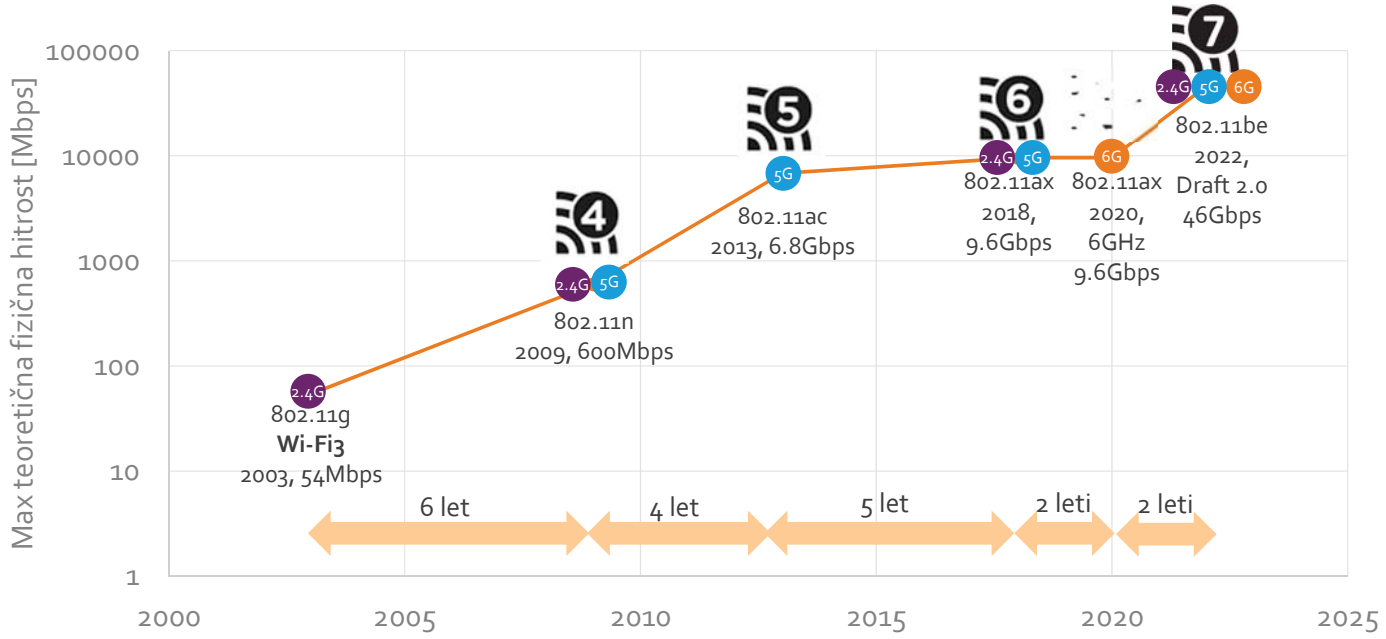
Globalni IP promet po tipu naprav



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Čas med novimi IEEE standardi se je znatno zmanjšal



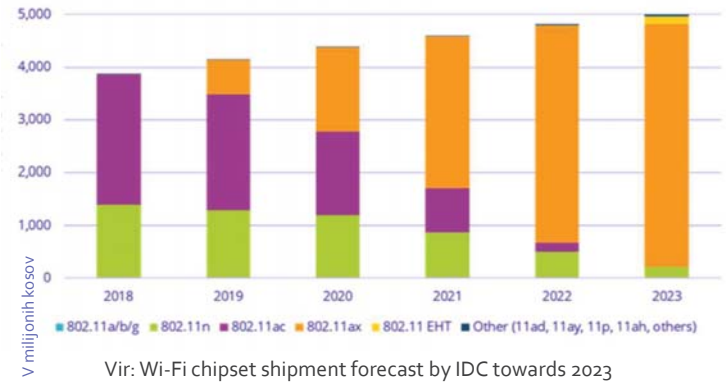
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5

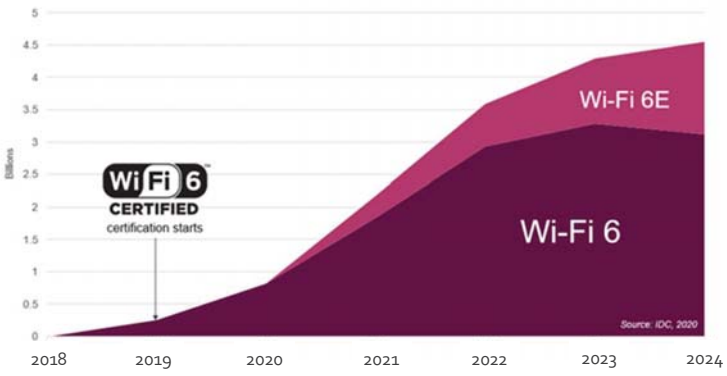
Vpeljava Wi-Fi standardov

Dobave naprav z Wi-Fi vmesnikom glede na Wi-Fi protokol



Vir: Wi-Fi chipset shipment forecast by IDC towards 2023

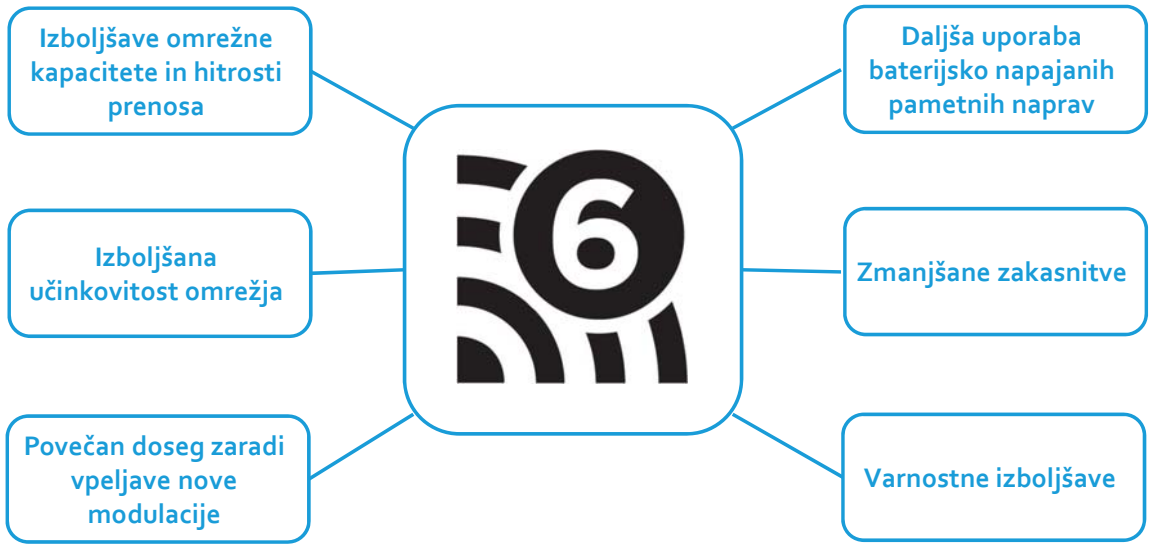
Napoved dobave naprav z Wi-Fi 6



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Zakaj Wi-Fi 6?



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Ključne izboljšave pri omrežnih kapacitetah in prenosnih hitrostih

4× večji pretok podatkov

37% višje maksimalne fizične hitrosti na posameznega uporabnika

75% zmanjšana zakasnitev

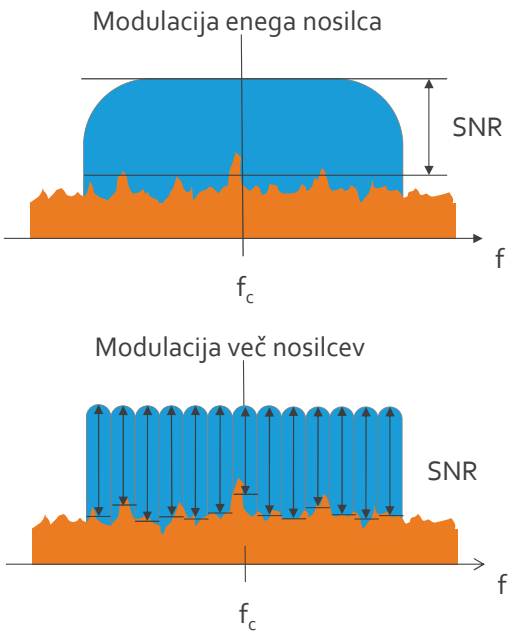
- OFDM in OFDMA (polegTDMA, SDMA)
- Manjši razmak med frekvencami in dinamična prilagoditev razmaka
- 1024 QAM
- 160 MHz kanali
- Tehnika tvorbe snopa (beamforming) na 2.4 GHz in 5 GHz
- Max 8× MU-MIMO prostorskih pretokov in OFDMA uplink

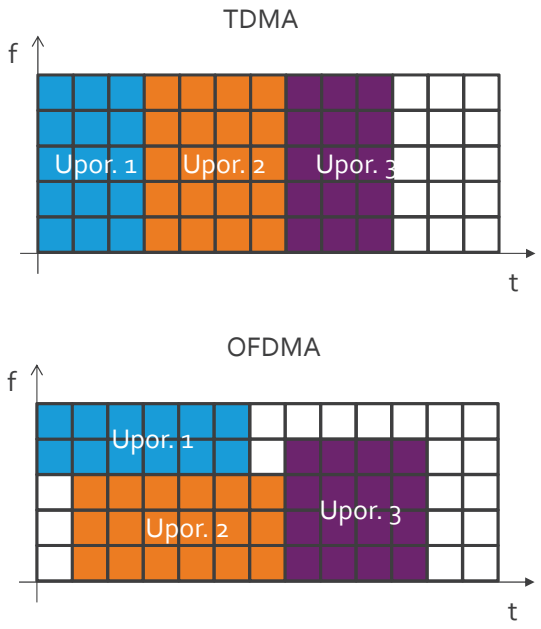
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OFDM in OFDMA



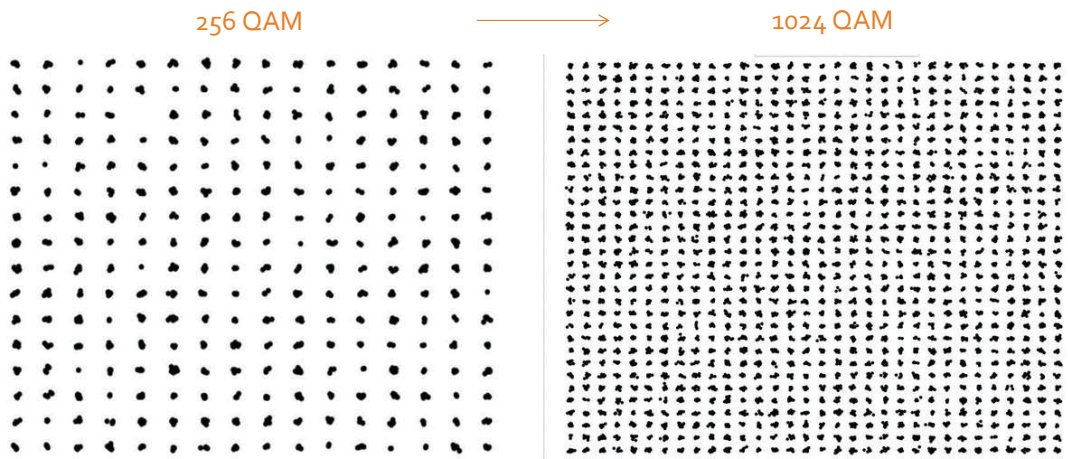


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Sprememba modulacije



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Izboljšano pokritje, trajanje baterije, izboljšana varnost

- OFDM izboljša domet in pokritje
  - Do 8 dB izboljšanj SNR z uporabo 2 MHz podkanalov
  - Pokritje **dveh dodatnih sob**



- Izboljšanje trajanja baterije pametnih naprav
  - Ciljni buden čas, časovno razporejanje
  - Podpora baterijskih IoT senzorjev





- Varnostne izboljšave
  - WPA3



WPA2



WPA3

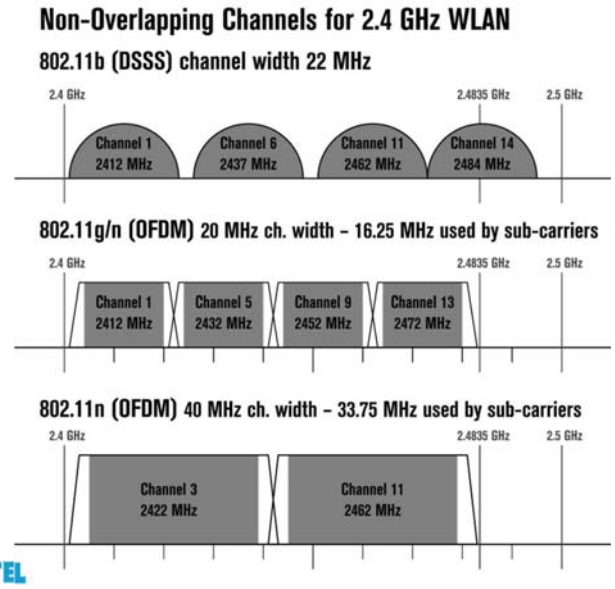
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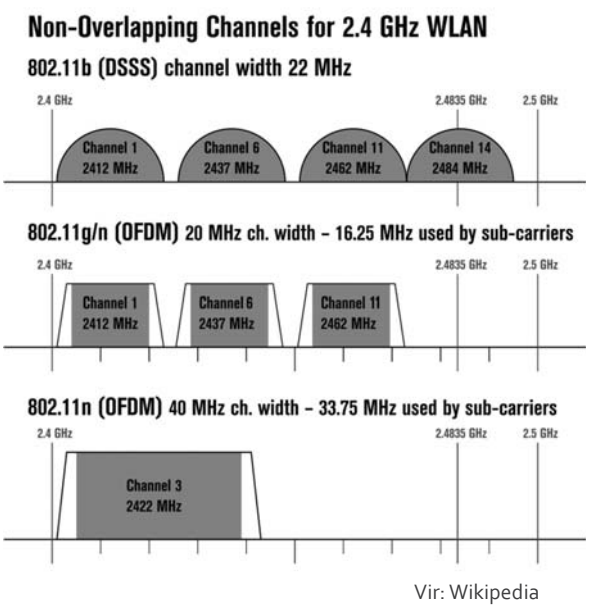
11

2.4 GHz Wi-Fi kanali









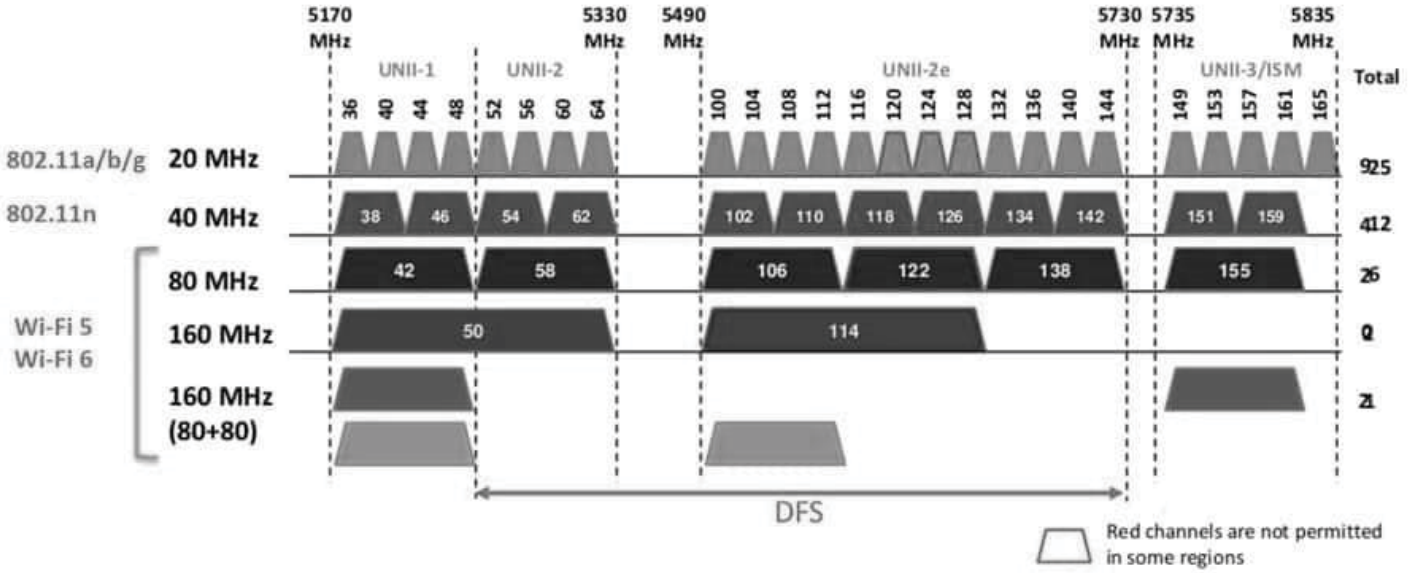
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Vir: Wikipedia

5 GHz Wi-Fi kanali



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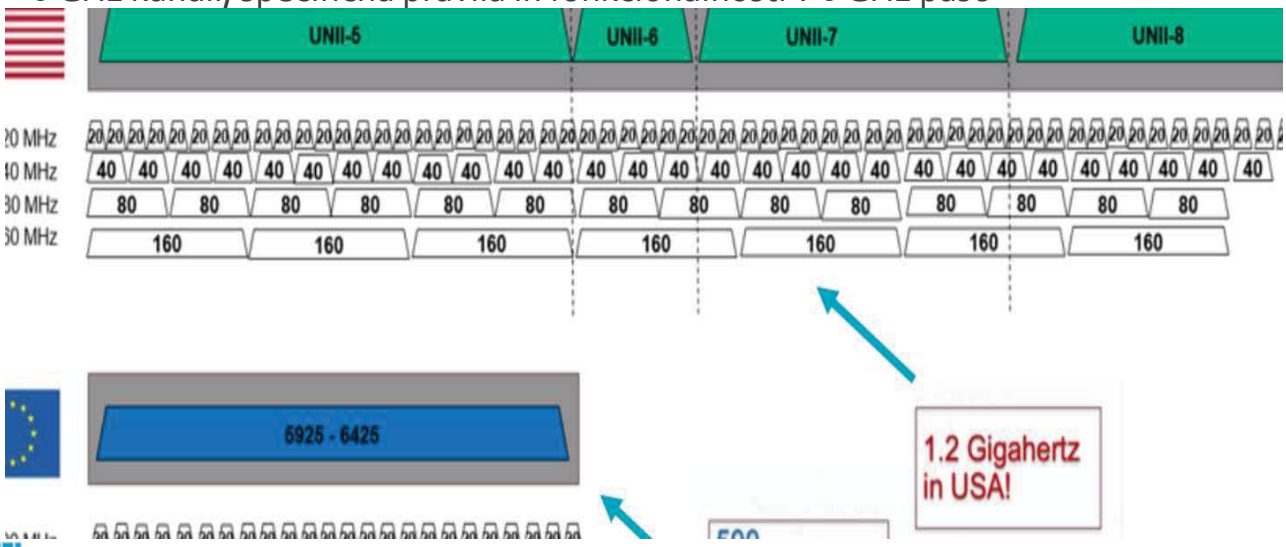
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Vir: Wikipedia

Razširjeni Wi-Fi spekter: Wi-Fi 6E

IEEE 802.11ax 6.0

– 6 GHz kanali, specifična pravila in funkcionalnosti v 6 GHz pasu



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Vir: Extreme webinar

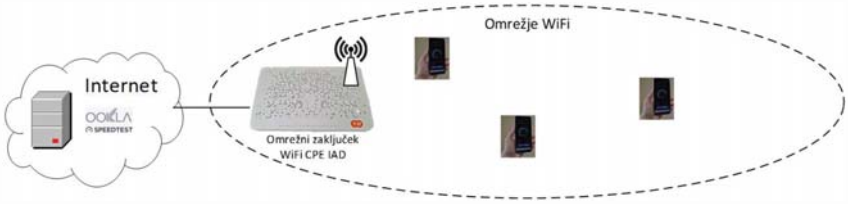
Razvoj produkta – sodelovanje proizvajalec / operater



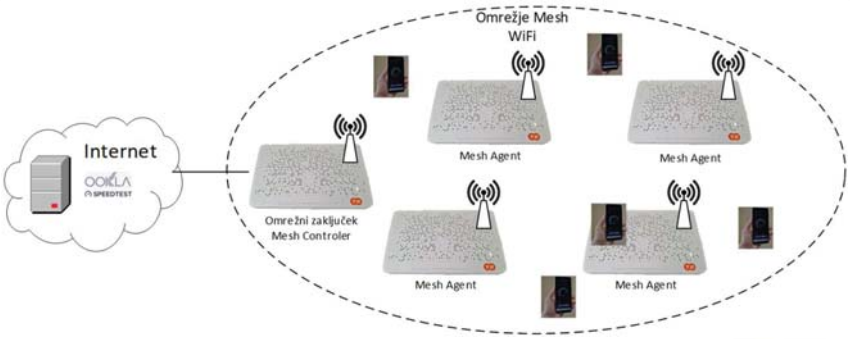
- Zaključna faza razvoje produkta poteka na relaciji proizvajalec / operater:
  - Testiranja v laboratoriju operaterja, testni uporabniki,…
  - IT integracija v sisteme operaterja, prilagoditev tehničnim pogojem operaterja
  - Upoštevanje razvojnih predlogov in izboljšav operaterja,
- Rezultat:
  - Hitrejši prehod iz razvoja in testiranj na trg (time to market),
  - Boljše, stabilnejše in zanesljivejše delovanje,
  - Produkt „približan“ potrebam operaterja in uporabnikov

Tehnična topologija priključka Wi-Fi / Wi-Fi Mesh

- Wi-Fi:
  - Ena Wi-Fi naprava oz. omrežni zaključek z funkcijo Wi-Fi



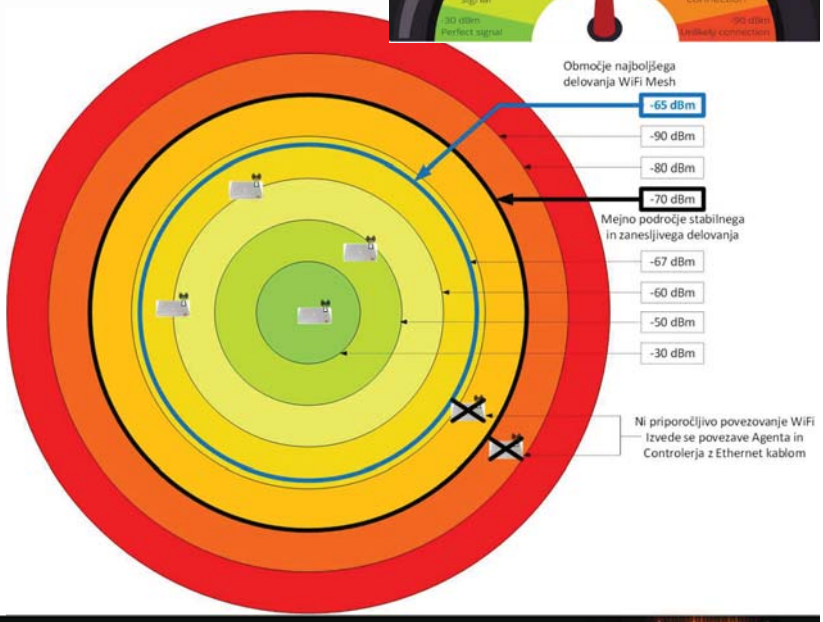
- Wi-Fi Mesh omrežje:
  - Mesh Controler
  - Mesh Agenti



Priporočilo za Mesh vozlišča



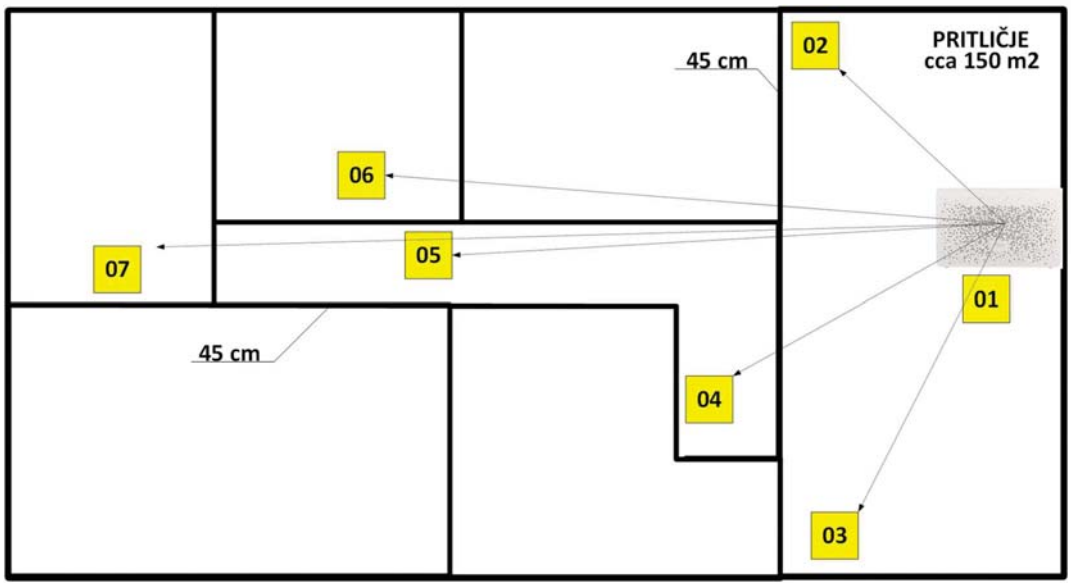
- Priporočljivo je instalirati Mesh vozlišča tako, da sprejemna moč najbližjega sosednjega Mesh vozlišča ni nižja od **-65 dBm**.
- Skrajna meja sprejemnega signala, ki še zagotavlja kolikor toliko stabilno in zanesljivo delovanje pa je cca **-70 dBm.**
- Mesh vozlišča izven območja **-65 dBm** se običajno z Mesh Controlerjem poveže z fizično z ethernet kablom



Metodologija performančnih Wi-Fi / Wi-Fi Mesh meritev v tipičnem rezidenčnem objektu

- Optimalna instalacija Wi-Fi / Wi-Fi Mesh omrežja,
- Za potrebe izvajanja t.i. meritev se v objektu določijo primerne merilne točke,
- Objekt se razdeli za t.i. zaključene celote oz. prostore,
- V vsaki točki se izvede več meritev, ter izračuna povprečje (3 meritve),
- Meritev se izvede s pomočjo OOKLA hitrostnega testa na mobilnem telefonu,
- Za meritev je bil uporabljen mobilni telefon s podporo Wi-Fi 6.

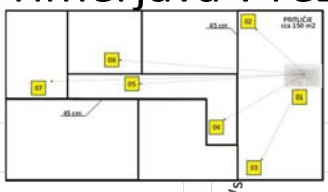
Wi-Fi 5 / Wi-Fi 6 – Primerjava v rezidenčnem objektu (1)

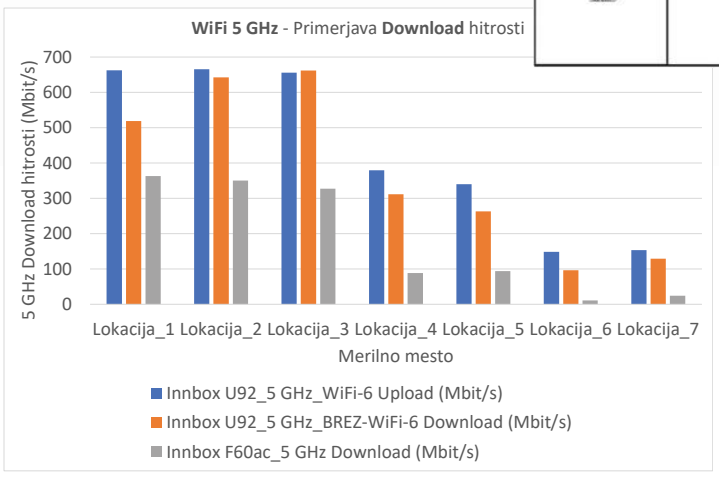


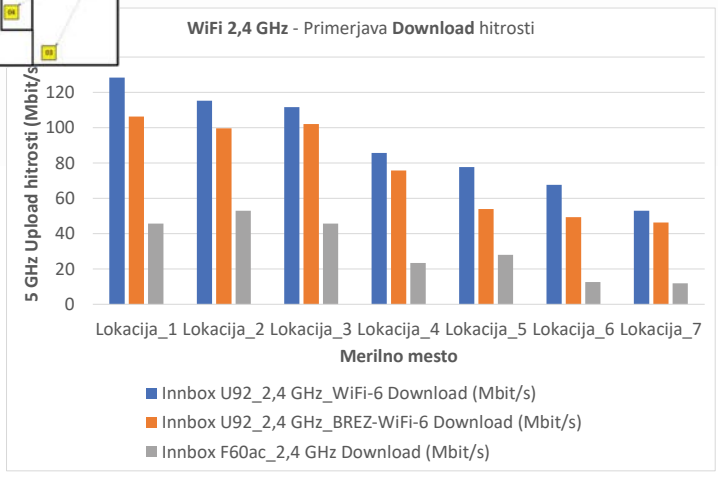


OOKLA hitrostni IP test (speed test)

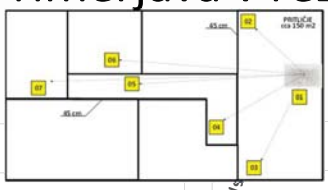
Wi-Fi 5 / Wi-Fi 6 – Primerjava v rezidenčnem objektu (2)

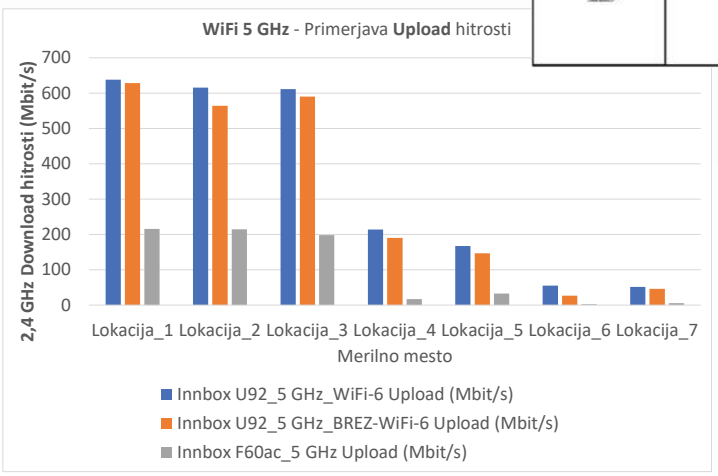


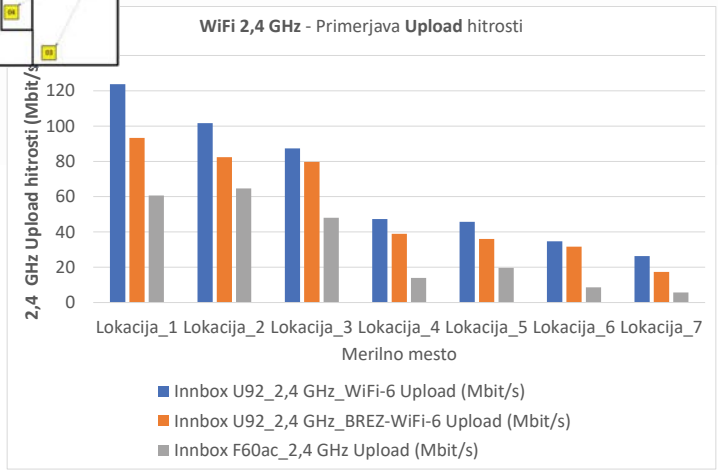




Wi-Fi 5 / Wi-Fi 6 – Primerjava v rezidenčnem objektu (3)

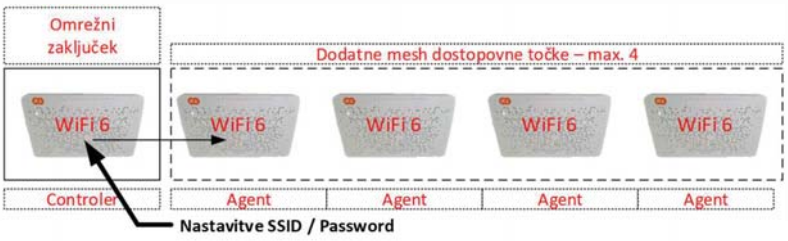




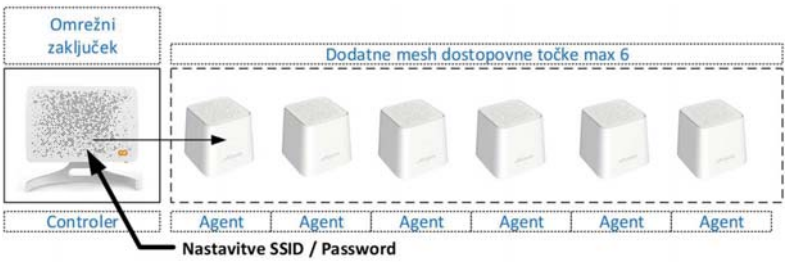


Vloge - Mesh „*Controler*“ / Mesh „*Agent*“

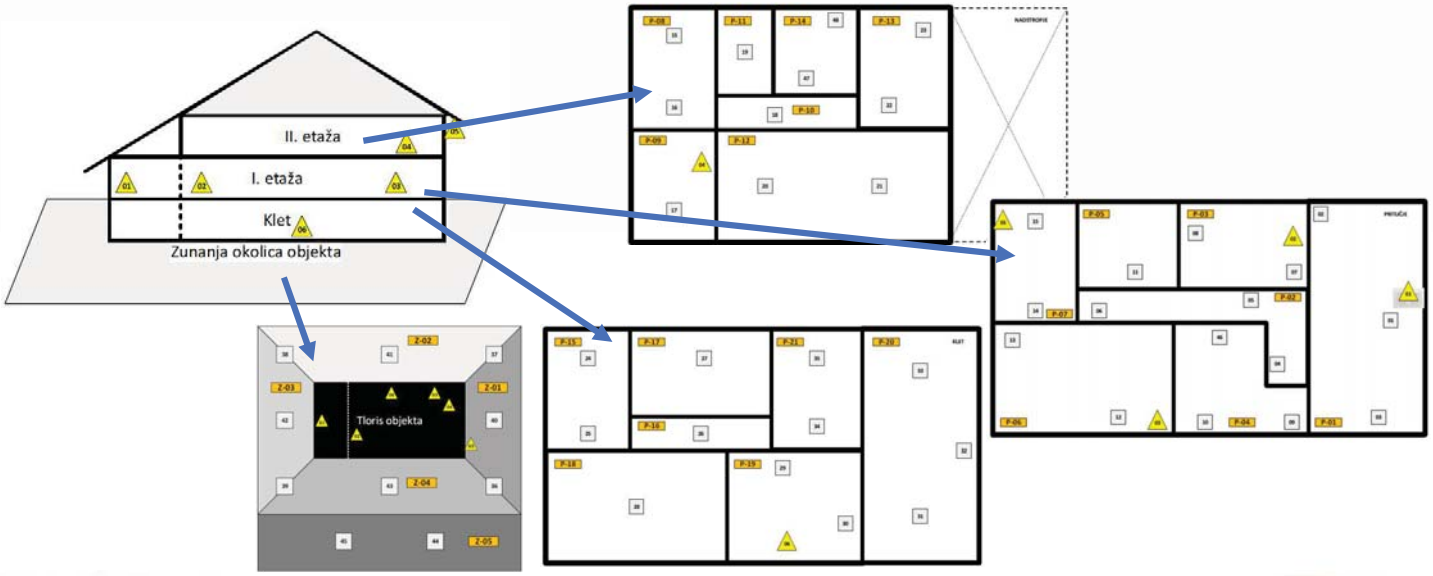
- **Wi-Fi 6 Mesh**



- **Wi-Fi 5 Mesh**

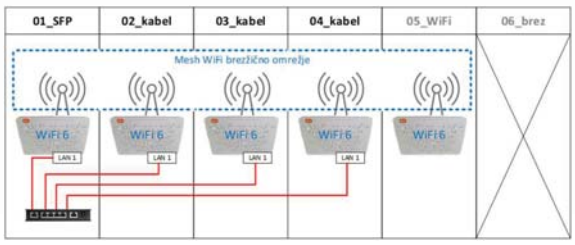


Tehnični načrt merilnih točk primerjalne meritve Wi-Fi 5 Mesh in Wi-Fi 6 Mesh

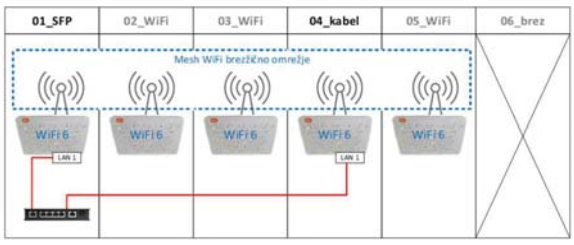


4 različne postavitve omrežij Mesh Wi-Fi 5 / Wi-Fi 6 in primerjava med njimi

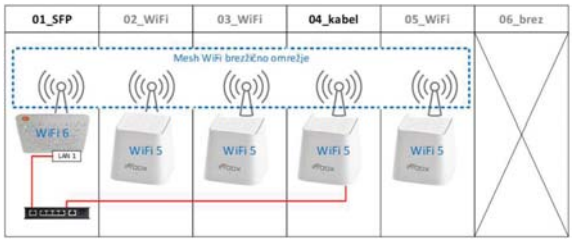
(1) Wi-Fi 6 Mesh Controler / Wi-Fi 6 Mesh Agenti povezani z UTP kablom



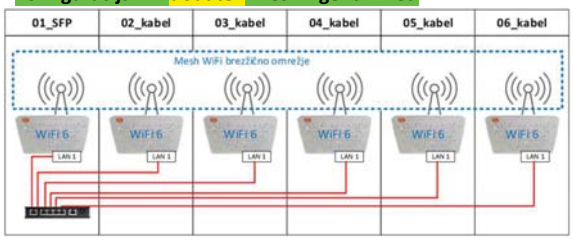
(2) Wi-Fi 6 Mesh Controler / Wi-Fi 6 Mesh Agenti povezani prek Wi-Fi



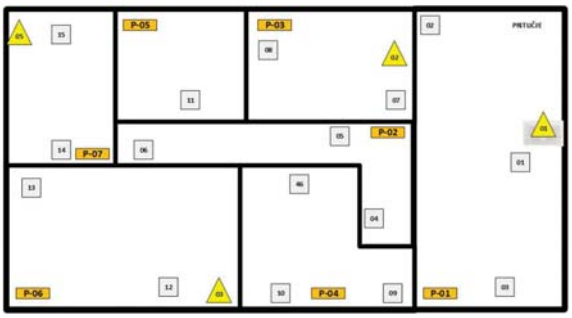
(3) Wi-Fi 5 Mesh Controler / Wi-Fi 5 Mesh Agenti povezani prek Wi-Fi



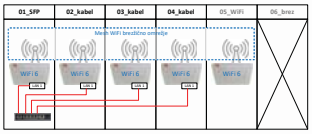
(4) Wi-Fi 6 Mesh Controler / Wi-Fi 6 Mesh Agenti povezani z UTP kablom konfiguracija 1 + dodaten Mesh Agent v kleti



I. etaža - Primerjava postavitev 1, 2, 3 in 4



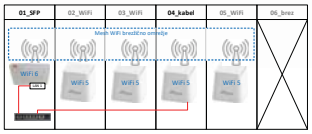
(1) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom



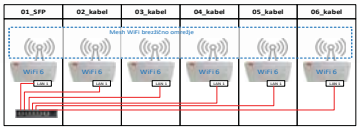
(2) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani prek WiFi



(3) WiFi 5 Mesh Controler / WiFi 5 Mesh Agenti povezani prek WiFi

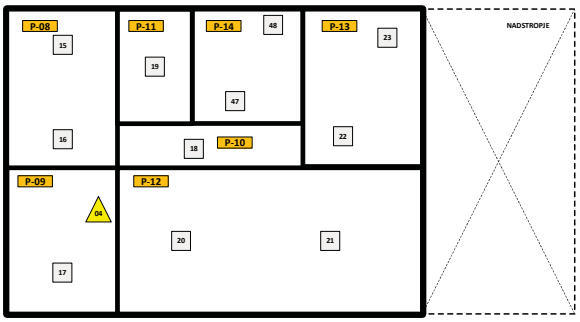


(4) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom konfiguracija 1 + dodaten Mesh Agent v kleti

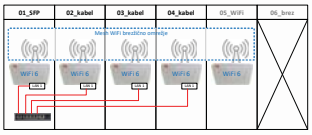


Objekt - I. ETAŽA												
Postavitev_1			Postavitev_2			Postavitev_3			Postavitev_4			
Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			
Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	
498	427	925	219	166	385	183	163	346	480	399	879	

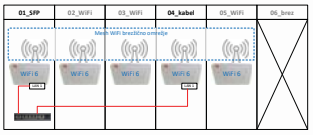
II. etaža - Primerjava postavitev 1, 2, 3 in 4



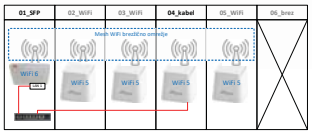
(1) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom



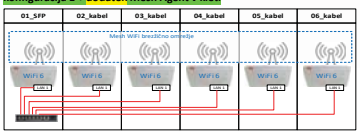
(2) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani prek WiFi



(3) WiFi 5 Mesh Controler / WiFi 5 Mesh Agenti povezani prek WiFi

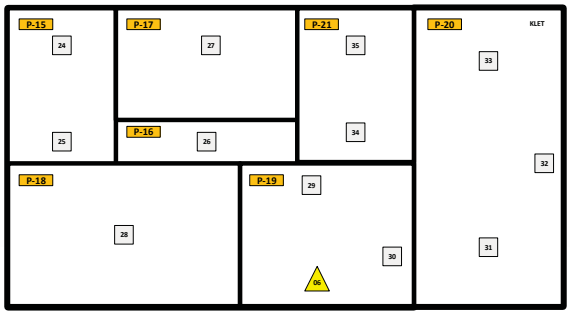


(4) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom konfiguracija 1 + dodaten Mesh Agent v kleti

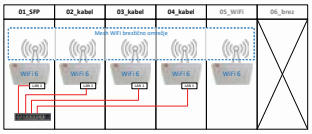


Postavitev_1 - II. ETAŽA												
Postavitev_1			Postavitev_2			Postavitev_3			Postavitev_4			
Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			
Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	
452	368	820	387	316	703	254	263	518	471	409	880	

Klet - Primerjava postavitev 1, 2, 3 in 4



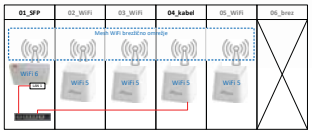
(1) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom



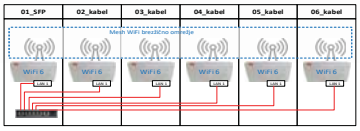
(2) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani prek WiFi



(3) WiFi 5 Mesh Controler / WiFi 5 Mesh Agenti povezani prek WiFi



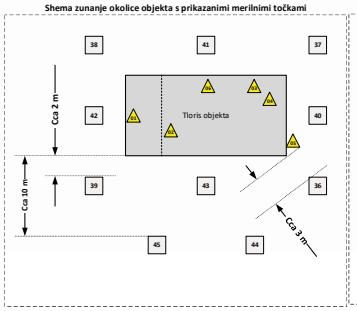
(4) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom konfiguracija 1 + dodaten Mesh Agent v kleti



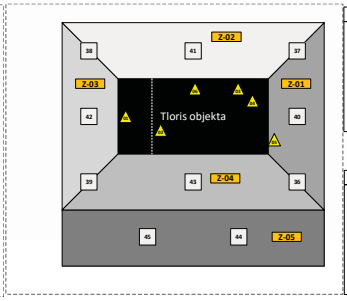
Postavitev_1 - Klet												
Postavitev_1			Postavitev_2			Postavitev_3			Postavitev_4		
Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)		
Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)
73	37	110	29	22	51	55	31	86	338	258	596

Zunanja okolica objekta – Primerjava postavitev 1, 2, 3 in 4

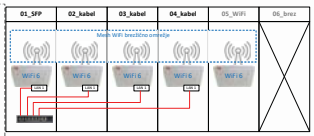
Shema zunanje okolice objekta s prikazanimi merilnimi točkami



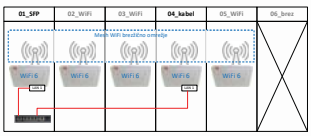
Shema zunanje okolice objekta s prikazanimi sektorji in merilnimi točkami



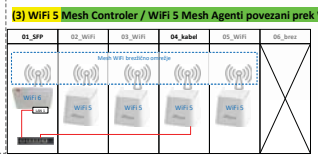
(1) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom



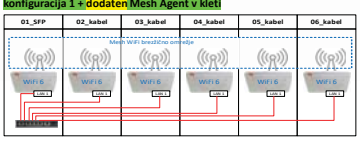
(2) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani prek WiFi



(3) WiFi 5 Mesh Controler / WiFi 5 Mesh Agenti povezani prek WiFi



(4) WiFi 6 Mesh Controler / WiFi 6 Mesh Agenti povezani z UTP kablom konfiguracija 1 + dodaten Mesh Agent v kleti

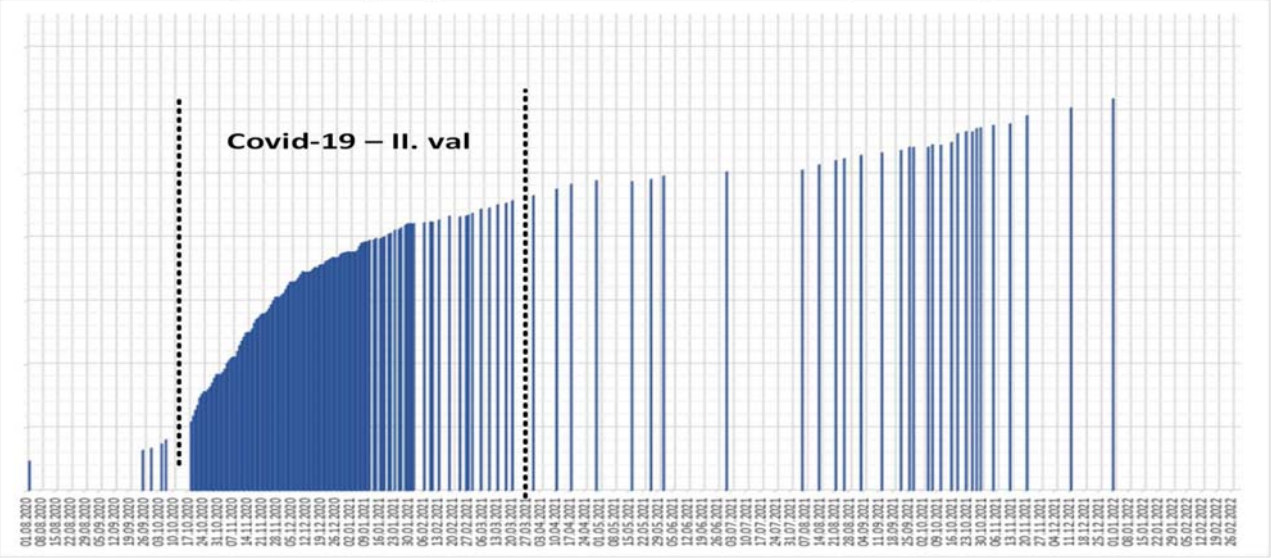


Postavitev_1 - Zunanja okolica												
Postavitev_1			Postavitev_2			Postavitev_3			Postavitev_4		
Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)			Povprečen prenos v etaži (skica objekta)		
Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)	Down (Mbit/s)	Up (Mbit/s)	Vsota povprečja Down+Up (Mbit/s)
142	83	225	99	75	174	98	50	148	246	199	445

Zaključek

- Kabelske povezave elementov Mesh omrežja omogočajo maksimalno zmogljivost in izkoristek pasovnih širin,
- Wi-Fi povezovanje elementov Mesh omrežja omogoča vzpostavitev tudi v objektih, kjer ni razpoložljivih kabelskih povezav,
- Wi-Fi 6 bistveno poveča zmogljivost in doseg: ~20-30%
- Novejši „chip-set“ zagotavljajo boljše delovanje na osnovi najnovejših standardov Wi-Fi,
- Napovedane so že nove generacije Wi-Fi: Wi-Fi 6E, Wi-Fi 7,…

Dodatek:
Covid-19 (2020) vpliv na dinamiko prodaje



One global network of Wi-Fi networks based on the Open Roaming architecture and business model

Klaus Samardžić

Smart Com, d. o. o.

klaus.samardzic@smart-com.si

Abstract

The importance and value of a communication network depends on the number and quality of communication services offered and the area in which the services are accessible to users. Most technologies for building communication networks have made their way from offering services in a specific area limited by signal parameters or communication protocols and standards to global accessibility. Wi-Fi technology is no exception. Today, more than two-thirds of user data traffic is transmitted over Wi-Fi access networks. Nevertheless, Wi-Fi is synonymous with WLAN (Wireless Local Area Network). Hotspot 2.0 technology has provided the technological basis for the most significant step in offering communication services over Wi-Fi access networks. In May 2020 Wireless Broadband Alliance (WBA) launched OpenRoaming. Based on Hotspot 2.0 technology, the OpenRoaming is an architecture and business model for the provisioning of communication services through a global network (WGAN - Wireless Global Area Network) of Wi-Fi networks. The very importance of the realization of such a network depends on the quality of offered communication services, which is provided by the introduction of the IEEE 802.11 ax (Wi-Fi 6) standard. Wi-Fi 6 uses an advanced way of multiplexing signals OFDMA (Orthogonal Frequency Division Multiple Access) and antennas with MU-MIMO (multi-user, multiple input, multiple output) functionality. This allows the user to experience the quality of service QoE (Quality of Experience) as used to from the 4G or 5G mobile networks. The efficient provision of communication services achieved through the implementation of these technologies is described. OpenRoaming provides a way to seamlessly and secure offer services globally between Wi-Fi networks owned by different organisations. Architecture of such a global network consisting of local Wi-Fi networks and the implemented protocols are described. The role of ANP (Access Network Provider) and IDP (Identity Provider) in the WBA (Wireless Broadband Alliance) OpenRoaming Federation is explained. The presented material addresses the question of whether the existing Wi-Fi networks used in different organization can offer services in accordance with the OpenRoaming business model and for which role in the WBA (Wireless Broadband Alliance) OpenRoaming Federation the organisation should apply.

Biografija avtorja

Klaus Samardžić ima tridesetletne izkušnje pri razvoju in implementaciji komunikacijskih sistemov. Prvih deset let je sodeloval ali vodil razvoj komunikacijskih sistemov. V podjetju Fotona, takrat uveljavljenemu podjetju na področju optičnih sistemov,

je sodeloval pri razvoju komunikacijskega sistema za prenos po optičnih vlaknih, ki je bil uspešno implementiran v Sloveniji in Sovjetski zvezi. V podjetju Smart Com, vodilnem sistemskem integratorju, že dvajset let sodeluje pri realizaciji komunikacijskih omrežij, z implementacijo optičnih in radijskih komunikacijskih sistemov v Sloveniji in na območju Jadranske regije. Kot pooblaščeni inženir Inženirske Zbornice Slovenije, z izkušnjami pri realizaciji projektov, ima vpogled v vse faze življenjskega cikla projekta, od načrtovanja, izvedbe in preizkusa sprejemljivosti do prehoda v operativno fazo. Takšne izkušnje mu omogočajo razumevanje potreb operaterjev komunikacijskih omrežij in želja uporabnikov komunikacijskih storitev. Razumevanje potreb vseh vpletenih strani mu pride prav pri sodelovanju v tržnih dejavnostih ali pri evaluaciji prihodnjega razvoja komunikacijskih storitev.

Author's biography

Klaus Samardžić has thirty years of experience in the development and implementation of communication systems. The first ten years he has participated or led the development of communication systems. In Fotona, at that time an established vendor of optical systems he colaborated in development of an optical fiber communication system and its successfull implementation in Slovenia and the Soviet Union. In Smart Com, a leading system integrator he has been involved in the realization of communication networks, implementing optical and radio communication systems in Slovenia and the Adriatic region for twenty years. As a Certified and Authorized Engineer for electrical engineering in civil works at Engineering Chamber of Slovenia with experience in the realization of communication networks projects he has insight into all phases of the project life cycle, from planning, implementation and acceptance testing to the transition into the operational phase. Such experiences allows him to understand the demands of communication networks operators and wishes of communication services users. When participating in marketing activities or evaluating the future development of provisioning communication services such understanding of the demands and wishes gives him the opportunity to offer solutions of mutual benefits for all involved parties.



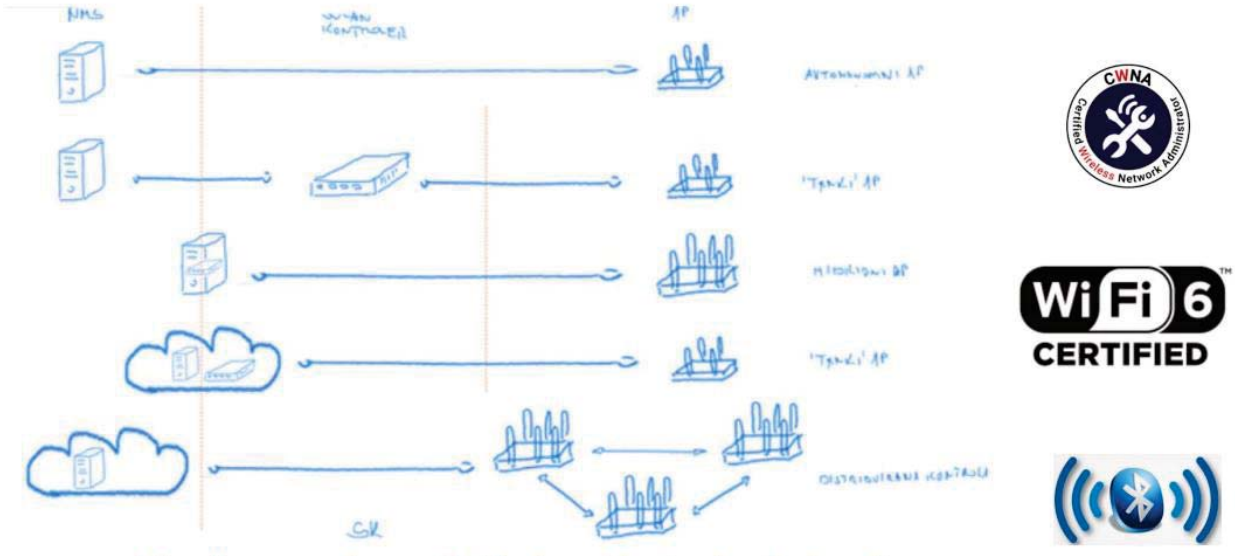
Globalno omrežje Wi-Fi omrežji na osnovi arhitekture in poslovnega modela OpenRoaming

Klaus Samardžić

“Svet ni eden, svetova sta dva!“



Različne arhitekture Wi-Fi WLAN omrežji skozi čas



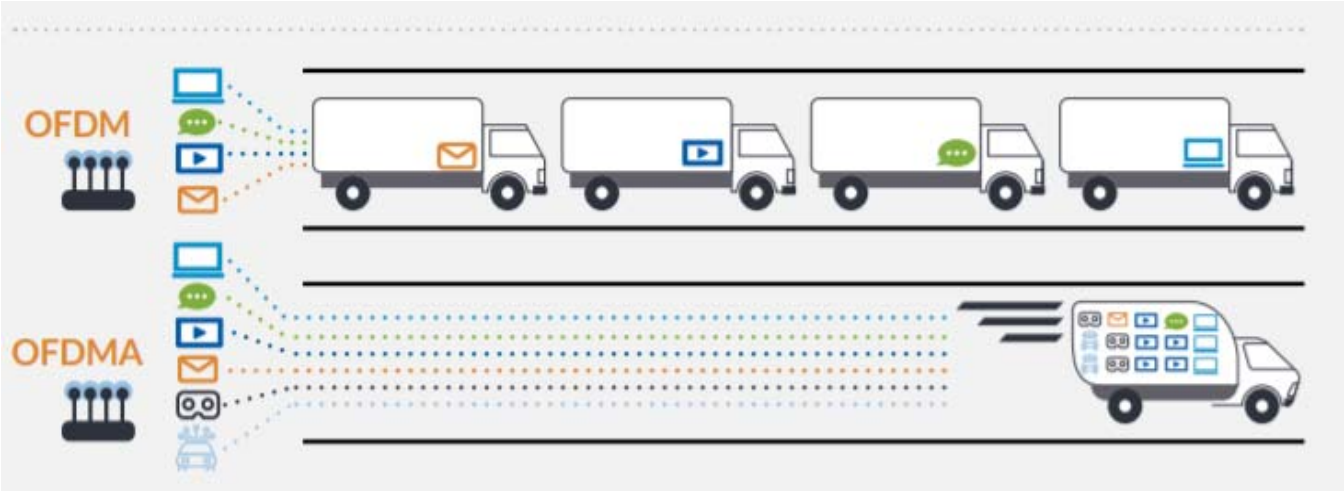
https://www.smart-com.si/wi-fi-wlan-sistemi-nekoc-in-danes/

Wi-Fi 6

- Danes se več kot pol uporabniškega podatkovne prometa prenaša skozi Wi-Fi dostopovna omrežja. Wi-Fi je sinonim za WLAN (Wireless Local Area Network).
- Tehnologija Hotspot 2.0 je podala tehnološko osnovo za najbolj pomemben korak v ponujanju komunikacijskih storitev skozi Wi-Fi dostopovna omrežja. Na osnovi Hotspot 2.0 tehnologije je zasnovana OpenRoaming arhitektura in poslovni model ponujanja storitev skozi globalno omrežje Wi-Fi omrežji (WGAN - Wireless Global Area Network).
- Sam pomen realizacije takšnega omrežja je odvisen od kvalitete komunikacijskih storitev, ki je omogočena z uvajanjem IEEE 802.11 ax (Wi-Fi 6) standarda. Wi-Fi 6 uporablja sodoben način multipleksiranja signalov OFDMA (Orthogonal Frequency Division Multiple Access) in antene z MU-MIMO (multi-user, multiple input, multiple output) funkcionalnostjo, ki omogočajo izkušnjo kvalitete storitve QoE – (Quality of Experience) podobno kot v mobilnih omrežjih 5G.

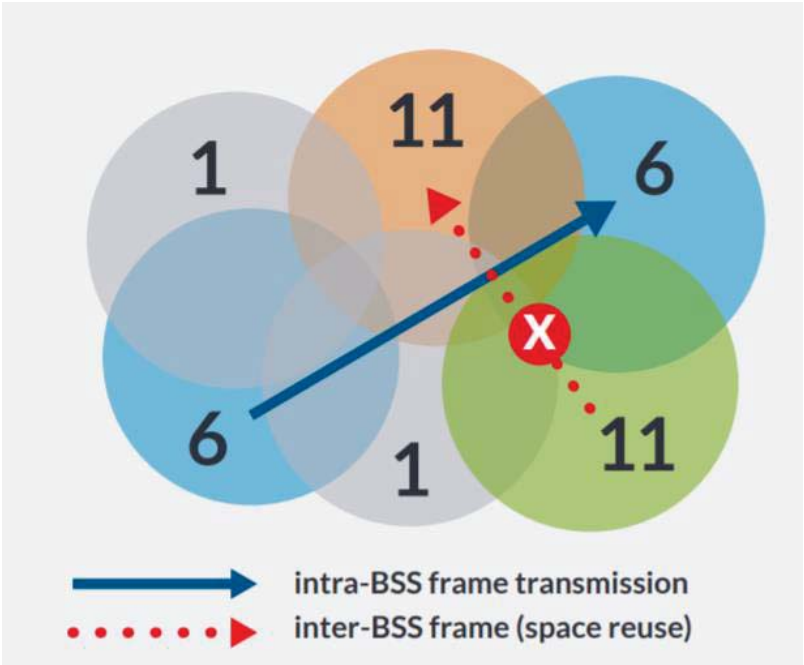


Wi-Fi 6 IEEE 802.11 ax



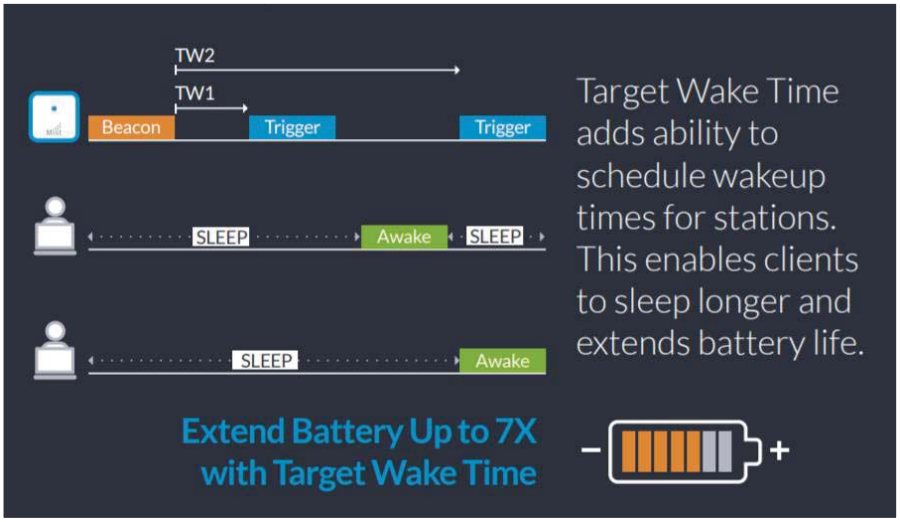
OFDMA – Orthogonal frequency-division multiple access

Wi-Fi 6 IEEE 802.11 ax



- BSS Coloring

Wi-Fi 6 IEEE 802.11 ax



TWT – Target Wake Time

Wi-Fi 6 in Wi-Fi 6Extended

- Wi-Fi 6**E** standard, ki ga je določil IEEE (Institute of Electrical and Electronics Engineers) 802.11 ax je Wi-Fi 6 standard, razširjen v na novo sproščen spekter **6 GHz**.
- Konec aprila 2020 je FCC (Federal Communications Commission) Združenih držav izglasoval, da dovoli nelicencirano uporabo pasu 6 GHz. To je omogočilo 1200 MHz (5,925 do 7,125 GHz) spektra za naprave, kot so Wi-Fi dostopovne točke.
- Ta dodani spekter je največja sprememba v Wi-Fi brezžičnih omrežjih, odkar je bila prvotna dodelitev ISM (Industrial, Scientific and, Medical) frekvenčnih pasov leta 1985.
- **EU** je sprejela odločitev, da članice odobrijo uporabo spektra **5,945-6,425 GHz** v pasu **6 GHz**.



Wi-Fi 6, Wi-Fi 5 in starejši standardi

- Starejše generacije Wi-Fi, kot sta 802.11n in 802.11ac, so temeljile na modulaciji OFDM (Orthogonal frequency-division multiplexing), kjer je bil vsak kanal v celoti rezerviran za enega samega uporabnika za vsak prenos.

- OFDM**A** kanal razdeli na podkanale, znane tudi kot enote virov (RU). To omogoča, da več uporabnikov komunicira hkrati, namesto da čaka na vrsto. Vsakič, ko naprava Wi-Fi 5 ali starejša naprava oddaja v omrežju Wi-Fi 6, se način prenosa vrne nazaj na standardni OFDM z enim uporabnikom, ki zasede celoten spekter.

- Preklapljanje naprej in nazaj med OFDM in OFDMA zmanjša učinkovitost delovanje Wi-Fi omrežje za vse, še posebej za naprave Wi-Fi 6. Delovanje postane še počasnejše, ko se v mešanici starejših naprav z nizko hitrostjo prenosa podatkov najdejo naprave, ki podpirajo samo 802.11b ali 802.11g.

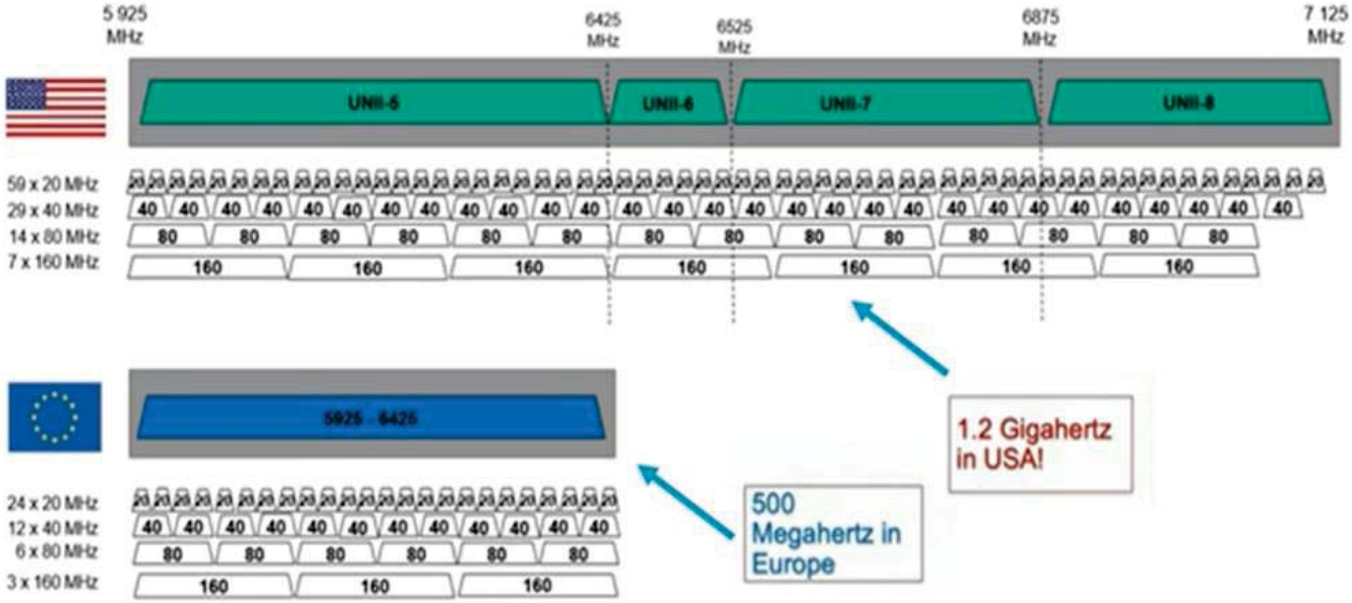
Wi-Fi 6 in Wi-Fi 6Extended

- Večina omrežij Wi-Fi 6E bo dvo - ali tripasovnih, kar bo starejšim odjemnim napravam omogočilo povezavo s starim spektrom, medtem ko bodo izključno odjemne naprave 6E omogočile delovanje v frekvenčnem spektru 6 GHz.

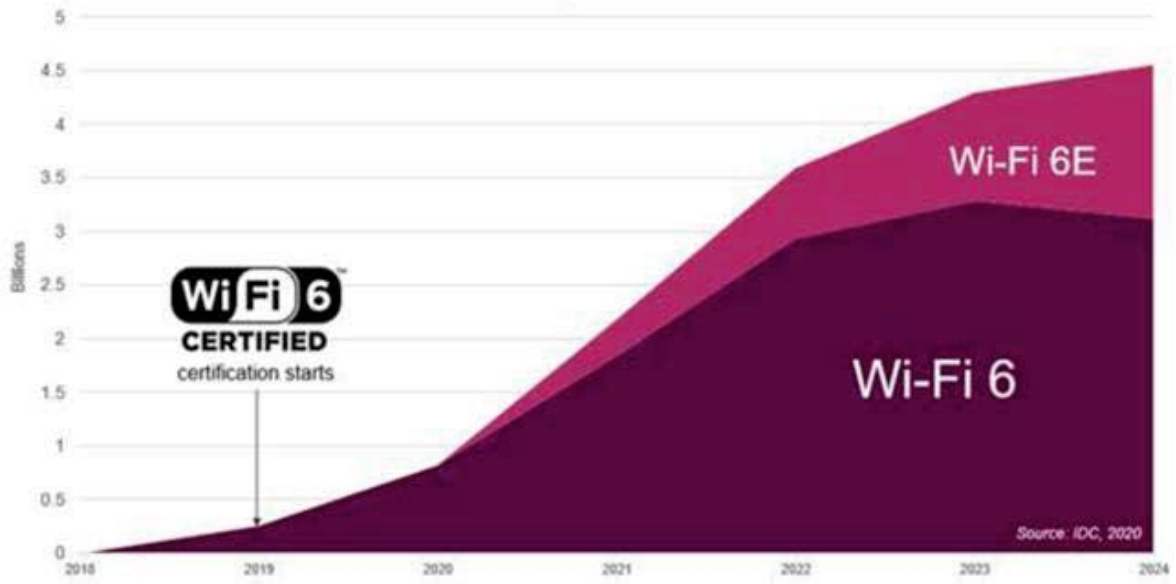
- To bo zagotovilo veliko prednosti. Vse Wi-Fi 6E naprave v omrežju podpirajo tehnologije, kot sta OFDMA (Orthogonal frequency-division multiple access) in Target Wake Time, zaradi česar bodo prenosi učinkovitejši.

- OFDMA zahteva, da so vse naprave, ki sodelujejo pri prenosu, sinhronizirane. Čas, frekvenca in oddajna radijska moč delovanja naprav morajo biti sinhronizirani med Wi-Fi dostopovno napravo (Access Point) in odjemno napravo - klijentom. OFDMA postane popolnoma učinkovit šele, ko ga uporabljajo vse odjemne naprave in Wi-Fi dostopovne točke.

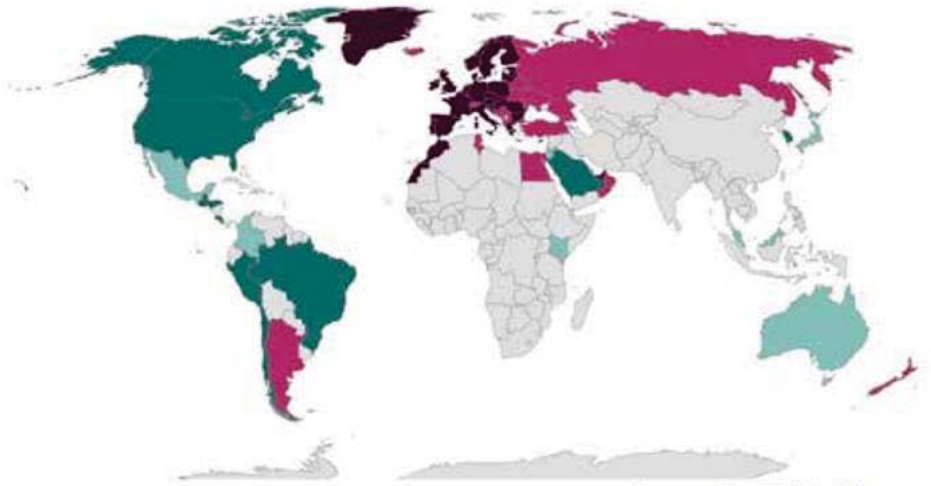
Wi-Fi 6E radijski kanali v 6 GHz obsegu



Wi-Fi 6 in Wi-Fi 6Extended



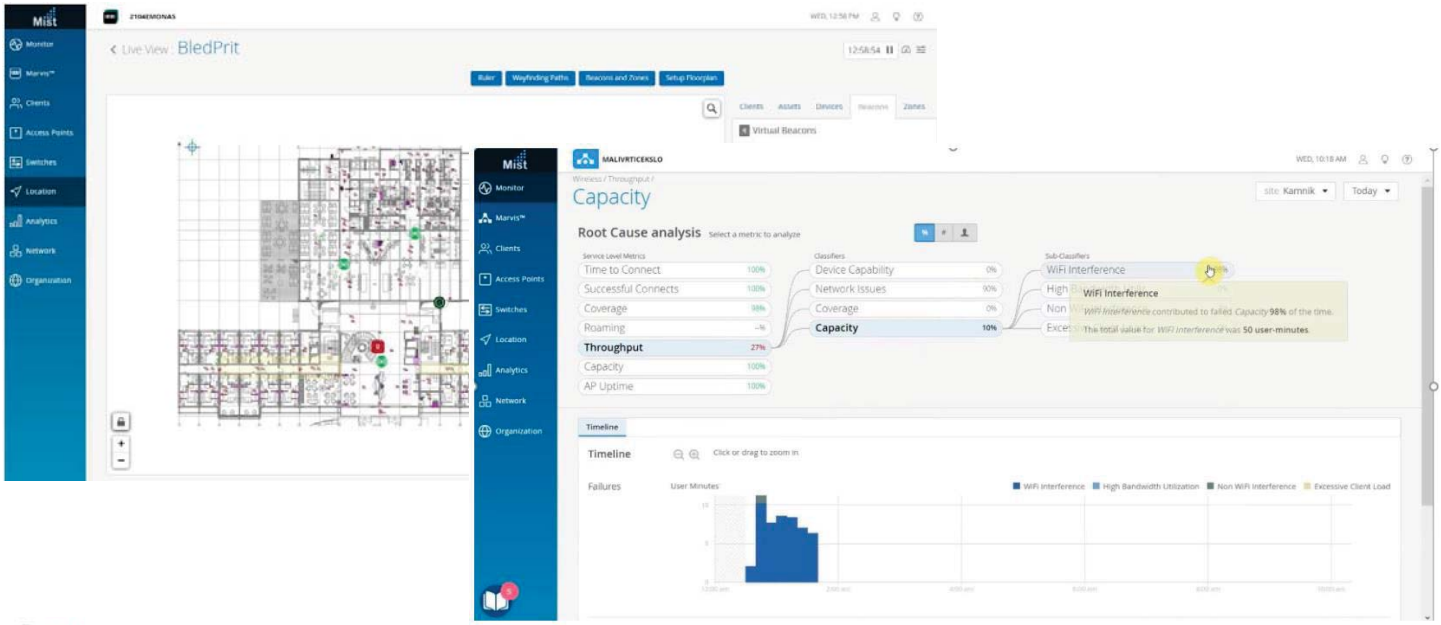
Wi-Fi 6Extended



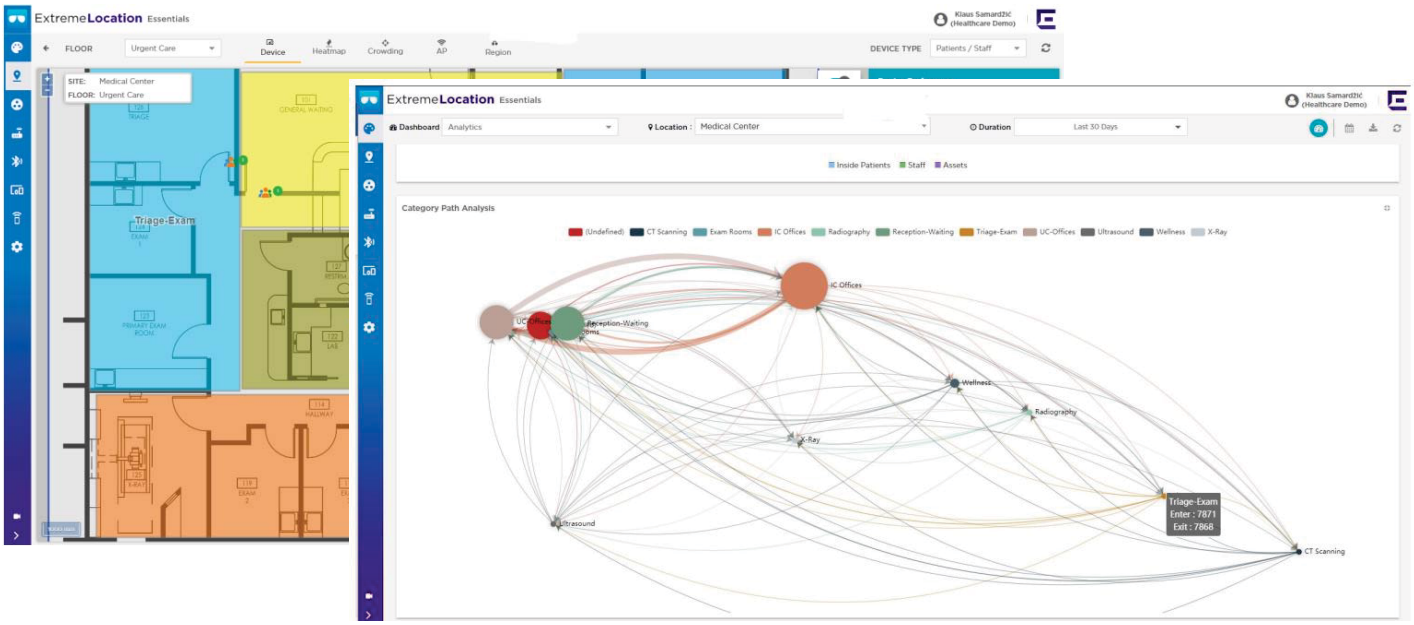
Source: The Wi-Fi Alliance

- Temno zelena in rdeča so področja kje je odobrena uporaba spektra 6 GHz za Wi-Fi 6E. Za področja označena z svetlo zeleno ali rdečo je postopek odobritev sprožen.

Nadzor delovanja omrežja in uporabnikov



Nadzor delovanja omrežja in uporabnikov

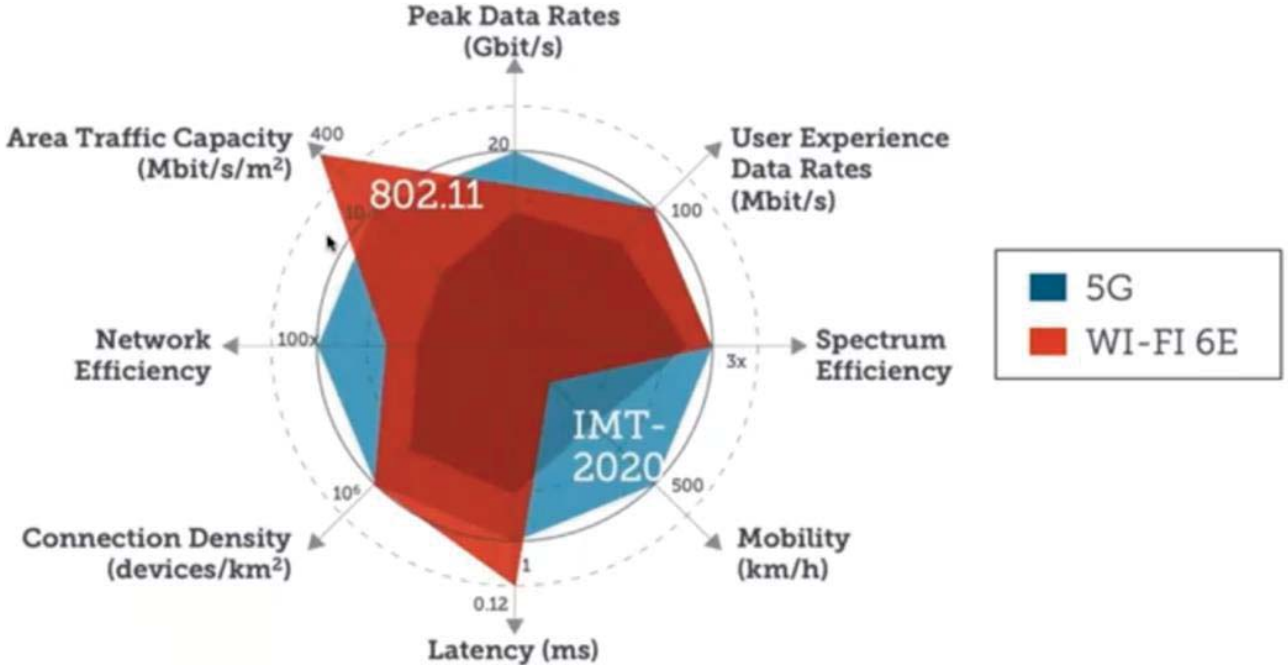


Vpliv naključne izbire MAC naslova

- Apple je leta 2014 svojim napravam dodal naključno izbiro MAC naslovov. Sledila sta Google Android OS in Windows OS s podobno funkcionalnostjo.
- Zadnja sprememba je bila leta 2020. Apple je dodal podporo za naključno izbiro MAC naslova za omrežja v operacijskem sistemu iOS 14, iPadOS 14 in watchOS 7.
- Generiranje naključnih MAC naslovov je urejeno v skladu s pravili, ki jih določi IEEE. V MAC OUI delu naslova se za označevanje naključnega/lokalno upravljanega naslova uporabi drugi znak. Če je drugi znak 2, 6, A ali E, potem je to naključni naslov.



Wi-Fi 6E in 5G mobilna omrežja



"Brez vas ni nas!"



Brez uporabnikov ni omrežij!

- Pomen in vrednost komunikacijskega omrežja je odvisna od števila in kvalitete komunikacijskih storitev, ki se ponujajo ter področja v katerem so storitve dostopne uporabnikom.

- Večina tehnologij za graditev komunikacijskih omrežjih je naredila pot od ponujanja storitev v določenem področju omejenem s parametri signalov ali komunikacijskimi protokoli in standardi do globalne dostopnosti. Tehnologija Wi-Fi ni nobena izjema.

$$\int_a^b f(x)dx = \lim_{\Delta x \to 0} \sum_{i=0}^{n} f(x_i^*)\Delta x$$

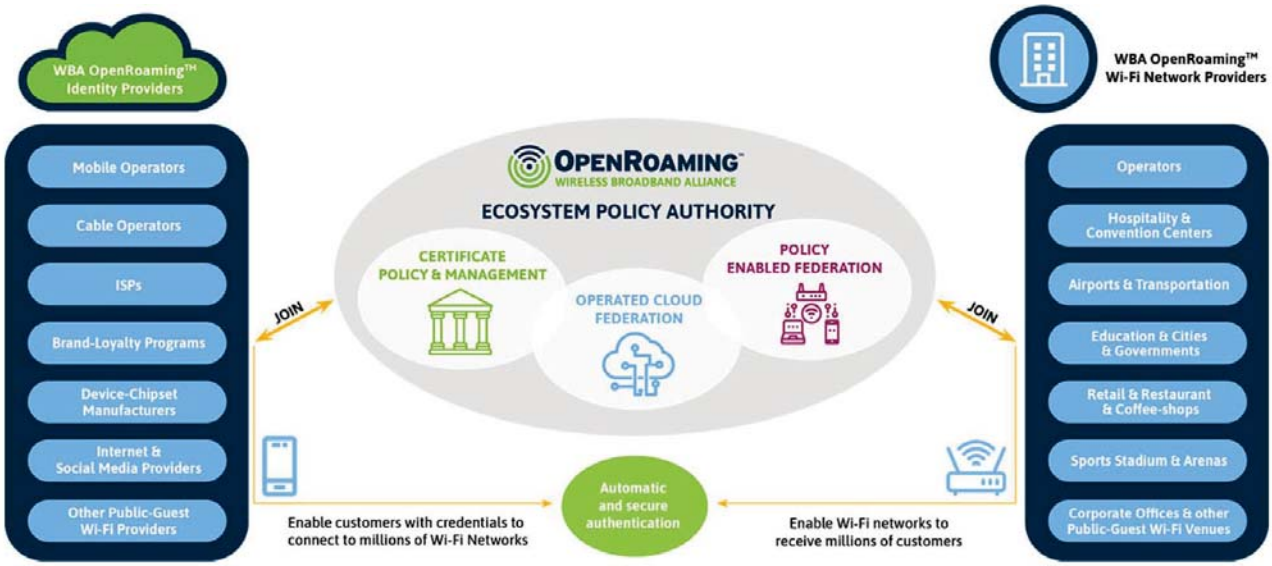
- OpenRoaming omogoča nemoteno in varno ponujanje storitev po vsem svetu med omrežji Wi-Fi v lasti različnih organizacij.

Brez uporabnikov ni omrežij!

- OpenRoaming je struktura industrijskih partnerstev, tehničnih standardov in sodelovanja zasebnih in javnih podjetij, ki omogoča kateremkoli uporabniku naprave s preverjeno pristnostjo z Wi-Fi vmesnikom, da se poveže s ponudnikom identitete, ki ima v lasti ali zagotavlja konfiguracijo te naprave za dostop do storitev skozi Wi-Fi dostopovno omrežje.
- OpenRoaming uporabnikom Wi-Fi dostopovnih omrežji avtomatično ponuja zaščiteno povezavo v komunikacijsko omrežje neodvisno od lokacije podobno izkušnjam mobilnih uporabnikov v javnih 4G ali 5G omrežjih.
- OpenRoaming aplikacija za mobilne naprave:
  - Apple iOS 13.3 =>
  - Android 9 =>
- Operacijski Sistem mobilnih naprav podpira OpenRoaming:
  - Samsung Android 10 =>
  - Google Pixel Android 11 =>

30 SMART COM SRK 2022 25. seminar radijske komunikacije

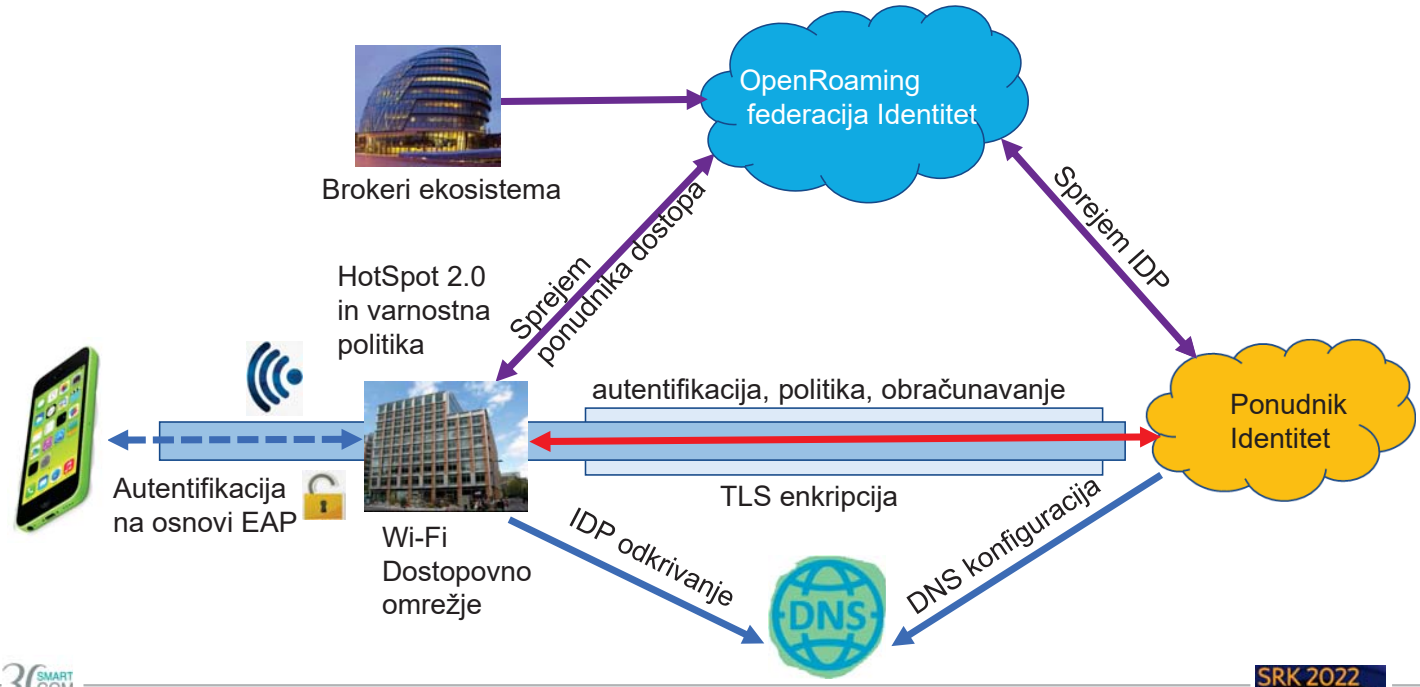
WBA OpenRoaming



WBA kot neodvisni administrator

- WBA (Wireless Broadband Alliance) je ustvaril OpenRoaming Federation. Arhitektura takšnega globalnega omrežja, ki ga sestavljajo lokalna Wi-Fi omrežja in implementirani protokoli vsebuje naslednje subjekte:
- ANP (Access Network Provider)
- IDP (Identity Provider)
- Broker
- Pogoj za delovanje OpenRoaming Federation z obstoječimi ali novimi Wi-Fi omrežji so sodobne dostopovne točke (Access Point), ki podpirajo Hotspot 2 funkcionalnost in uporabniške naprave z ustrezno funkcionalnostjo.
- Ponujajo se različne storitve v skladu s poslovnim modelom OpenRoaming. Posamezna organizacija se odloči za vlogo v WBA (Wireless Broadband Alliance) OpenRoaming Federation na osnovi lastnih interesov.

Varno povezovanje v dostopovno omrežje



Avtomatizacija postopka s Hotspot 2.0

Pred uporabo 802.11u



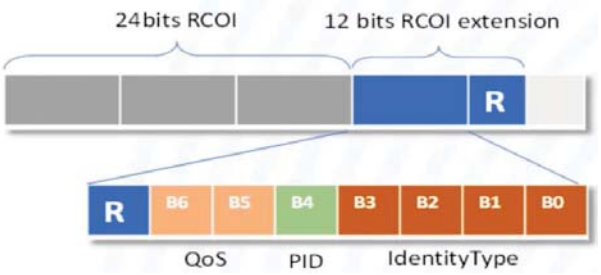
	Hotspot	Hotspot 2.0
Izbira omrežja	Manualno (SSID)	802.11u
Autentifikacija uporabnika	Captive Portal	802.1X
Enkripcija radijskega signala	NE	AES-CCMP 802.11i
Medsebojna autentifikacija	NE	EAP-SIM/AKA, EAP-TLS, EAP-TTLS
Kibernetska zaščita	NE	802.1X/EAP

Z uporabo 802.11u



OpenRoaming implementacija politik

- Kombinirani 36-bitni identifikatorji organizacije - Roaming ConsortiumOI (RCOI)
  - Dva 24-bitna edinstvena identifikatorja organizacije določena s strani IEEE.
  - 12-bitna razširitev WBA kontekstualni identifikatorji.
- Trenutno opredeljeni RCOI so:
  - OpenRoaming — Brezplačni RCOI (5A-03-BA-xx-x)
    - Za ponudnike omrežja (ANP), ki ne pričakujejo plačila za storitve Wi-Fi.
  - OpenRoaming - RCOIS, urejeni s poravnavo (BA-A2-D0-xx-x)
    - Za ponudnike omrežja (ANP), ki zahtevajo poravnavo za storitve Wi-Fi.



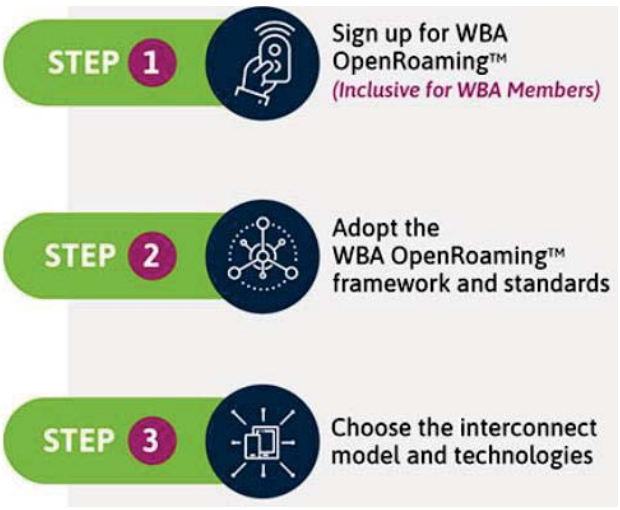
ID-Type Field				Description
B3	B2	B1	B0	
0	0	0	0	Any identity type is permitted
0	0	0	1	A service provider identity
0	0	1	0	A cloud provider identity
0	0	1	1	A generic enterprise identity
0	1	0	0	A government identity e.g., including city
0	1	0	1	An automotive identity
0	1	1	0	A hospitality identity
0	1	1	1	An aviation industry identity
1	0	0	0	An education or research identity
1	0	0	1	A cable industry identity
Other values				Reserved (for future allocation by WBA)

QoS Field		
B6	B5	
0	0	Baseline QoS
0	1	Silver
1	0	Gold
1	1	Reserved

PID Field	Description
0	Baseline ID Policy applies, i.e., users can remain anonymous whilst using the service
1	A Permanent ID will be returned by the HSP

OPENROAMING™
WIRELESS BROADBAND ALLIANCE

https://wballiance.com/openroaming/join/





email: klaus.samardzic@smart-com.si

twitter: @klaussamardzic

Tel: +386 40 882 594

www.**smart-com**.si

Pogled na uvajanje video analitike v koncept pametnih mest

A look at introducing video analytics into the concept of smart cities

Marjana Senčar Srdič

A1 Slovenija

marjana.sencar.srdic@a1.si

Povzetek

Pametna mesta predvidevajo zbiranje ogromne količine podatkov iz različnih sistemov, zato so politike razvoja in upravljanja s podatki njihova pomembna komponenta. Raziskovalci ob primerjavi razvojnih strategij več pametnih mest opažajo, da je t. i. privid varnosti (security theater) eno glavnih gonil razvoja na tem področju. Medtem, ko ima v splošni javnosti video analitika večinoma žal negativen pridih in se jo enači z nadzorom ter mnogi odločevalcem očitajo, da se pri svojih investicijah v koncept pametnega mesta osredotočajo predvsem na področje video-nadzora in zanemarjajo ostale vidike pametnih mest (npr. Bruselj, London in Beograd), sem se v svojem prispevku osredotočila na tehnološki razvoj in potencial video analitike v pametnih mestih. Poudarek je na »pametnih območjih« – entitetah, ki efektivno koristijo vse razpoložljive informacije za optimalen izkoristek resursov, globalnih trendih, razvoja mest in mega-mest, arhitekturi združenega podatkovnega pretoka, transportni varnosti, kontroli bivališč in komunalnih servisov, video analitiki v izobraževanju in poenotenih plačilnih sistemih.

Abstract

Smart cities provide for the collection of huge amounts of data from different systems, so data development and management policies are an important component of them. Researchers comparing the development strategies of several smart cities note that t. i. security theater is one of the main drivers of development in this area. While in the general public, video analytics mostly has a negative connotation and is equated with surveillance, and many criticize decision-makers for focusing their investments in the smart city concept on video surveillance and neglecting other aspects of smart cities (eg Brussels, London and Belgrade), in my paper I focused on the technological development and potential of video analytics in smart cities. The emphasis is on "smart areas" - entities that effectively use all available information for optimal use of resources, global trends, urban and mega-urban development, integrated data flow architecture, transport security, control of housing and utilities, video analysts in education and unified payment systems.

Biografija avtorja



Marjana Senčar Srdič je **v**odja oddelka tehnologij interneta stvari in inovacij v podjetju A1 Slovenija. Od leta 2001 je pridobivala delovne izkušnje na področju informacijskih tehnologij in telekomunikacij, tako v manjših, kot velikih, mednarodnih podjetjih (nekdanji Hermes SoftLab, Hewlett Packard). V okviru A1

Slovenija je že nekaj let vključena v raziskovalne in inovacijske projekte ter uvajanje novih tehnologij. Je registrirana raziskovalka pri Agenciji za raziskovalno dejavnost RS (ARRS), aktivna v raziskovalni organizaciji, vodi vertikalo Mobilnost, transport in logistika v okviru strateškega razvojnega inovacijskega partnerstva (SRIP) Pametna mesta in skupnosti (PMiS).

Author's biography

Marjana Senčar Srdič is Head of IoT Technology and Innovations department at A1 Slovenia. She has been gaining work experience in the field of information and telecommunications technologies, in both small and large, international companies (former Hermes SoftLab, Hewlett Packard) since 2001. Within A1 Slovenia, she has been involved in research and innovation projects and roll-out of new technologies for several years. She is a registered researcher at the Research Agency of the Republic of Slovenia (ARRS), active in a research organization and leads the Mobility, Transport and Logistics vertical within SRIP PMiS (Strategic Research & Innovation Partnership for the Smart Cities and Communities topic).



2. februar 2022 Marjana Senčar Srdič

POGLED NA UVAJANJE VIDEO ANALITIKE V KONCEPT PAMETNIH MEST



Cilj implementacije tehnologije mora biti:

Boljša kakovost življenja
Boljše poslovno okolje
Trajnostni razvoj

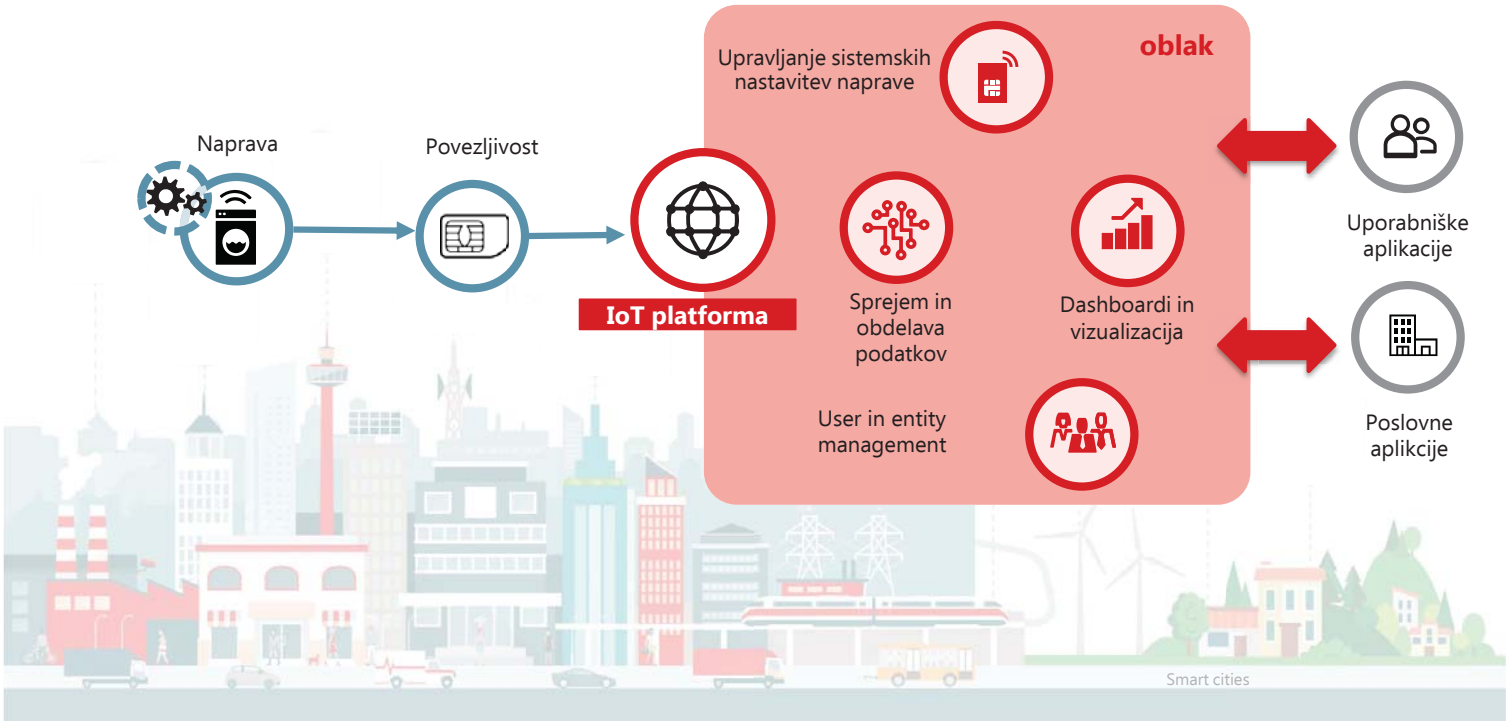
Velika množica mestnih informacij v realnem času, ki jih bodo omogočala tipala, omrežja ter spletne in mobilne aplikacije.

Marjana Sencar Srdic



Porast glasovnega in podatkovnega prometa, nadpovprečno obremenjeno omrežje

Koncept „pametnega mesta"





Informiranje deležnikov

Odprta, povezljiva komunikacijska platforma

Odprti API-ji
Ločitev podatkov od aplikacij
Upravljanje naprav
Uporaba standardnih gradnikov
Data lake (podatki iz vseh povezanih služb) & data management (o. uradov in IoT)

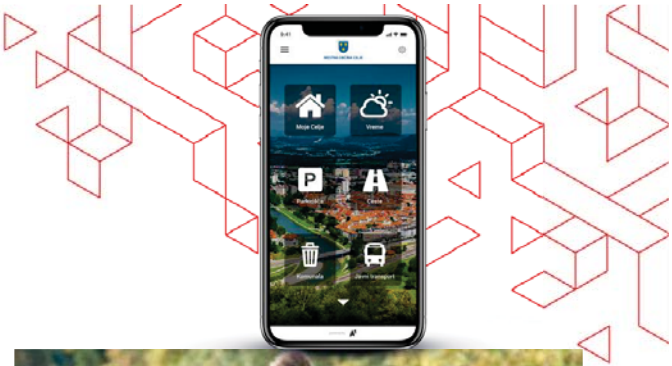


Kibernetska varnost

Marjana Sencar Srdic

Prebivalci najbolj poznajo svoj kraj

- Podatkovna avtonomija in lastništvo podatkov
- Podatki morajo v čim večjem obsegu ostati v lastništvu mest, ki naj bi dostop do njih (na varen in s področjem varovanja osebnih podatkov skladen način) ponudila svojim prebivalcem.
- Prebivalci najbolj poznajo svoj kraj in lahko prispevajo zanimive predloge za izboljšave.
- In nenazadnje najbolj vedo, kakšen prikaz informacij jim najbolj ustreza.







V križišču, v katerem je minuli konec tedna prišlo do nesreče, ste opazili nekaj, kaj nekatere spominja na radar, druge na kamero.

Več bralcev Sobotainfo se je obrnilo na nas z vprašanjem, kdo in kaj je to postavil v križišču pri prvi osnovni šoli.

Štetje prometa

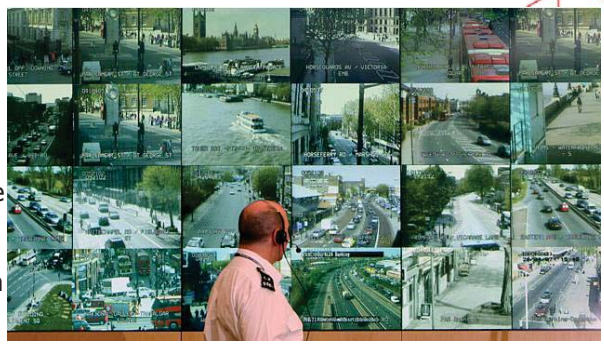
Številni ste se spraševali, ali ni morda to radar. Za več informacij smo se obrnili na policijo, kjer pa pravijo, da oni z zadevo nimajo opravka.

> Po naših informacijah je šlo za kamero za štetje prometa, ki so jo pa včeraj zvečer tudi že odstranili.



„PAMETNA MESTA" koncept/ potreba po uvajanju video analitike

- **zbiranje ogromne količine podatkov iz različnih sistemov** - pomembnost politik razvoja in upravljanja s podatki.
- Je privid varnosti (security theater) eno glavnih gonil razvoja na tem področju (npr. Bruselj, London in Beograd)?
- video analitika = nadzor?
- Potencial video analitike v pametnih mestih = nudi informacije za optimalen izkoristek virov, transportno varnost, kontrolo bivališč in komunalnih servisov, boljši pregled nad dogajanjem v mestu, hitrejšo prilagodljivost različnim situacijam in možnost zgodnjega reagiranja na različne situacije.



CCTV in 5G

- S 5G podprta „Pametna CCTV", **razširja možnosti**, ki smo jih imeli z uporabo na 4G.
- Večja hitrost (10-krat hitrejša od trenutne na 4G) in nizka latenca (manj kot pol sekunde med prenosom in sprejemom) namigujeta, da je CCTV morda idealen primer uporabe za 5G, saj izjemno nizka zakasnitev omogoča zelo hiter reakcijski čas.
- Omogoča nam boljše in čistejše slike, ki se bodo prenašale skoraj v realnem času.
- S pomočjo podatkov in omogočenih algoritmov bo zmožnost razumevanja videnega pomenila, da pametna CCTV ne bo imela možnosti le zaznati vedenja, temveč ga bo tudi sledila in nato ovrednotila. Z drugimi besedami, informacije bodo hitro podane v sistem, ki se lahko skoraj takoj odzove, ustvarja opozorila ali sprejema druge odločitve.



Marjana Sencar Srdic

V „pametnem mestu" „veliki brat" pazi na vsak tvoj korak



- Medtem ko ima pametna CCTV očitne koristi tako za družbo kot za posameznike, bo prišlo do **številnih izzivov**, pri čemer bo **zasebnost** eden največjih.
- S povečane zmožnosti za sledenje in spremljanje prebivalstva
- Ravnanje z **ogromno količino podatkov**, ki bodo ustvarjeni, bo še en izziv, tako z vidika **stroškov** kot s stališča **shranjevanja**.
- Aplikacije 5G IoT v realnem času bodo zahtevale **sisteme**, ki so **na robu** in so povezani z zalednim repozitorijem, kot je oblak.

Marjana Sencar Srdic

„PAMETNA MESTA“ koncept/ potreba po uvajanju video analitike

- Poenotena informacijska platforma **pretoka upravljanja**
- Poenoten plačilni sistem
- Javna varnost
- Upravljanje prometa
- Preventiva v prometni varnosti
- Upravljanje javnega prevoza
- Vpogled v bivalne in komunalne servise ter resurse gospodinjstev
- Spremljanje ekoloških razmer
- Digitalizacija v zdravstvu
- E-izobraževanje

11

“PAMETNO OBMOČJE/REGIJA” – območje, ki učinkovito uporablja vse razpoložljive informacije za optimalno uporabo svojih virov

Promet/logistika

- Prometna infrastruktura mestna, prometna vozlišča
- EKO-prevoz
- Operativno upravljanje z vsemi vrstami prevozov

Socialna infrastruktura

- Poenotene podatkovne baze prebivalstva
- Digitalne/elektronske storitve
- Delovni pogoji
- Kvaliteta življenja

Javna varnost

- CCTV sistemi
- Alarmni sistemi
- Nujna govorna komunikacija
- GIS

Zagotavljanje virov/varčevanje z viri

- Visokotehnološke predelava podatkov
- Tehnologije obnovljivih virov energije
- Ponovna uporaba
- Nadzor nad gibanjem in predelavo odpadkov

Znanost in izobraževanje

- Oddaljeno izobraževanje in e-izobraževanje
- Raziskovalni centri
- Zaščita intelektualne lastnine

Gradbeništvo

- Tehnologije varčevanja z energijo
- Krajinsko oblikovanje
- Upravljanje stavb na daljavo
- 24/7 nadzor objektov v razmerah nezadostno razpoložljivega omrežja

12

Vpogled v prihodnost »PAMETNIH MEST«, upoštevaje globalne trende in trende razvoja mest in mega-mest

Globalni trendi

Globalne informacijske vsebine

- Razvoj sistemov pametnih domov in stopnja njihove interakcije z zunanjo infrastrukturo
- Razvoj sistemov za obdelavo podatkov, vklj. iskalnike, sisteme za analizo podatkov itd.
- Razvoj plačilnih sistemov, povečanje stopnje njihove integracije z drugimi storitvami/napravami
- Razvoj interneta stvari in povezane infrastrukture
- Nadaljnje izboljšave računalništva v oblaku in sistemov za shranjevanje
- Izboljšanje varnostnih sistemov, vklj. video nadzornimi sistemi, prepoznavo obrazov itd.

Naraščanje stopnje urbanizacije

- Naraščanje razmerja urbane populacije
- Naraščanje števila mega-mest in strnjenih naselij

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Trendi pri razvoju mest

Tehnologije

- Razvoj/vlaganja v plačilne sisteme in stopnja njihove integracije v ostale storitve/naprave
- Izboljšave varnostnih sistemov, vključno z video nadzornimi sistemi, prepoznavo obrazov, itd.

Transport

- Razvoj sistemov za analitiko potniškega prometa in prometnih razmer
- Razvoj socialnih navigacijskih sistemov
- Razvoj „IT parkirnih sistemov"

Gradbeništvo, infrastruktura ter gospodinjske in komunalne storitve

- Zaostrovanje okoljevarstvenih zahtev in nadzor uporabe virov
- Razvoj pametnih bivalnih sistemov in stopnje njihovih interakcij glede na zunanjo infrastrukturo
- Decentralizacija urbanih strnjenih naselij

Predlagani sistemi omogočajo uporabo ene IT platforme za obdelavo informacij, nadzor in upravljanje različnih življenjskih področij, upoštevaje naraščajoče številke prebivalstva

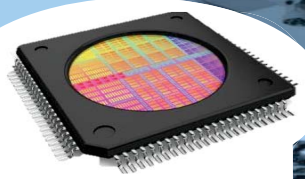
Funkcionalni diagram sistemov PAMETNIH MEST

Enotni plačilni sistemi

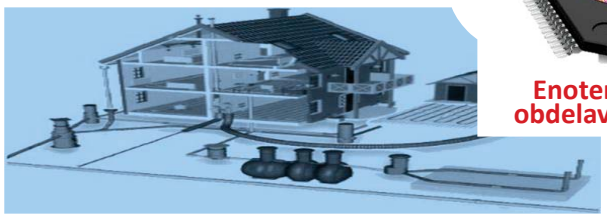


Javni varnostni sistemi





Enoten sistem za obdelavo informacij



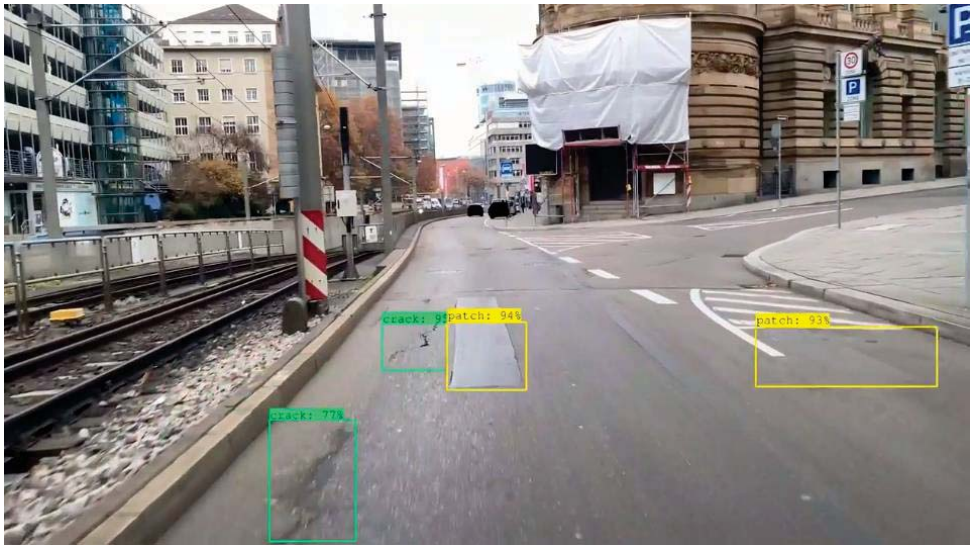
Spremljanje komunalnega omrežja



Nadzor prometa

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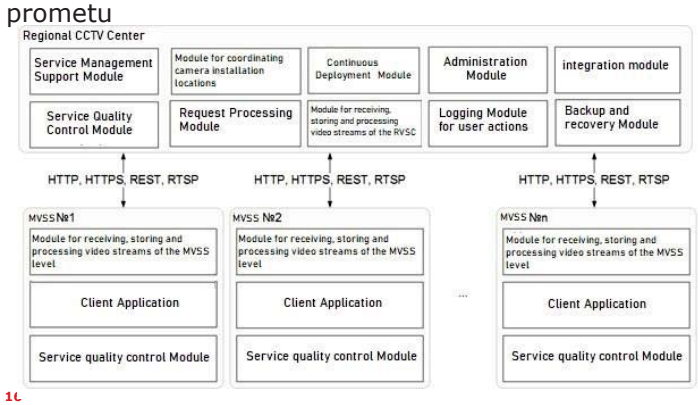
Zaznavanje poškodb na vozišču – vezano na področje krepitve odpornosti infrastrukture in prometa na podnebne spremembe



15

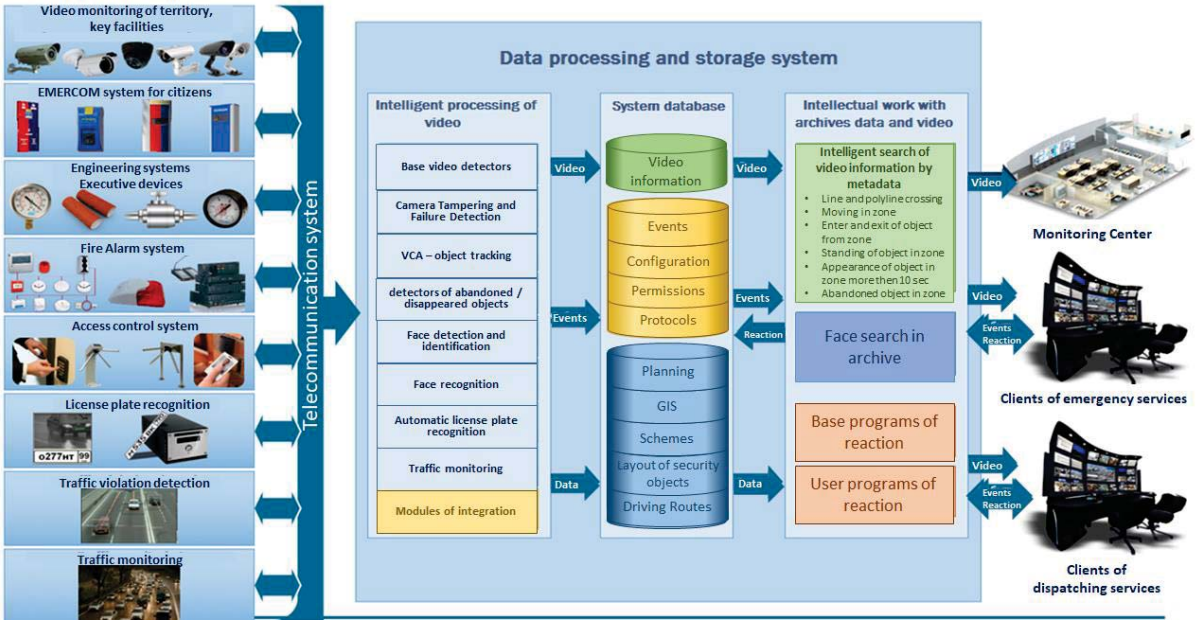
Arhitektura sistema za združevanje toka podatkov

- Lokacija objektov z video nadzorom preko realno časnih in arhiviranih video posnetkov;
- Pop-up sporočilna okna, na primer; video analitika, senzor premikov;
- Spremljanje sprememb v dinamiki video nadzorovanega objekta z opazovanjem realno časnega ali arhiviranega video posnetka ob določeni frekvenci;
- Vizualizacija pretoka informacij, na primer; prikaz obremenitve mobilnega omrežja pri nalaganju ali vozil v prometu





Sistem javne varnosti je sestavljen iz več podsistemov za zbiranje informacij, sistema za obdelavo in shranjevanje podatkov ter sistemov AWS za dispečerske, nujne in operativne službe



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Transportna varnost, instrumenti za nadzor tirnih vozil

- ✓ Integracija sistemov vozovnic
- ✓ Identifikacija voznikov preko dostopnih kartic
- ✓ Oddaljeno nalaganje in upravljanje poti
- ✓ Podpora temperaturnim senzorjem
- ✓ Obdelava podatkov o štetju potnikov potniškega prometa
- ✓ Spremljanje goriva iz senzorjev nivoja tekočine in/ali CAN bus
- ✓ Diagnostika vseh naprav na vozilu, z opozorili voznikom ali dispečerjem v primeru zaznanih napak

- ✓ Video snemanje v visoki kakovosti, podpora za do 21 Full HD video kamer;
- ✓ Video nadzor (prepoznavanje obrazov, prepoznavanje registrskih tablic, sledenje predmetom, iskanje dogodkov in predmetov v arhivu);

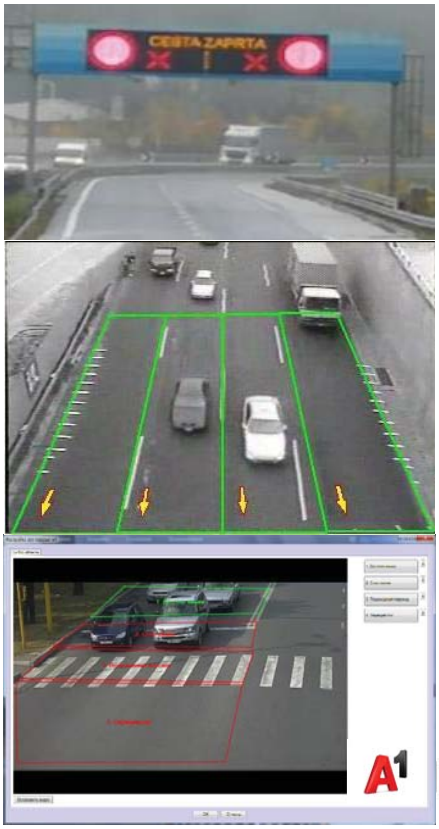
- ✓ Govorna komunikacija preko dispečerjev
- ✓ Nadzor in integracija z dispečerskimi sistemi v javnem transportu
- ✓ Opozarjanje voznikov v primerih odstopanj od načrtovanih poti intervencijskih vozil

- ✓ Prilagojene funkcionalnosti ekrana v vozilu za potrebe voznikov
- ✓ Zvočno in svetlobno opozarjanje potnikov v vozilih
- ✓ Analiza izdihanega zraka, vezana na zaklep vžiga vozila



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Transportna varnost – nadzor infrastrukture in orodja za preprečevanje incidentov

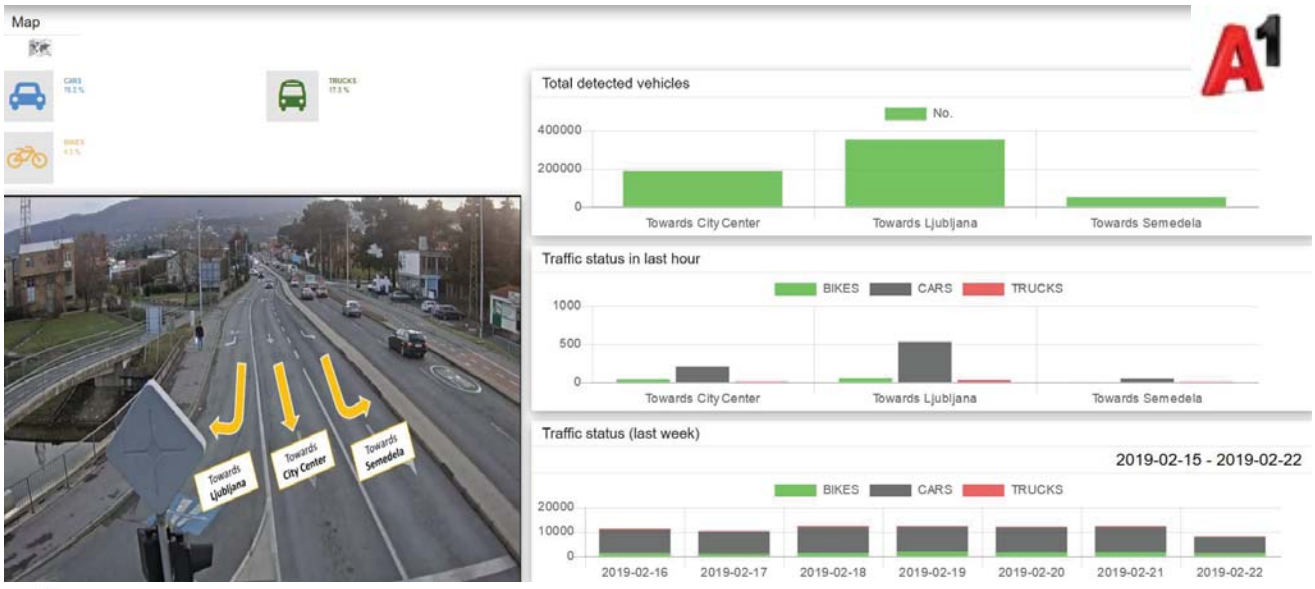


- Preiskovalna orodja - funkcija prepoznavanja avtomobilskih številk omogoča iskanje in prepoznavanje registrskih tablic avtomobilov, pa tudi iskanje v video arhivu tako po dogodkih kot po simbolih številke.
- Orodja za obveščanje o izrednih razmerah, vremenskih razmerah in popravke prometnih vzorcev
- Orodja za upravljanje prometa – omogočajo prilagajanje prometne obremenitve cest in avtocest
- Orodja za prepoznavo kršenja prometnih pravil:

- Prekoračitve hitrosti, vključno s povprečno hitrostjo
- Kršitev pravil o lokaciji vozila na cestišču
- Kršitev pravil prehoda križišč, prehodov za pešce, železniških tirov

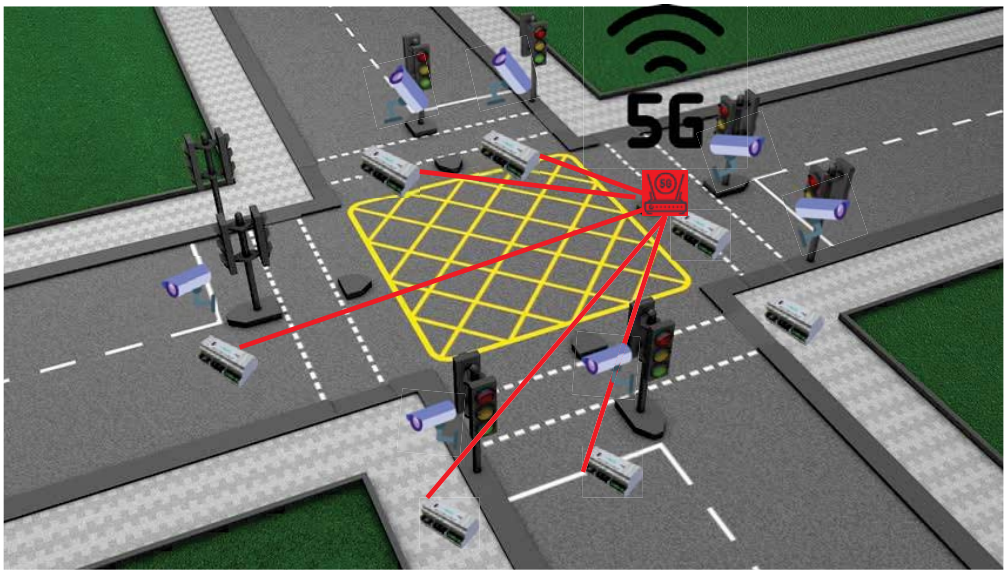
19

Pametno mesto – demo okolje – pametni promet (kamera za štetje in klasifikacijo prometa)



Marjana Sencar Srdic

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- Senzorji zajamejo stanje na prometnem toku
- Informacijo posredujejo v STC krmilnik
- STC krmilnik
- Na podlagi informacij upravlja s semaforjem
- STC krmilnik podatek posreduje do komunikacijske enote 5G
- Podatki se preko 5G posredujejo v platformo pametnega mesta
- Istočasno se iz platforme pošiljajo informacije o vozilih na nujni vožnji za omogočanje prioritetne vožnje.

Promet – ANPR (automatic number plate recognition) oz. samodejna prepoznava registrskih oznak



Nadzor stanovanjskih in komunalnih storitev in komunikacija prebivalcev s pooblaščenimi predstavniki občinskih služb



- Integracija domofonskega sistema v enoten iskalni sistem z možnostjo dostopa do vseh zainteresiranih
- 24 uren vizualen dostop preko ekranov
- Hitro obveščanje služb pregona in drugih služb za nujne primere mesta o nastanku ali sumu situacij, ki ogrožajo življenje in zdravje ljudi, varnost njihovega premoženja, pa tudi varnost občinskega premoženja
- Pomoč pri operativnem vodenju osebja med prazniki in množičnimi dogodki
- Zagotavljanje arhivskih podatkov službam pregona in drugim zainteresiranim službam mesta za obnovitev poteka dogodkov, podporo izvajanju operativnih preiskovalnih ukrepov itd.
- Nadzor dvigal v objektih
- Obračun in nadzor virov toplote, vode in električne energije - integracija merilnikov
- Vizualni nadzor osvetlitve ponoči
- Nadzor nad izvajanjem ukrepov za izboljšanje bivalnega področja
- Nadzor kakovosti in pravočasnosti čiščenja področja, odvoza smeti in njihove predelave

23

Primeri uporabe povezani z ekologijo



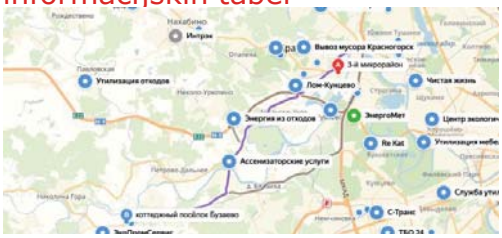
- Pametno zbiranje smeti:
  - Ločeno zbiranje po več kot 5 kriterijih
  - Primarna obdelava za zmanjšanje količine skladiščenih odpadkov
  - Uporaba alternativnih virov energije za delovanje sistema
  - Samodejno obveščanje o potrebi po praznjenju in servisu zbiralnikov
  - Nadzor nad odstranjevanjem in recikliranjem odpadkov



- Spremljanje odlagališč odpadkov, s pomočjo prikazovanja iz GIS baze podatkov



- Obveščanje uporabnikov o nepredvidenih razmerah z uporabo informacijskih tabel



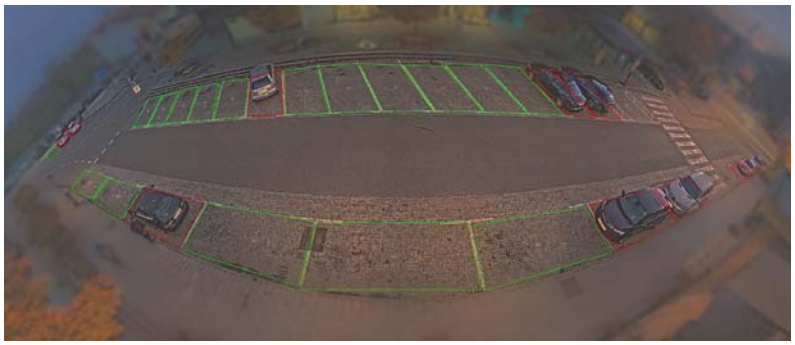
24

Zaznavanje prostih parkirnih mest z videoanalitiko

Funkcionalnosti sistema:

- Zaznavanje prostih parkirnih mest,
- časa zasedenosti posameznih parkirnih mest,
- napačno parkiranih vozil,
- zaznava vozil, ki so na parkirišču prepovedana (npr. avtodomi, avtobusi),
- tipa parkiranih vozil.

Možnost zaznave vozil z detektorji kovin na vhodih na parkirišča, ker pokrivanje s kamerami ni mogoče, kot na primer peščena parkirišča, drevesa.





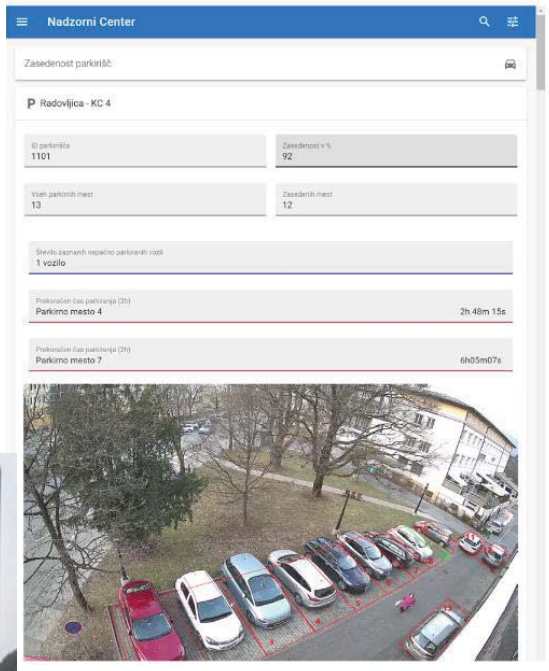
Funkcionalnosti sistema:

Posredovanje in analiza podatkov:

- na usmerjevalne table,
- v nadzorni center za upravljanje parkirišč,
- na prometno informacijske centre,
- v redarske aplikacije,
- na interne prometne spletne strani.

Nadzorni center omogoča:

- spremljanje trenutne slike parkirišča,
- posredovanje podatkov o prekoračitvi dovoljenega časa parkiranja,
- zaznava napačno parkiranih vozil,
- zmožnost upravljanja usmerjevalnih tabel.

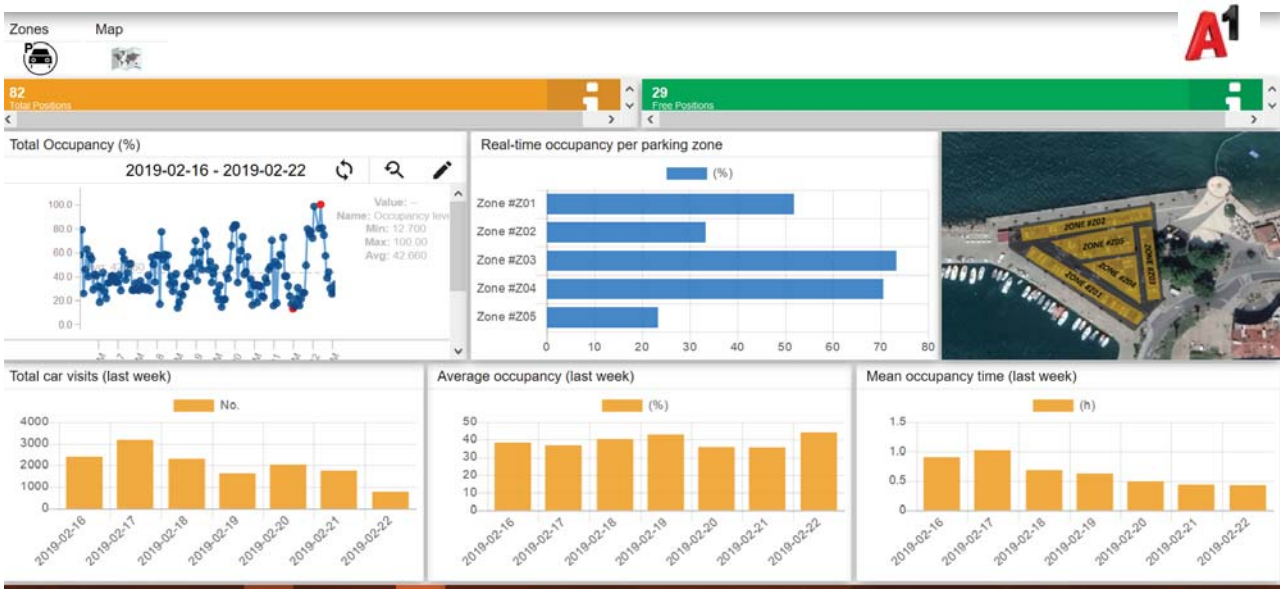




Delovanje

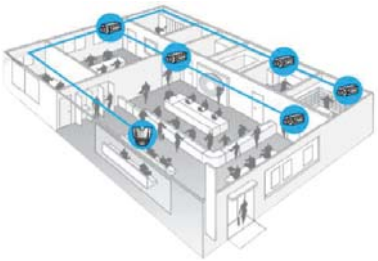
- 24-urno delovanje. Enaka zanesljivost delovanja tako podnevi kot ponoči.
- Sistem generira slike v realnem času, kar pripomore h zviševanje varnosti v prometu, zaščiti vozil pred krajo vozil ali uničevanjem infrastukture.
- Prepoznava modela vozil (osebno vozilo, avtobus, kombinirano vozilo, motorno kolo, tovornjak).
- Natančen in hiter dostop do informacij o zasedenosti parkirišč preko informacijskih LED-prikazovalnikov, voznikom močno olajša iskanje prostih parkirnih mest.
- Uporaba aplikacije na vseh napravah: osebni računalnik, tablica in pametni telefon.
- Prihranek časa pri iskanju prostega parkirnega mesta (kar do 43%) in zmanjšanje CO2 v ozračju (do 30%).
- Avtomatsko obveščanje administratorjev preko e-pošte, SMS-ov ali preko centralnega sistema.
- Povezljivost sistema z zunanjimi aplikacijami in rešitvami preko API
- Programska oprema je v celoti skladna z določili GDRP in trenutno veljavno zakonodajo (ZVOP-2), kar zagotavlja celovito zaščito anonimnosti podatkov.
- Enostavna prestavitev na drugo lokacijo.
- Sistem ne izvaja klasičnega video nadzora na parkiriščih, saj so osebe in registrske tablice v programski opremi zamegljene

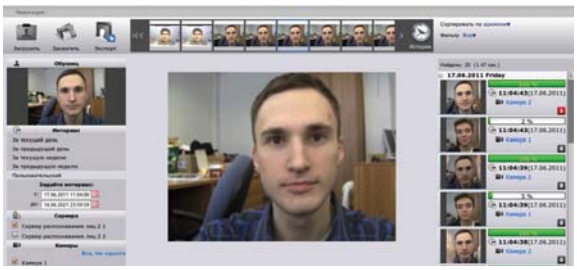
Pametno parkiranje (7 kamer in parkirni analizator)



Nadzor v izobraževalnih ustanovah in družbeno pomembnih institucijah

- Prepoznavanje obrazov na vhodih izobraževalnih ustanov in kulturnih inštitucij
- Obveščanje staršev o vstopih/izstopih preko mobilnih telefonov,
- Integracija sistema javne varnosti z zdravstvenimi bazami podatkov za pridobitev "posebnih kontrolnih seznamov" in dodatne identifikacije državljanov
- Integracija obstoječih informacijskih sistemov v tako imenovane »pametne regije«
- Razporeditev delovnega časa objektov socialne infrastrukture glede na zunanje podatke okoljskih sistemov, inteligentnega transportnega sistema in drugih.
- Implementacija najnovejših algoritmov video analitike, ki temeljijo na tehnologijah nevronskih omrežij za uporabo v medicini.





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Sistem pobiranja plačil, ki optimizira delovanje obstoječe finančne infrastrukture in monetizira storitve pametnega mesta.

Prednosti vgrajene plačilne rešitve

Optimizacija delovanja obstoječe plačilne infrastrukture

- Uvedba plačilnega sistema bo omogočila prehod na en sam elektronski gospodinjski račun, kar bo optimiziralo delovanje obstoječe infrastrukture za obdelavo plačil (banke in druge kreditne organizacije, pošta itd.)

Izboljšave kvalitete življenja

- Prehod na enotno poravnavo gospodinjskega računa bo izboljšal udobje plačevanja storitev sistema "pametnega mesta" (danes mora eno gospodinjstvo vsak mesec plačati 4-7 računov)

Povečanje finančnega donosa iz storitev in zmanjšanje deleža neporavnanih zapadlih plačil

- Za prejemnike plačil je enoten elektronski račun mehanizem za neposredne obračune s plačniki, ki zagotavlja pravočasen prejem plačila storitev, pa tudi izterjavo zapadlih dolgov.

Povečanje »fleksibilnosti« celotnega sistema

- Delujoči sistem plačil bo v prihodnosti omogočil hitro integracijo drugih storitev v sistem "pametnega mesta" in zagotovil njihovo monetizacijo

Prisotnost vgrajenega sistema obračunavanja / obdelave plačil bo povečala stopnjo monetizacije storitev sistema "pametnega mesta" in povečala finančni donos od mestnih storitev, hkrati pa zagotovila dvig kakovosti življenja prebivalcev.

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Gradnja sistema »pametnega območja« se mora začeti z izgradnjo sistema javne varnosti kot najbolj zahtevanega

Zunanji faktorji

- Teroristične grožnje
- Ponavljajoča se kriminalna dejanja
- Povečana intenzivnost prometa
- Povečana gostota prebivalstva v mega-mestih

Notranji faktorji

- Potreba skrajševanju časa za razrešitev kaznivih dejanj
- Potreba po izboljšanju odzivnosti vpletenih organov/služb
- Potreba po optimizaciji preobremenjenega operativnega osebja pri vpletenih organih
- Potreba po izboljšanju učinkovitosti pri preventivni obravnavi kaznivih dejanj/nujnih primerov

Vpeljava tovrstnega sistema je prednostna naloga velike večine mest, namenjena predvsem preprečevanju in predvidevanju groženj in izrednih dogodkov.

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Marjana Senčar Srdič
Vodja oddelka interneta stvari in inovacij

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marjanasencar/

sencarsrdic

Testiranje in optimiranje 5G za potrebe industrije

Testing and optimizing 5G for industrial verticals

Rudolf Sušnik, Janez Sterle, Luka Koršič

Internet Institute

rudolf.susnik@iinstitute.eu

Povzetek

Aplikacije za potrebe industrije so eno izmed najpomembnejših področij, ki jih naslavlja tehnologija 5G saj funkcionalnosti prejšnjih generacijah mobilnih tehnologij niso ravno najbolje dosegale zahtev industrijskih aplikacij kot so npr. pametne tovarne, avtonomna mobilnost, gosta senzorska omrežja (npr. pametna mesta), ipd. Vsaka aplikacija oz. storitev v 5G omrežju ima svoje specifike in zahteve, prav tako je tudi samo omrežje 5G dokaj kompleksno, zato si uvajanje novih 5G storitev težko zamislimo brez ustreznega testiranja vse od zasnove storitve do njene produkcijske uporabe. Cilj testiranja je pridobiti čim več relevantnih podatkov o delovanju storitve (in tudi omrežja) v različnih okoliščinah, saj se na podlagi temeljite analize izmerjenih podatkov odločamo o nadaljnjih korakih prilagajanja oz. optimiranja storitve in omrežja s ciljem čim boljše uporabniške izkušnje ob sočasni optimalni izrabi virov. Da bi zagotovili čim bolj relevantne rezultate, v testnih scenarijih ne smemo pozabiti na testiranja “end-to-end” in na realistično generiranje testnega prometa. Poleg izzivov in možnih pristopov k testiranju v 5G bomo v prispevku predstavili tudi nekaj konkretnih primerov iz prakse.

Abstract

Industry related use cases are among most promising for the 5G (e.g., factories of the future, logistics, power grids, etc.), however, since not two use cases have the same requirements, combining technological features to realize required service is a challenge in each single case. Due to the complexity of the 5G, testing plays a critical role since the very first stages of the network integration (e.g., lab testing) and remains during the production stage as monitoring, also serving as an input for the network optimization. It is a good idea to have ability to collect as much as possible parameters related to the service tested, as well, it is also helpful to collect data in various situations, e.g., continuous vs. on-demand testing, fixed locations testing vs. drive/flight testing. Further (AI-based) data analysis may show what data are meaningful in a certain use case. Since services created within the 5G ecosystem tend to tightly couple communications and data processing features, testing should not be limited to network parameters only, but should also include other end-to-end service parameters/KPIs relevant for the customer experience. In the article, we are, besides challenges and possible approaches, also discussing on practical experiences gained in the field.

Biografije avtorjev

Rudolf Sušnik je vodja raziskovalnih projektov v podjetju Internet Institut. Ima širok nabor izkušenj iz IT industrije, še posebej s področja operative, razvoja in

raziskav ter projektnega vodenja. Izkušnje si je pridobival z delom pri telekomunikacijskih operaterjih ter proizvajalcih komunikacijske opreme in storitev. Leta 2007 je doktoriral s področja telekomunikacij na na Fakulteti za elektrotehniko Univerze v Ljubljani, kjer je bil zaposlen kot mladi raziskovalec.

Janez Sterle je soustanovitelj in direktor podjetja INTERNET INSTITUT d.o.o. Magistriral in doktoriral je s področja telekomunikacij na Fakulteti za elektrotehniko, Univerze v Ljubljani. Njegovo glavno področje dela je načrtovanje, razvoj in upravljanje omrežij ter storitev, testiranje in in verifikacija tehnologij 4G/5G, NFV, IPv6, QoS in QoE; PPDR in NATO podprtih taktičnih komunikacijskih sistemov; preskušanje, merjenje in preverjanje najsodobnejših protokolov in tehnologij. Ima uveljavljene mednarodne izkušnje na področju raziskav in razvoja ter industrijskih projektov v različnih sektorjih (telekomunikacije, logistika, varnost in zaščita) vključno s projekti H2020 Evropske komisije na področju 5G tehnologij 5G-LOGINNOV, Int5Gent, EVOLVED-5G, 5GASP, 5G-INDUCE, 5G-IANA, MATILDA-5G in 5GINFIRE. Tesno sodeluje z industrijskimi akterji, regulatornimi in zakonodajnimi organi tako na strateški kot tehnični ravni. Ima industrijske certifikate in različne ameriške patente na področju mobilnih sistemov.

Luka Koršič je soustanovitelj in vodja razvoja v podjetju INTERNET INSTITUT d.o.o. Magistriral je s področja telekomunikacij na Fakulteti za elektrotehniko, Univerze v Ljubljani. Njegovo glavno področje dela je načrtovanje in upravljanje omrežij ter storitev; testiranje in verifikacija omrežnih tehnologij NFV/SDN, IPv4/IPv6, MPLS, QoS in QoE, brezžičnih in mobilnih 4G/5G sistemov; načrtovanje in upravljanje VPN omrežij in tehnologij. Njegove izkušnje vključujejo delo na oblačnih sistemih na osnovi OpenStack in Kubernetes, razvoj in upravljanje "cloud-native" aplikacij, delo na opremi proizvajalcev Cisco, Juniper, Extreme, Iskratel. Sodeloval je na več raziskovalnih in komercialnih projektih, med katerimi izstopa razvoj storitvene programabilne infrastrukture za potrebe kritičnih komunikacij v okviru EU projekta MATILDA (2017-2019). Na področju 5G aktivno sodeluje še pri projektih 5G-LOGINNOV, Int5Gent, EVOLVED-5G, 5GASP, 5G-INDUCE, 5G-IANA v okviru programa EC 2020.

Authors' biographies

Rudolf Sušnik *manages research and innovation-oriented projects at Internet Institute. He has a wide range of experiences from IT industry, especially in operations, R&D, and project management. He has been working for network operators and for global technology providers. As well, he has research and teaching experiences from the University of Ljubljana, where he has gained his Ph.D. degree in telecommunications in 2007.*

Janez Sterle *is a co-founder and CEO of INTERNET INSTITUTE Ltd. He received his M.Sc. and Ph.D. degrees in telecommunications from the University of Ljubljana, Slovenia. His main area of work concerns network design, planning, service management, testing and implementation in production networks for 4G/5G, NFV, IPv6, QoS and QoE, PPDR and NATO enabled tactical communication system; testing, measurement and verification of state-of-the-art protocols and technologies. He has an established track record of R&D and production-grade projects in communications, safety and security sectors, including EC's H2020 projects 5G-LOGINNOV, Int5Gent, EVOLVED-5G, 5GASP, 5G-INDUCE, 5G-IANA, MATILDA-5G and 5GINFIRE on the topic of 5G, and cooperates closely with the respective industries, practitioners, regulatory and legislative bodies on strategic and technical levels. He holds industrial certification and various US patents in the field of mobile systems.*

Luka Korsic *is a co-founder and head of Research and Development at Internet Institute. He received his M.Sc. degree in telecommunications from the University of Ljubljana, Slovenia. His main area of work includes network design and planning, service operation and management, testing and implementation of network technologies such as NFV/SDN, IPv4/IPv6, MPLS, QoS and QoE, wireless/mobile 4G/5G systems; VPN planning and management; testing, measurement and verification of network/service protocols and technologies. Throughout his work he has gained a lot of practical experience in the field (cloud-based solutions such as OpenStack and Kubernetes, cloud-native applications development and operations, neworking equipment such as Cisco, Juniper, Extreme, Iskratel etc.) and also worked as a technical lead on many research/commercial projects. His previous projects and experience include development of a service-driven sliced programmable 5G infrastructure for emergency response purposes in MATILDA EU project (2017 – 2019) while he is also actively involved in several EC2020 5G-related ongoing projects, namely 5G-LOGINNOV, Int5Gent, EVOLVED-5G, 5GASP, 5G-INDUCE, 5G-IANA.*



Testing and optimizing 5G for industrial verticals

Rudolf Sušnik, Janez Sterle, Luka Koršič
February 2, 2022

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Agenda

- Introduction
- The need for testing and optimizing 5G networks and services
- Methodology and analytics
- Tools
- Use cases
- Conclusions



About

qMON www.qmon.eu
Telco grade system to deliver the next generation of quality assurance in mobile and cloud environments



rMON
Automation of remote IoT measurements for industrial and outdoor environments



PPDRONE
Cloud-based private 4G/5G for Industrial and outdoor environments



- Company facts
  - Startup established in 2014
  - Located in Ljubljana, Slovenia
  - 100% IPR ownership
  - First employees Q4 2017
  - Trusted R&I partner in EU H2020
- Core Expertise: development, deployment and operation of telco grade Quality Assurance (QA) and Critical Communications Systems (CCS)
- Main technologies verticals
  - QA | Quality assurance of mobile, fixed and cloud systems | ***www.qmon.eu***
  - CCS | Solutions for 5G/IoT-based critical communications | ***5gsafety.net***

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How we started with 5G | R&I

5G PPP The 5G Infrastructure Public Private Partnership

MATILDA matilda-5g.eu

5GLOGINNOV 5g-loginnov.eu

5GASP 5gasp.eu

5G INDUCE 5g-induce.eu

5GINFIRE 5ginfire.eu

Int5Gent int5gent.eu

evolved 5G evolved-5g.eu

5G IANA 5g-iana.eu

2017 PPDR

2018 PPDR

2020 PPDR | Ports | Smart Factories |

2021 Industry 4.0 | Automotive

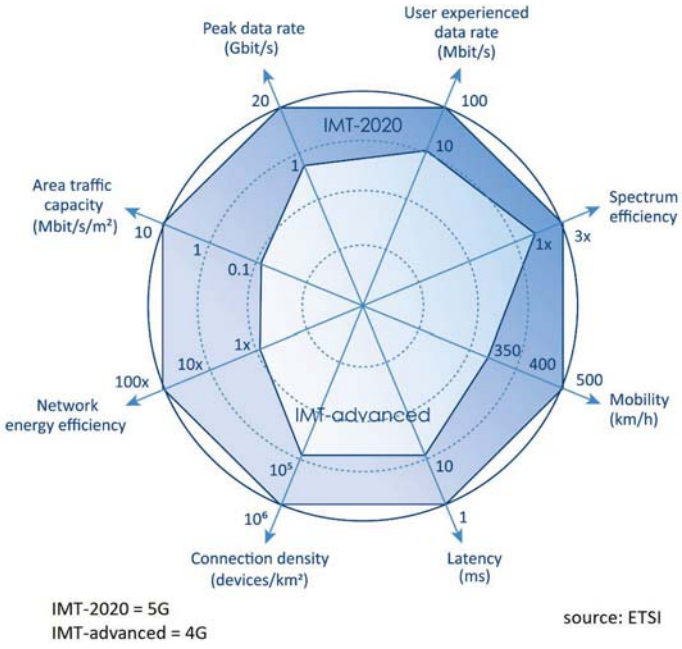
- 5G qMON – Network Test Automation
- Operational Private 5G (SA mode)
- Cloud RAN | n78

This projects received funding from the European Union's Horizon 2020 research and innovation programme grant agreements No. 761898, 732497, 957400, 957403, 101016448, 101016608, 101016941 and 101016427.

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Introduction – role of 5G

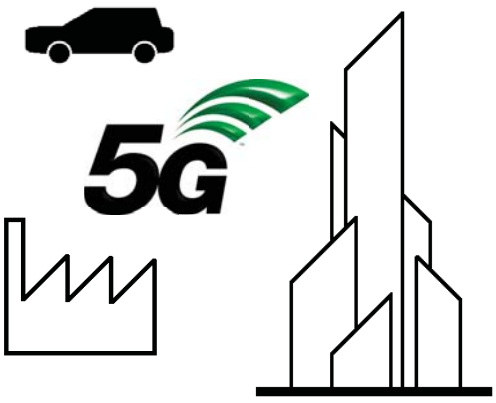
- 5G opportunities
  - Industry (e.g., Industry 4.0, IoT)
    - private 5G networks
  - Consumer market (e.g., mobile gaming, fixed wireless access, new immersive user experience)
- 5G technology benefits
  - eMBB: > 10 Gbps
  - uRLLC: 99,99 % reliability, below 1 ms latency
  - mMTC: 1 million (IoT) devices per km^2
  - MEC: Mobile Edge Computing
  - NFV: Network Function Virtualization
  - MANO: Management and Orchestration



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Introduction – emergence of new services and apps

- 5G technology as an enabler
- 5G technology as an improvement comparing to other comm. technologies
- Some verticals with interest for 5G
  - Automotive (e.g., connected autonomous mobility and driving)
  - Public Protection and Disaster Relief (PPDR)
  - Smart cities
  - Industrial
    - improving safety of the personnel involved in industrial processes
    - improving robots' effectiveness
    - optimizing logistics processes and traffic flows
    - introducing mixed-reality assisted manufacturing, maintenance, etc.



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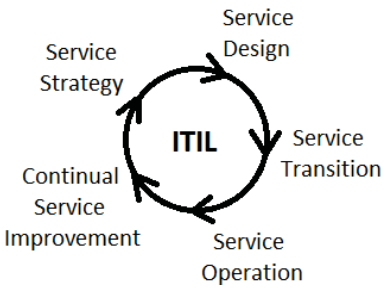
Introduction – testing and optimizing

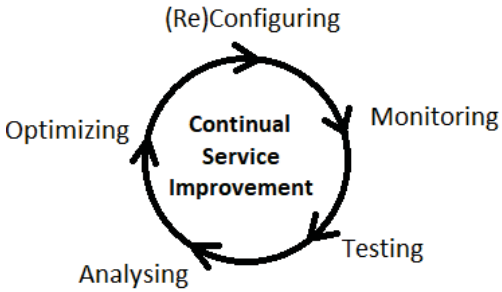


- Challenges testing and optimizing may help solve
  - 5G applications and services usually require very strict network conditions
  - The network should be available providing reliable service at any time
  - Balanced/optimal use of resources
- Based on the testing results, further steps are planned
  - Analyzing test results
  - Planning network and/or service optimization (re-configuration, topology, architecture, etc.)
- SLA (Service Level Agreement)
  - What it counts from the customer's point of view

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The need for testing and optimizing networks 1/4





- Testing plays crucial role since the very first stages of network integration
  - Lab testing
  - Deployment to the production
  - Production phase (Day-2 operation)

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The need for testing and optimizing networks 2/4

- Proactive testing and monitoring
  - Running live services (e.g., data download & upload) and observing effects in real time
  - Addressing relevant KPIs
- Proactive testing and monitoring as a first step in providing reliable network
  - Add testing and monitoring results to enrich data especially in production phase
  - Building a complete real-time picture of the network conditions
  - Detecting anomalies (ideally before customers do)
- Answers provided by proactive testing/monitoring
  - What are the performances the device/network is currently able to achieve
  - What is the effect to other devices in the network and to the network itself

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The need for testing and optimizing networks 3/4

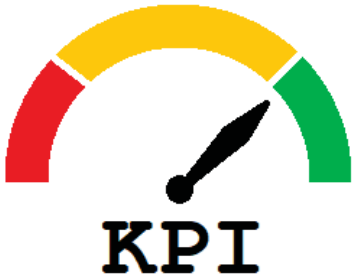
- Addressing complexity of 5G networks
  - Running tests within the network
    - Distributed network architecture
    - Physically distributed network components
- Optimizing network
  - Self-healing
  - Manual intervention
  - Optimizing network architecture and topology



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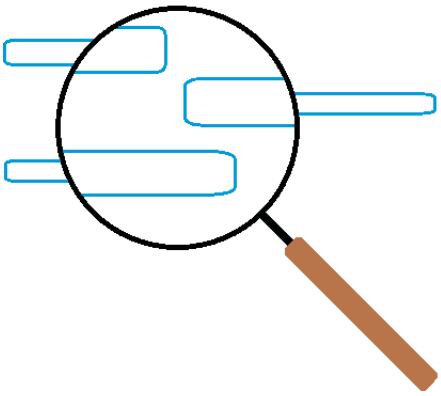
The need for testing and optimizing networks 4/4

- Some common KPIs for 5G services
  - Service availability
  - Service reliability
  - Bandwidth
  - End-to-end latency
  - Response time
  - Error rate
  - QoS and QoE
  - Positioning quality (in case 5G is used for localization services)
- Some KPIs for 5G network
  - Service onboarding and deployment time
  - Time to scale service/component
  - Reconfiguration time
  - Area traffic capacity
  - Connection density



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Methodology – key objectives

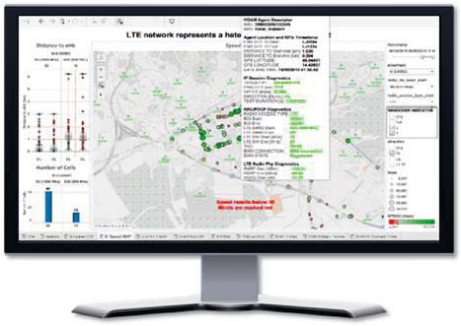


- Get relevant data
- Get data from most/all occasions customer can run into
  - Location
  - Moving speed
- Use of customer-like devices while testing customers point of view
- Be efficient
- Build a complete picture of the network/service status
  - Combine data from various sources (tests, monitoring, system data)
  - Use AI methods where appropriate

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Methodology – test types

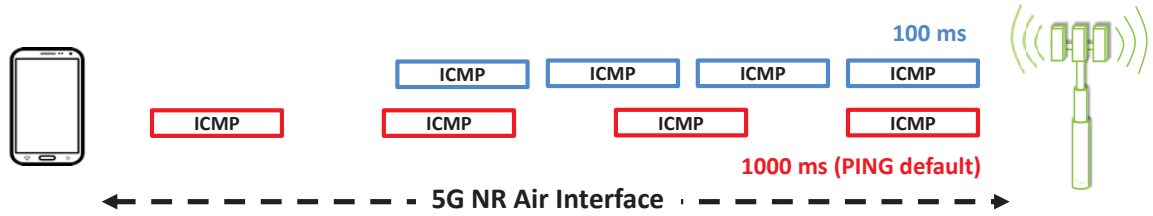
- Continuous testing/monitoring
  - Regularly running tests on pre-defined locations
  - Testing schedule
- On-demand testing
  - Testing on special purpose, e.g.,
    - Double-checking anomaly detected during the continuous testing
  - May include testing on unusual locations
    - Use of special equipment, e.g., drones
- Drive tests
  - Testing on a larger geographical area

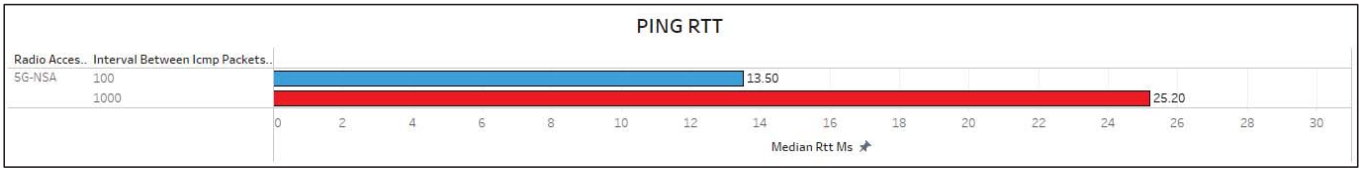


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Methodology – why does it matter?

- RTT Example – interval between sent test packets can affect observed RTT

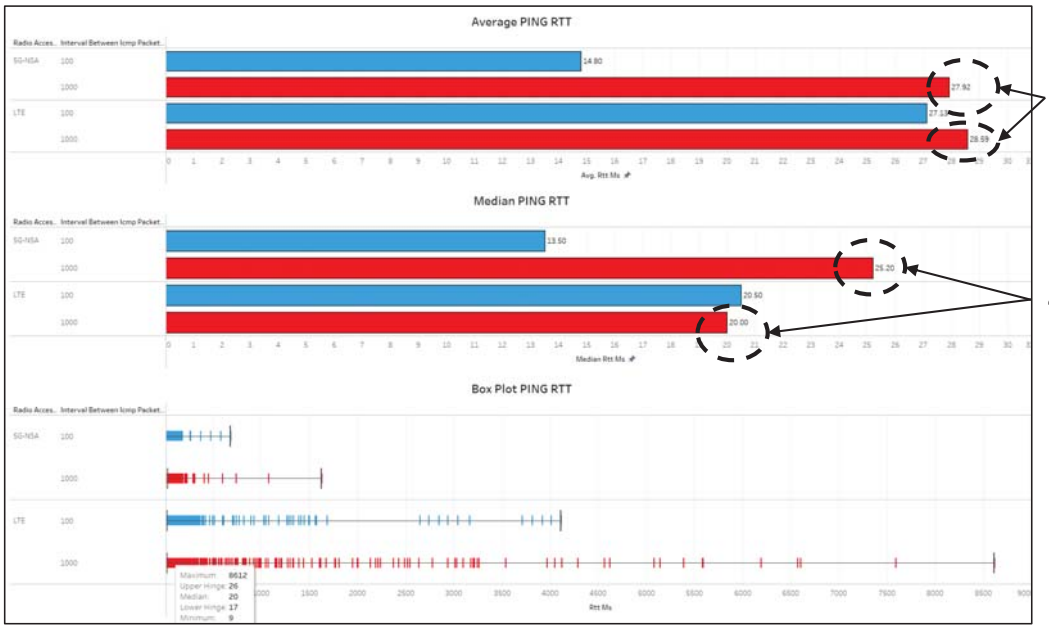




Results captured at commercial 5G mobile operator in Slovenia. More than 20K samples were taken in the duration of one month.

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Analytics – why does it matter?



Results presented as Average RTT:
5G is better than 4G. Looks OK!

Results presented as Median RTT:
4G is better than 5G? Misconfigured 5G NSA on the eNb/gNb?

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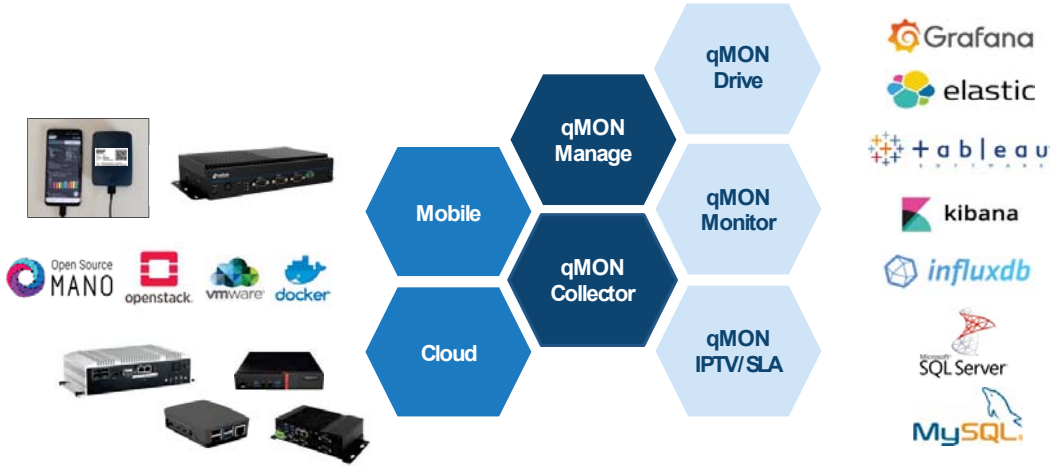
Tools

- Several commercial test tools exists on the market today
- Key requirements
  - Distributed architecture (e.g., autonomous agents/probes)
  - End-to-end test, realistic load generation, zero-loss data
  - 5G and Cloud architecture (VNF, MANO)
  - Analytics, reporting and visualization capabilities
  - Mobile network testing (e.g., RSSI, RSRP, RSRQ, SINR, Carrier Aggregation, Cell ID, etc.)
  - Network and service testing (e.g., DNS, ping, FTP, web browsing, multicast, Voice, etc.)
  - Supporting several technologies (e.g., 5G SA/NSA, LTE, HSPA, GPRS, EDGE, FE, GE, 10GE)
  - Over-the-Air (OTA) updates
  - Industrial and outdoor environment conditions support (temp. range -40°C to +60°C; IP67)

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Tools – our approach

- We have developed our own testing tool – qMON
  - System based on a modular architecture



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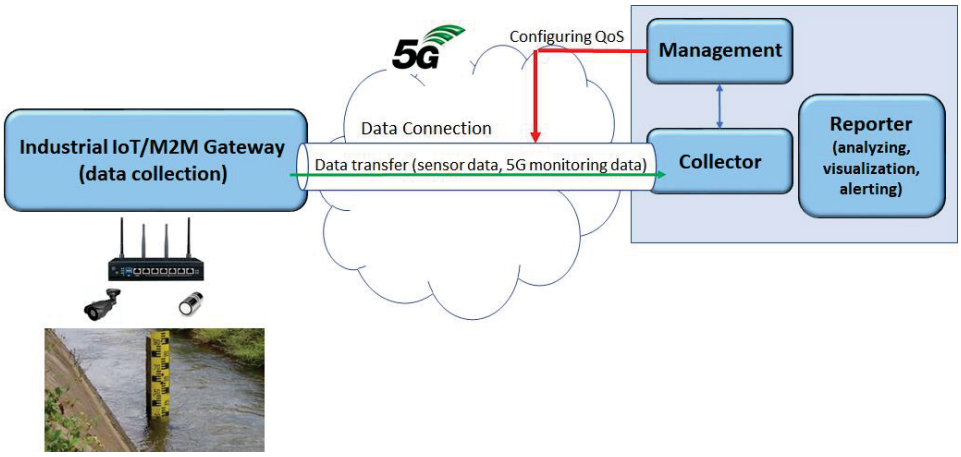
Tools – qMON

- qMON at a glance
  - Unified mobile, fixed and cloud (FMC) system operations
  - 5G and Cloud/VNF ready (MANO)
  - Distributed autonomous agents and system operation with zero data loss
  - Feature-rich and multi-layer with support of 100+ KPIs
  - True end-to-end automated measurements and realistic load generation
  - GIS and operator-based KPI data enrichment
- Supported use cases
  - End-to-end QoS and QoE monitoring of network and services in live environments
  - Continuous service and SLS/SLA monitoring in real-time
  - Drive and benchmark testing
  - Coverage and performance assessment
  - Live network and service troubleshooting
  - Network and services trending
  - Device and system performance predictions under realistic load conditions

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Use cases – EVOLVED-5G

- Industrial-grade 5G connectivity for the Factory of the Future IoT devices
  - IoT data collection via QoS guaranteed 5G connection



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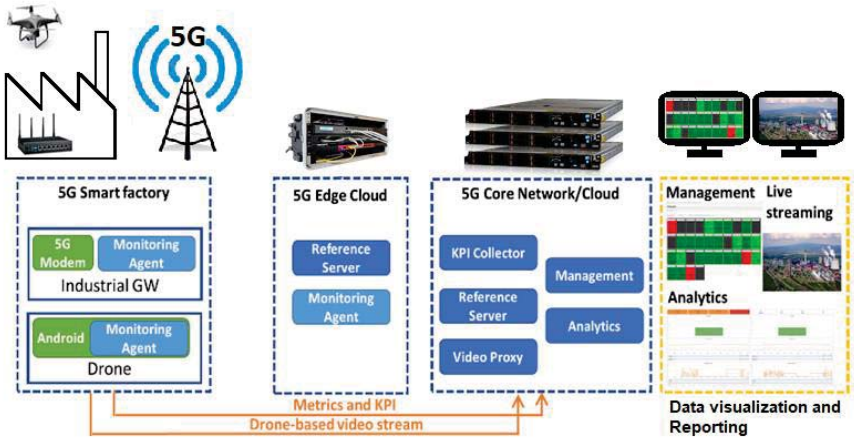
Use cases – EVOLVED-5G

- The use case scenario
  - IoT GW installed in the field/factory with non-5G enabled sensors connected to it
  - IoT GW provides 5G connectivity for data delivery to the database/collector
  - The requirement is to provide industrial grade 5G connectivity with assured QoS as defined by the SLA
- The solution
  - monitoring capabilities integrated on both sides to regularly run end-to-end tests
    - IoT GW: agent
    - Core network: collector, manager, reporter
  - Analyzing & optimizing
    - Network slice re-configuration in case of SLA not passing detected

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Use cases – 5G-INDUCE

- 5G Network performance and radio coverage monitoring for Industry 4.0, enhanced by drone



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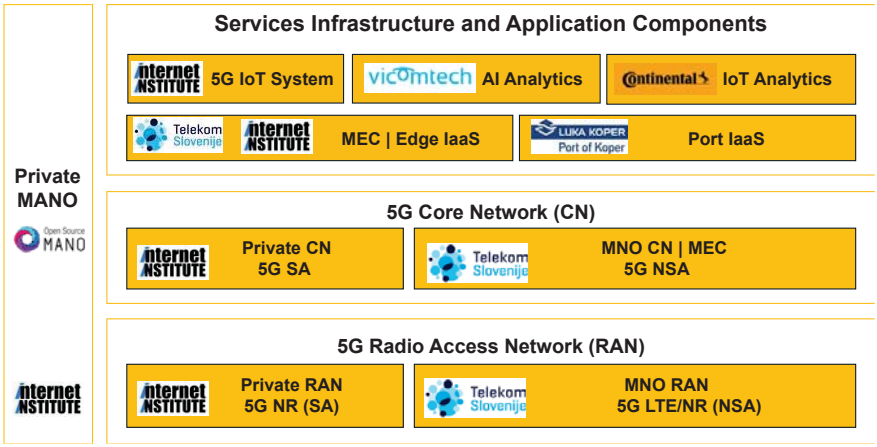
Use cases – 5G-INDUCE

- Monitoring 5G network performance and radio coverage
  - Smart-factory plant
  - Assuring high availability of critical communications needed for the main process to run (e.g., automated fork-lift operations)
  - Assuring high availability of services needed for the main process to run (e.g., video-based remote-control operation)
  - Drone assistance to provide height-related performance & coverage data
- Supporting automatic optimization of 5G network quality of service (QoS)
  - Utilizing collected monitoring data
- Optimizing 5G network coverage
  - Obstacles and/or interference sources in industrial environments,
  - Providing regular and/or on-demand drone-assisted measurements with detailed analytics

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Use cases – 5G-LOGINNOV

- 5G for logistics and security processes in a sea-port
  - Exploitation of applications and services based on 5G-assured Industry 4.0 scenarios

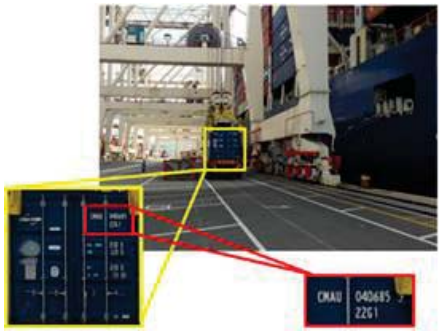


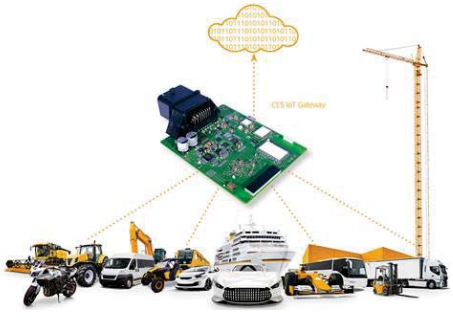
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Use cases – 5G-LOGINNOV

- Maintaining 5G network to provide various services and applications
  - Automation control of the container management (AI analytics)
  - Remote automation (IoT analytics)
  - Mission-critical port security services (video surveillance, CCTV applications)







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Use cases – 5G-LOGINNOV

- Providing continuous, on-demand and drive tests for several network and service KPIs
  - Service onboarding and deployment time, time to scale service/component, reconfiguration time, area traffic capacity, connection density
  - Service availability, service reliability, bandwidth, end-to-end latency



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Conclusions

- Providing reliable and high-quality communications
  - Knowing the network/service condition at any time
  - Maintaining SLA
    - Predict troubles before customers do
    - 5G is designed to support industrial and critical services, but this means responsibility as well
- Testing
  - Plays crucial role since the very first stages of network integration until production phase
  - A first step into providing reliable network and services
- Optimizing
  - Enabling continual improvements of network/service based on test results analysis

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Meritev smernosti anten

Antenna directivity measurements

Matjaž Vidmar

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Katedra za informacijsko komunikacijske tehnologije, Laboratorij za sevanje in optiko

matjaz.vidmar@fe.uni-lj.si

Povzetek

V prispevku so zajete naslednje teme: sevanje usmerjenega izvora, izračun smernosti poljubne antene, meritev rezov smernega diagrama, smernost iz dveh rezov, eliptična odprtina (skupina), postopek izračuna skupne smernosti, 33-elementna cigara za 2400 MHz, HB9CV za 435 MHz, sektorska skupina za 3400 MHz, meritev sektorske skupine, antena WiFi AliExpress in nizkofrekvenčni spekter detektorja.

Abstract

The following topics are covered in the paper: radiation of directional source, calculation of any antenna directivity, measurement of antenna radiation pattern, directivity from two planes, Elliptical aperture (group), procedure of total directivity calculation, 33-element cigar antenna for 2400 MHz, HB9CV antenna for 435 MHz, sector group antenna for 3400 MHz, sector group antenna measurements, WiFi AliExpress antenna and low frequency detector spectrum.

Biografija avtorja

Matjaž Vidmar je doktoriral leta 1992 z naslovom teme »Metoda korekcije ionosferskih pogreškov pri satelitski navigaciji in prenosu časa«. V ZDA je razvijal satelitske oddajnike za organizacijo AMSAT. V sklopu sodelovanja z AMSAT-om je sodeloval pri razvoju komunikacijske in navigacijske opreme za satelit "AMSAT-Phase-3D", ki je bil uspešno izstreljen v novembru 2000. Profesor Vidmar trenutno poučuje dodiplomske in podiplomske predmete s področja telekomunikacij na Fakulteti za elektrotehniko. Njegovo področje dela je mikrovalovna elektronika, ki obsega področja od letalske industrije do optičnih komunikacij.

Author's biography

Matjaž Vidmar *received his PhD in 1992 from the University of Ljubljana, for developing a single frequency GPS ionospheric correction receiver. Mr. Vidmar is currently teaching undergraduate and postgraduate courses in Electrical Engineering at the University of Ljubljana, where he serves as head of the Radiation and Optics Laboratory (LSO) at the department for Electrical Engineering (FE). His current research interests include microwave and high speed electronics ranging from avionics to optical-fiber communications. Under his leadership, the LSO developed most of the 10Gbps electronics (pulse modulator, clock recovery) used in the Ester (ACTS 063) project and many 40Gbps circuits used in the ATLAS (IST 10626) project: EAM drivers, transmitter clock distribution, 40Gbps and 80Gbps clock-recovery circuits and 40Gbps PMD compensation receiver electronics. Mr. Vidmar also developed and built satellite hardware flown in space in 1990 on the Microsat mission and in 2000 on the AMSAT-P3D satellite.).*

25. Seminar Radijske Komunikacije

Meritev smernosti anten

Matjaž Vidmar

LSO, FE, Ljubljana, 2−4.2.2022

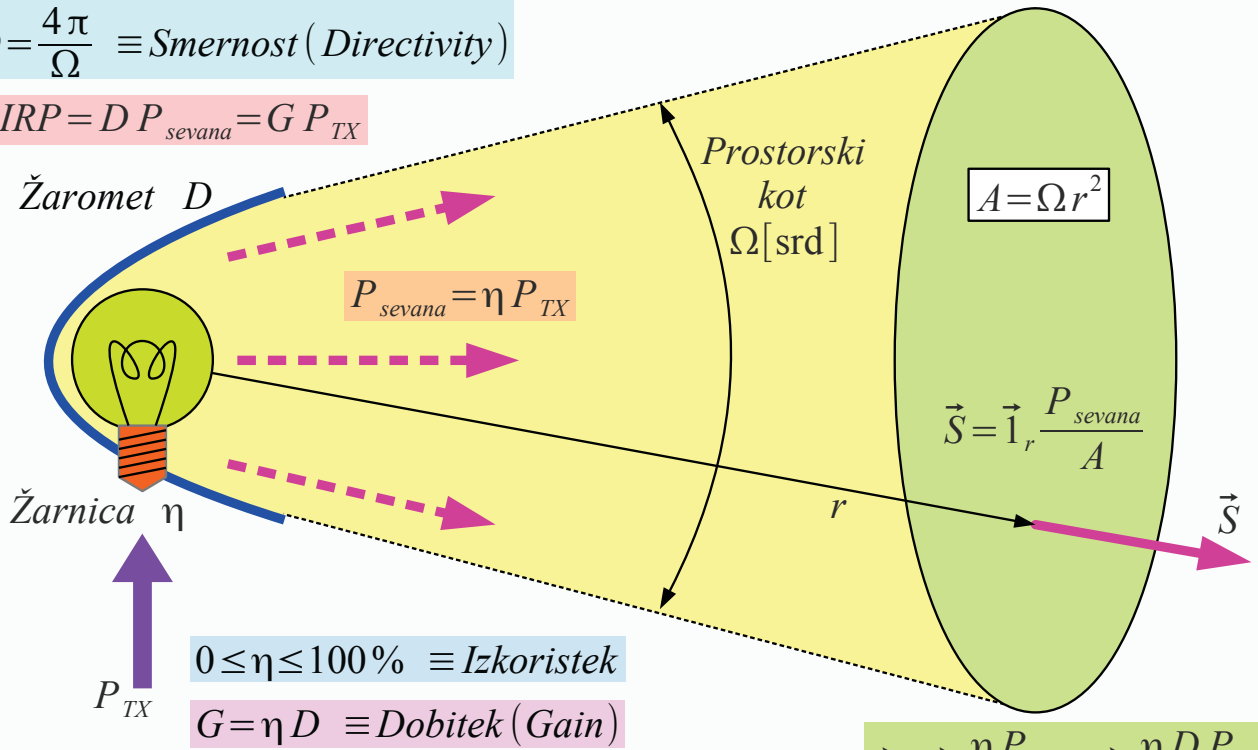
Seznam slik

Slika 1 − Sevanje usmerjenega izvora
Slika 2 − Izračun smernosti poljubne antene
Slika 3 − Izbira krogelnih koordinat
Slika 4 − Meritev rezov smernega diagrama
Slika 5 − Smernost iz dveh rezov
Slika 6 − Eliptična odprtina (skupina)
Slika 7 − Ravnina XZ
Slika 8 − Ravnina YZ
Slika 9 − Postopek izračuna skupne smernosti
Slika 10 − Razlika povprečenj smernosti
Slika 11 − Razlika iz delnih smernosti
Slika 12 − 33el. cigara za 2400MHz
Slika 13 − HB9CV za 435MHz
Slika 14 − Sektorska skupina za 3400MHz
Slika 15 − Meritev sektorske skupine
Slika 16 − Antena WiFi AliExpress
Slika 17 − Nizkofrekvenčni spekter detektorja

****

$D=\frac{4\pi}{\Omega} \equiv Smernost\,(Directivity)$

$EIRP = D\,P_{sevana} = G\,P_{TX}$



$0 \le \eta \le 100\,\% \equiv Izkoristek$

$G = \eta\,D \equiv Dobitek\,(Gain)$

$\vec{S} = \vec{1}_r \frac{\eta P_{TX}}{\Omega r^2} = \vec{1}_r \frac{\eta D P_{TX}}{4\pi r^2} = \vec{1}_r \frac{G P_{TX}}{4\pi r^2}$

Slika 1 − Sevanje usmerjenega izvora

$\vec{S}(r,\Theta,\Phi) \equiv Gostota\ pretoka\ sevane\ moči\,[\mathrm{W/m^2}]$

$|F(\Theta,\Phi)| \equiv Amplitudni\ smerni\ diagram\ antene$

$r \equiv Oddaljenost\ od\ antene$

$\Theta \equiv Polarna\ razdalja$

$\Phi \equiv Zemljepisna\ dolžina$

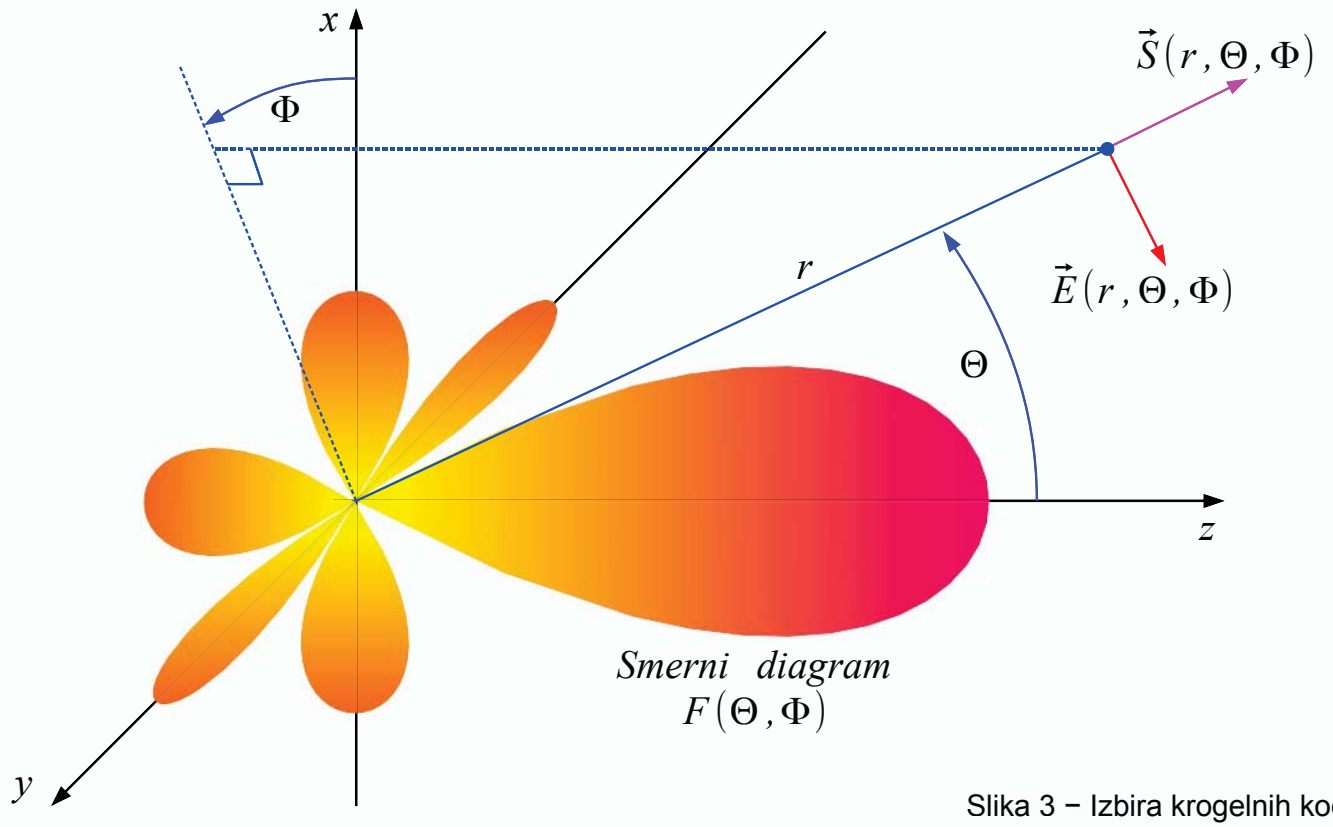
$$D = \frac{|\vec{S}(r=R,\Theta_{MAX},\Phi_{MAX})|}{\langle|\vec{S}(r=R,\Theta,\Phi)|\rangle} = \frac{|F(\Theta_{MAX},\Phi_{MAX})|^2}{\langle|F(\Theta,\Phi)|^2\rangle} =$$

$$= \frac{4\pi|F(\Theta_{MAX},\Phi_{MAX})|^2}{\oiint_{4\pi}|F(\Theta,\Phi)|^2\,d\Omega} = \frac{4\pi|F(\Theta_{MAX},\Phi_{MAX})|^2}{\int_0^{\pi}\int_0^{2\pi}|F(\Theta,\Phi)|^2\sin\Theta\,d\Theta\,d\Phi}$$

$|F(\Theta,\Phi)| \equiv Funkcija\ dveh\ spremenljivk\ !$

$D_{\mathrm{dBi}} = 10\log_{10} D \equiv Smernost\ v\ logaritemskih\ enotah\,[\mathrm{dBi}]$

Slika 2 − Izračun smernosti poljubne antene



Slika 3 − Izbira krogelnih koordinat

$$\oiint_{4\pi} |F(\Theta,\Phi)|^2 \, d\Omega \approx \frac{2\pi}{N} \sum_{j=1}^{N} \int_{0}^{\pi} |F(\Theta,\Phi_j)|^2 \sin\Theta \, d\Theta \quad \equiv \textit{Meritev N rezov } \Phi_1, \Phi_2, \Phi_3 \ldots \Phi_N$$

$$\oiint_{4\pi} |F(\Theta,\Phi)|^2 \, d\Omega \approx \frac{\pi}{N} \sum_{j=1}^{N} \int_{-\pi}^{\pi} |F(\Theta,\Phi_j)|^2 \sin|\Theta| \, d\Theta \quad \equiv \textit{Meritev N rezov preko tečaja}$$

$$D_j = \frac{4\left|F(\Theta_{MAX}=0, \Phi_{MAX}=\Phi_j)\right|^2}{\int_{-\pi}^{\pi} |F(\Theta,\Phi_j)|^2 \sin|\Theta| \, d\Theta} \quad \equiv \textit{Delna smernost reza pri zemljepisni dolžini } \Phi_j$$

$$D \approx \frac{N}{\frac{1}{D_1}+\frac{1}{D_2}+\frac{1}{D_3}+\ldots+\frac{1}{D_N}} = \frac{N}{\sum_{j=1}^{N} \frac{1}{D_j}} = \frac{1}{\langle 1/D_j \rangle} \quad \equiv \textit{Skupna smernost iz delnih smernosti}$$

Slika 4 − Meritev rezov smernega diagrama

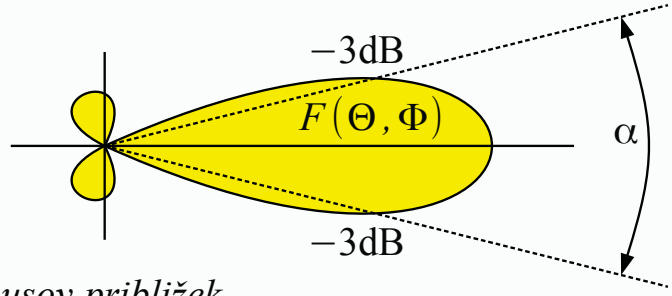
$D_E \equiv$ *Delna smernost v ravnini E*

$D_H \equiv$ *Delna smernost v ravnini H*

Samo dva reza premalo ?

$$D = \frac{2}{\frac{1}{D_E} + \frac{1}{D_H}} \equiv \text{Smernost iz dveh rezov}$$

Premajhna za pahljačast snop !



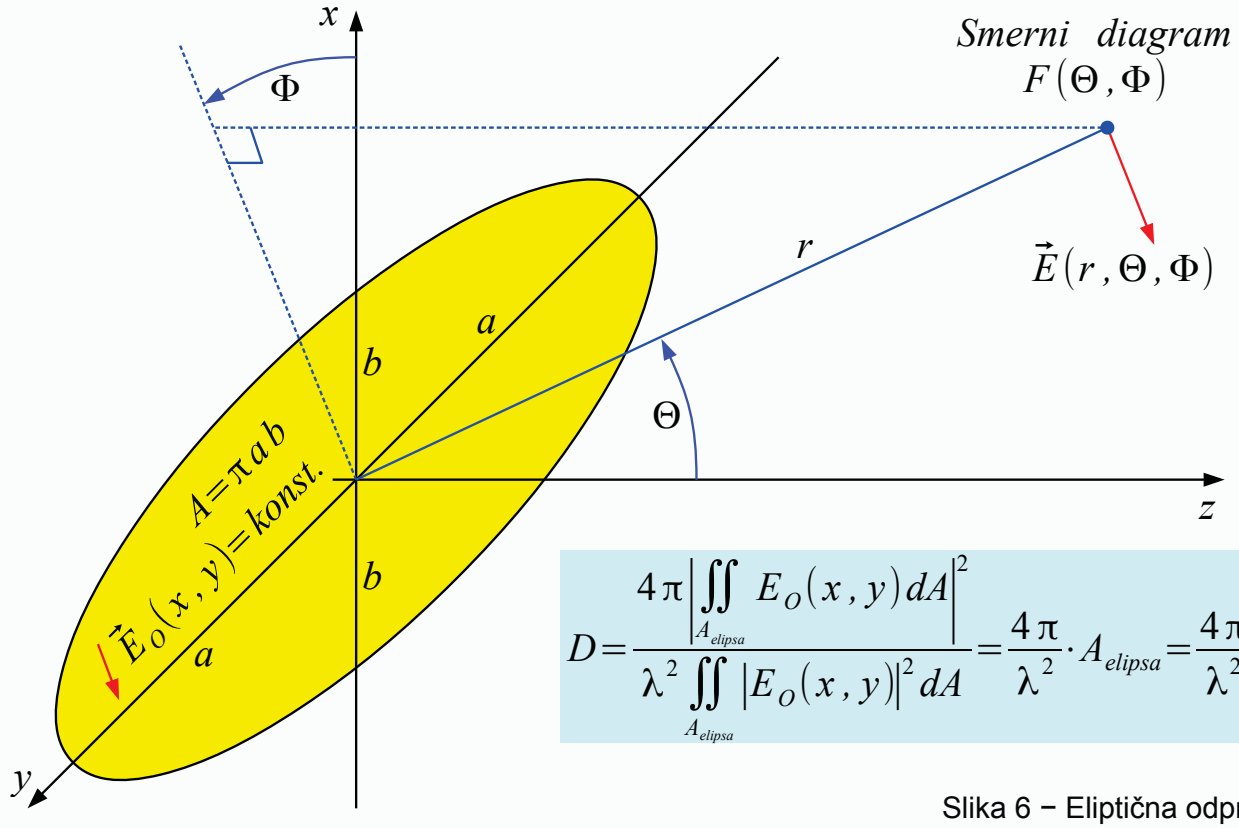
$\alpha_E \equiv -3\text{dB}$ *širina snopa v ravnini E*

$\alpha_H \equiv -3\text{dB}$ *širina snopa v ravnini H*

$$D = \frac{4\pi}{\Omega} \approx \frac{4\pi}{\alpha_E[\text{rd}]\alpha_H[\text{rd}]} \approx \frac{41253\,(^\circ)^2}{\alpha_E[^\circ]\alpha_H[^\circ]} \equiv \text{Krausov približek}$$

Prevelik zaradi stranskih snopov

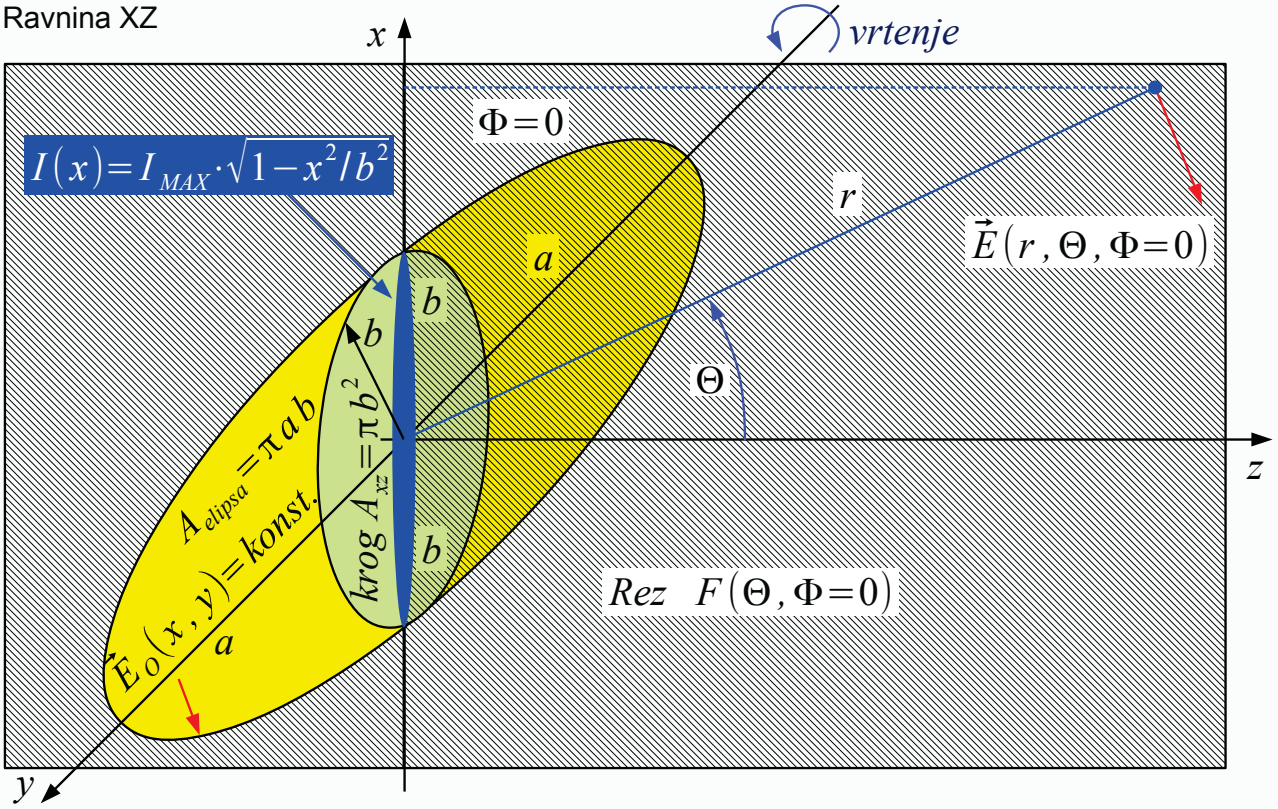
Slika 5 − Smernost iz dveh rezov



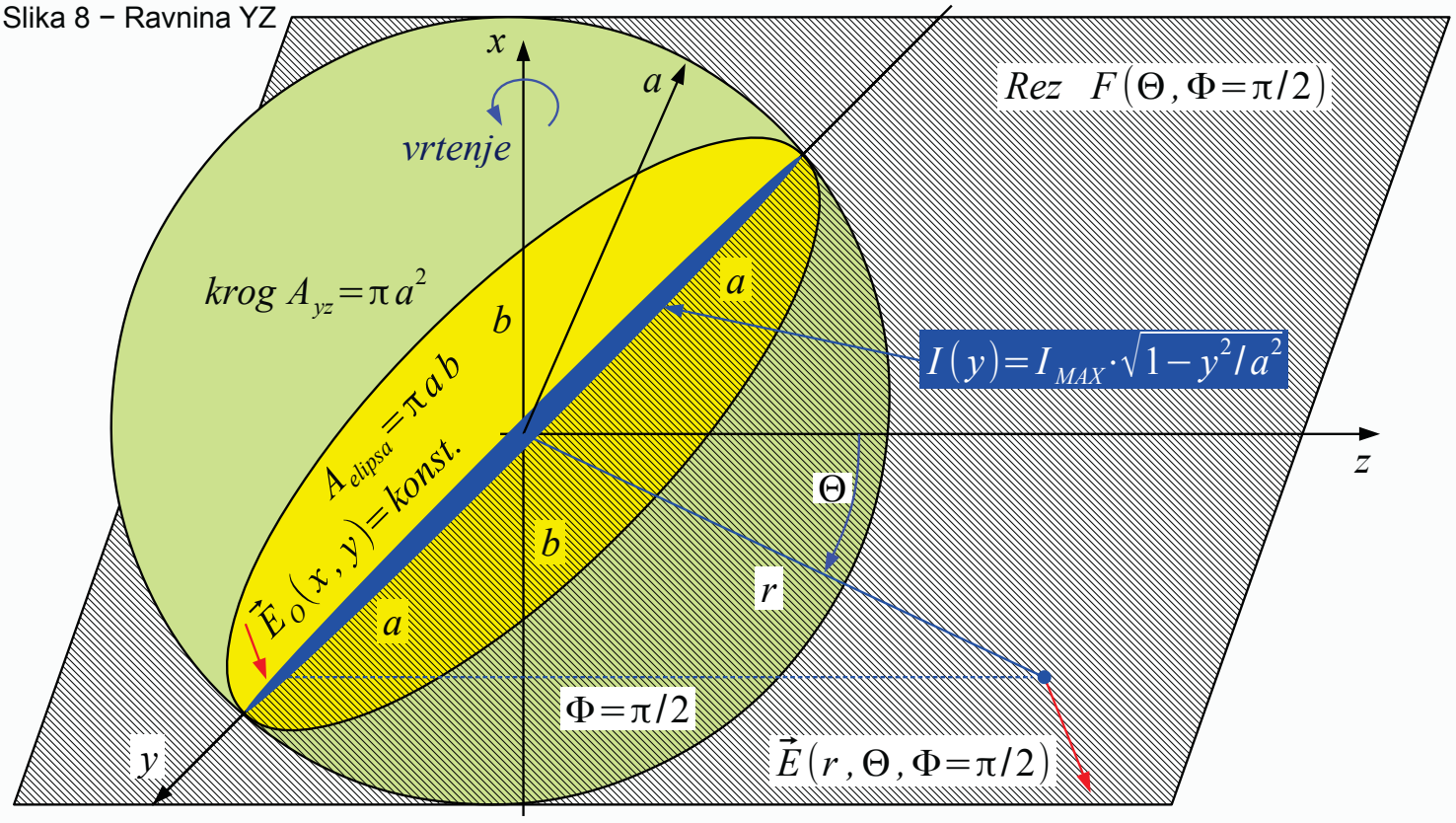
$$D = \frac{4\pi \left| \iint_{A_{elipsa}} E_O(x,y)\,dA \right|^2}{\lambda^2 \iint_{A_{elipsa}} |E_O(x,y)|^2\,dA} = \frac{4\pi}{\lambda^2} \cdot A_{elipsa} = \frac{4\pi}{\lambda^2} \cdot \pi\, a\, b$$

Slika 6 − Eliptična odprtina (skupina)

Slika 7 − Ravnina XZ



Slika 8 − Ravnina YZ



$$F(\Theta,\Phi=0)=\frac{2J_1\left(\frac{\pi b}{2\lambda}\sin\Theta\right)}{\frac{\pi b}{2\lambda}\sin\Theta}\cdot\frac{1+\cos\Theta}{2}\;\rightarrow\;D_{xz}=\frac{4\pi\left|\iint\limits_{A_{xz}}E_O(x,y)\,dA\right|^2}{\lambda^2\iint\limits_{A_{xz}}\left|E_O(x,y)\right|^2dA}=\frac{4\pi}{\lambda^2}\cdot A_{xz}=\frac{4\pi}{\lambda^2}\cdot\pi b^2$$

$$F\left(\Theta,\Phi=\frac{\pi}{2}\right)=\frac{2J_1\left(\frac{\pi a}{2\lambda}\sin\Theta\right)}{\frac{\pi a}{2\lambda}\sin\Theta}\cdot\frac{1+\cos\Theta}{2}\;\rightarrow\;D_{yz}=\frac{4\pi\left|\iint\limits_{A_{yz}}E_O(x,y)\,dA\right|^2}{\lambda^2\iint\limits_{A_{yz}}\left|E_O(x,y)\right|^2dA}=\frac{4\pi}{\lambda^2}\cdot A_{yz}=\frac{4\pi}{\lambda^2}\cdot\pi a^2$$

$$D=\frac{4\pi}{\lambda^2}\cdot\pi a b=\sqrt{\left(\frac{4\pi}{\lambda^2}\cdot\pi b^2\right)\cdot\left(\frac{4\pi}{\lambda^2}\cdot\pi a^2\right)}=\sqrt{D_{xz}\cdot D_{yz}}\;\equiv\textit{Geometrijska sredina delnih smernosti !}$$

$$\log D=\frac{1}{2}\left[\log D_{xz}+\log D_{yz}\right]=\langle\log D_j\rangle\;\equiv\textit{Povprečje logaritmov delnih smernosti !}$$

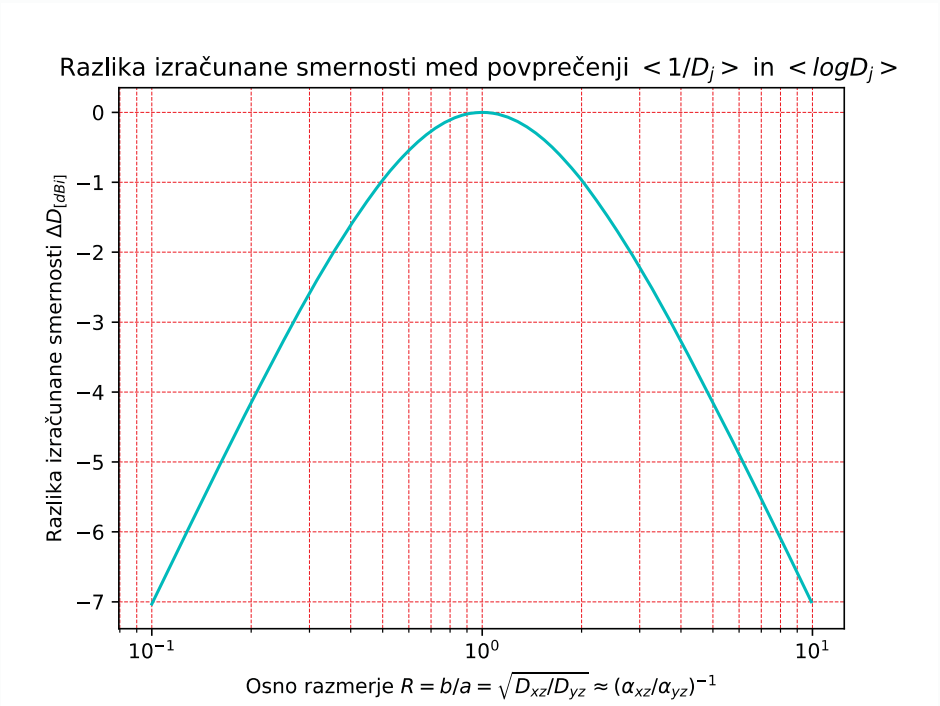
Slika 9 − Postopek izračuna skupne smernosti

$$\Delta D_{[\mathrm{dBi}]}=10\log_{10}\frac{\frac{2}{\frac{1}{D_{xz}}+\frac{1}{D_{yz}}}}{\sqrt{D_{xz}\cdot D_{yz}}}=$$

$$=10\log_{10}\frac{\frac{2}{\frac{D_{yz}}{D_{xz}}+1}}{\sqrt{\frac{D_{xz}}{D_{yz}}}}=$$

$$=10\log_{10}\frac{2R}{1+R^2}\le 0$$

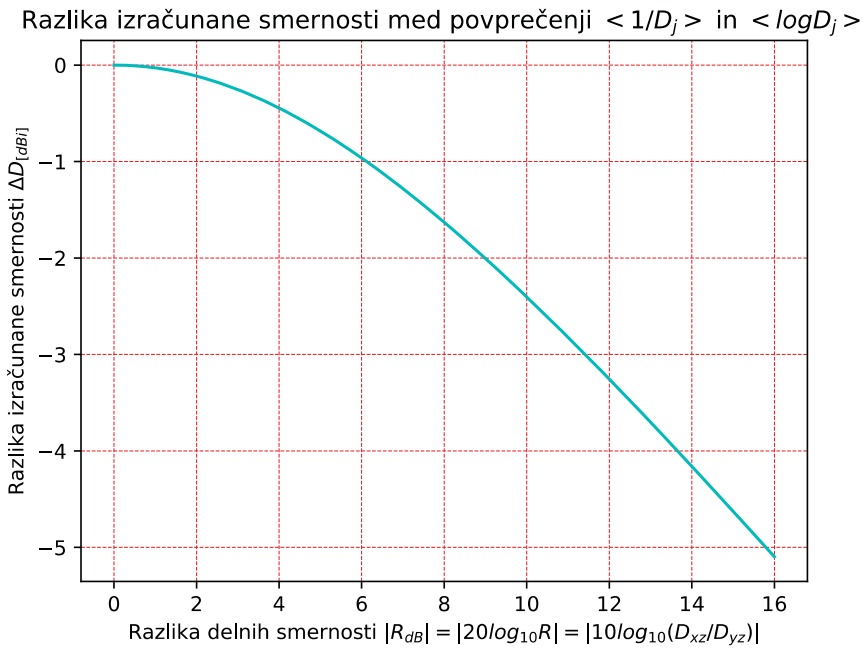
$$R=\frac{b}{a}=\sqrt{\frac{D_{xz}}{D_{yz}}}\approx\left(\frac{\alpha_{xz}}{\alpha_{yz}}\right)^{-1}\equiv\textit{Osno razmerje}$$



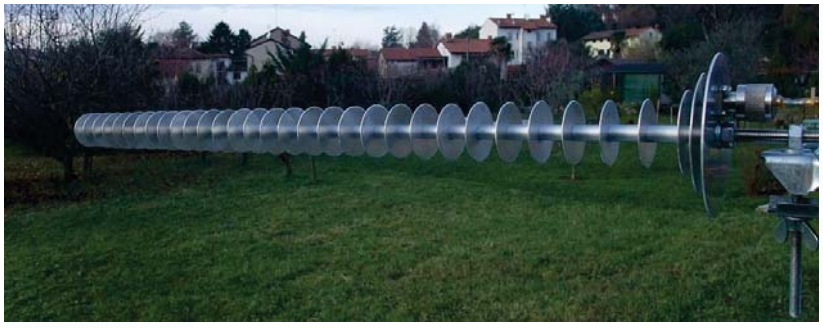
Slika 10 − Razlika povprečenj smernosti

$$R_{\mathrm{dB}} = 20\log_{10}\left(\frac{b}{a}\right) = 10\log_{10}\left(\frac{D_{xz}}{D_{yz}}\right) \approx -20\log_{10}\left(\frac{\alpha_{xz}}{\alpha_{yz}}\right) \equiv \textit{Razlika delnih smernosti}\,[\mathrm{dB}]$$

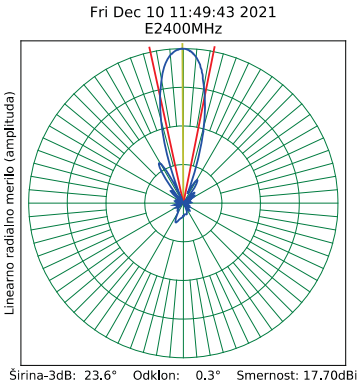
$$\Delta D_{[\mathrm{dBi}]} = 10\log_{10}\frac{2\cdot 10^{R_{\mathrm{dB}}/20}}{1+10^{R_{\mathrm{dB}}/10}}$$

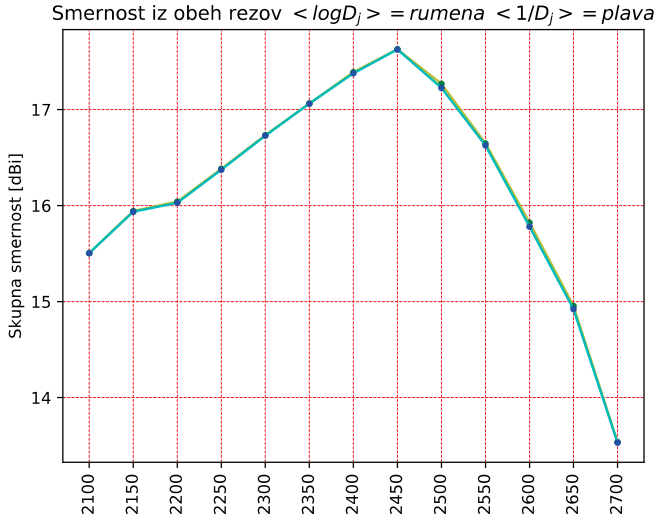


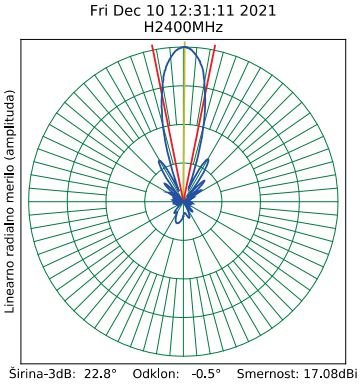
Slika 11 − Razlika iz delnih smernosti



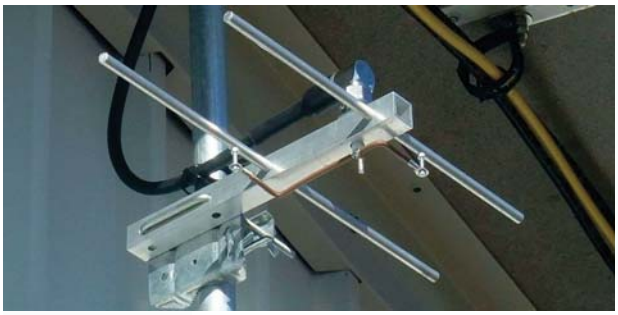
Kraus
$D \approx 18.85\mathrm{dBi}$



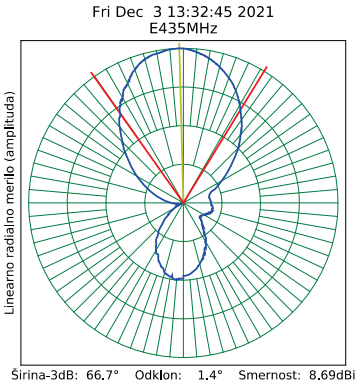


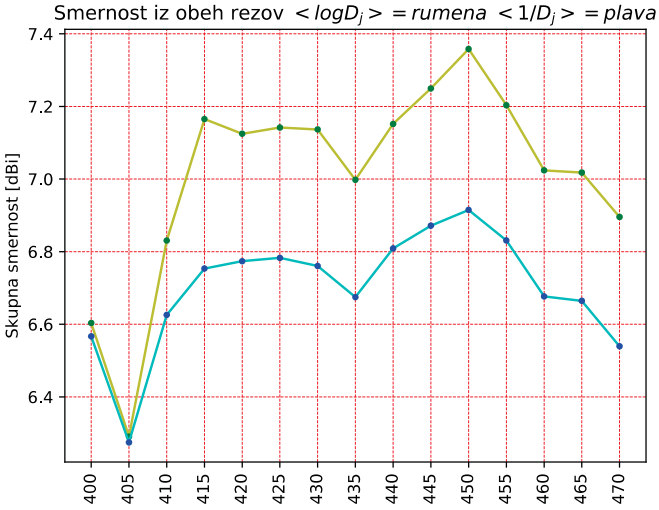


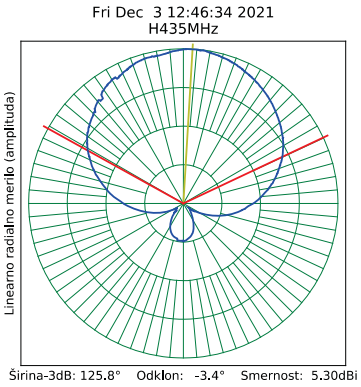
Slika 12 – 33el. cigara za 2400MHz



$$Kraus$$
$$D \approx 6.91\text{dBi}$$





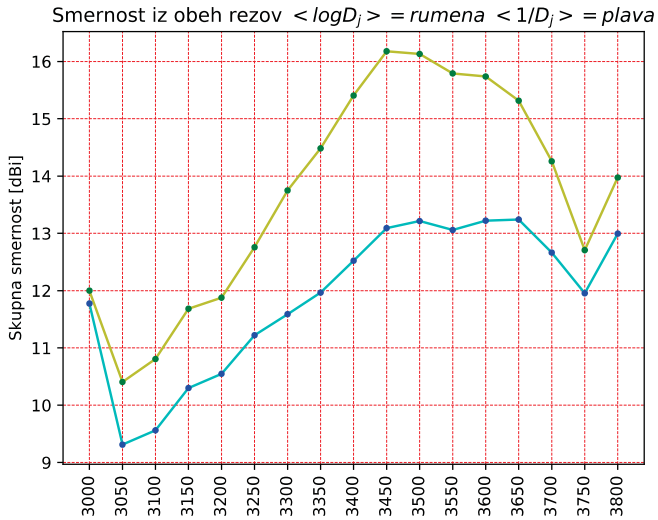


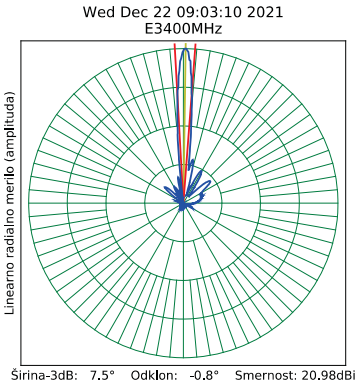
Slika 13 – HB9CV za 435MHz

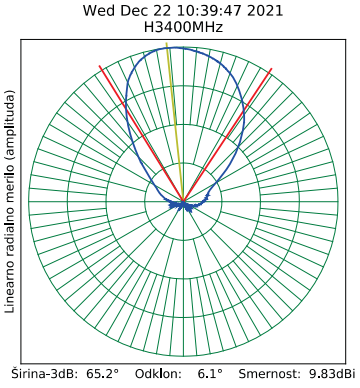
Slika 14 − Sektorska skupina za 3400MHz

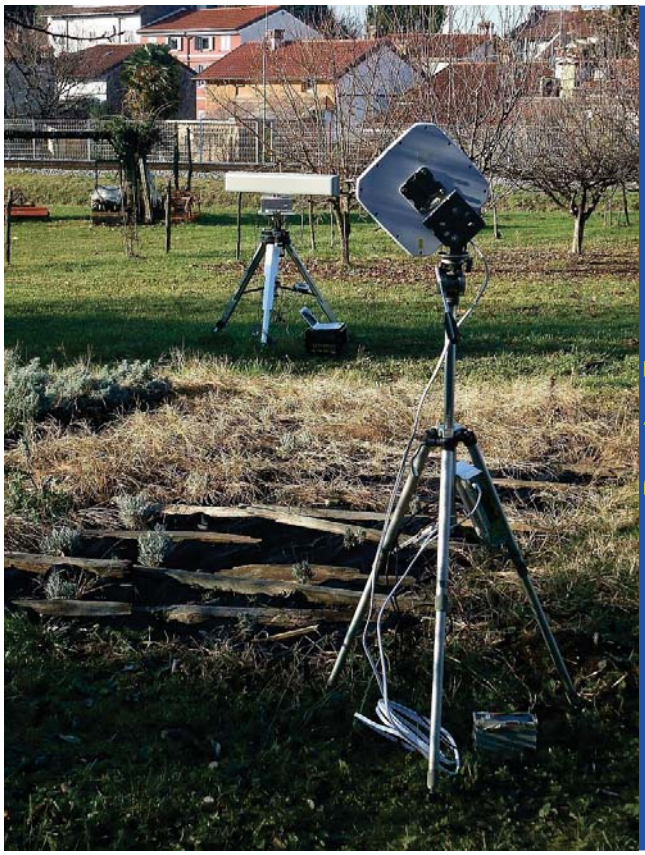


$$Kraus$$
$$D \approx 19.26\text{dBi}$$







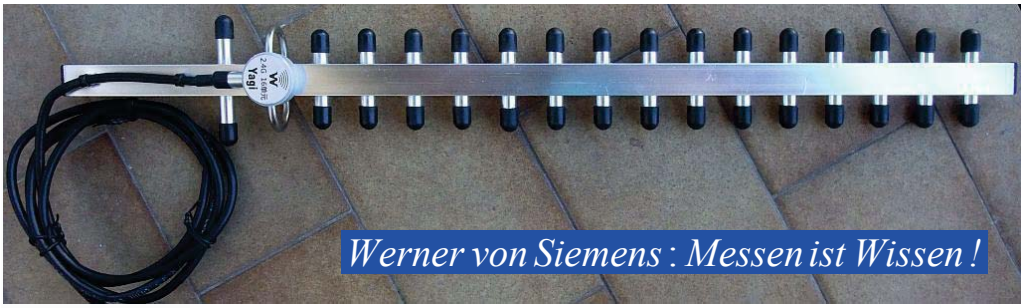


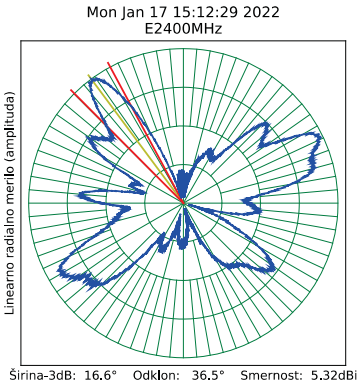
Ravnina E

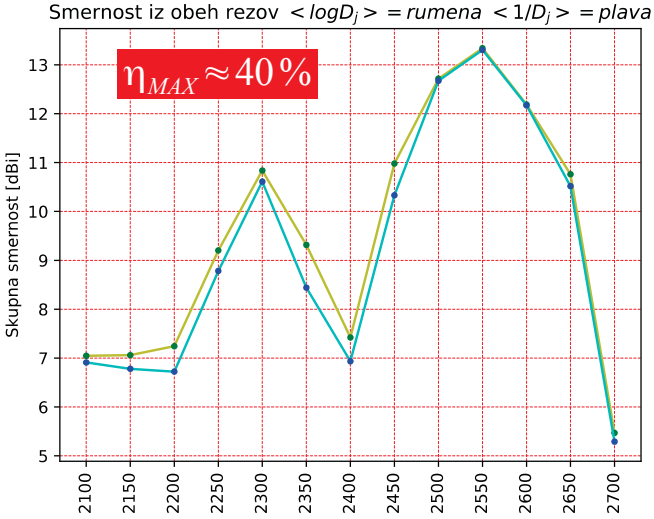
Slika 15 – Meritev sektorske skupine

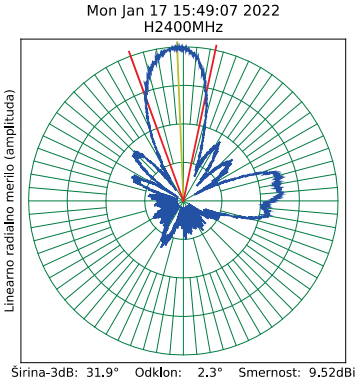
Ravnina H



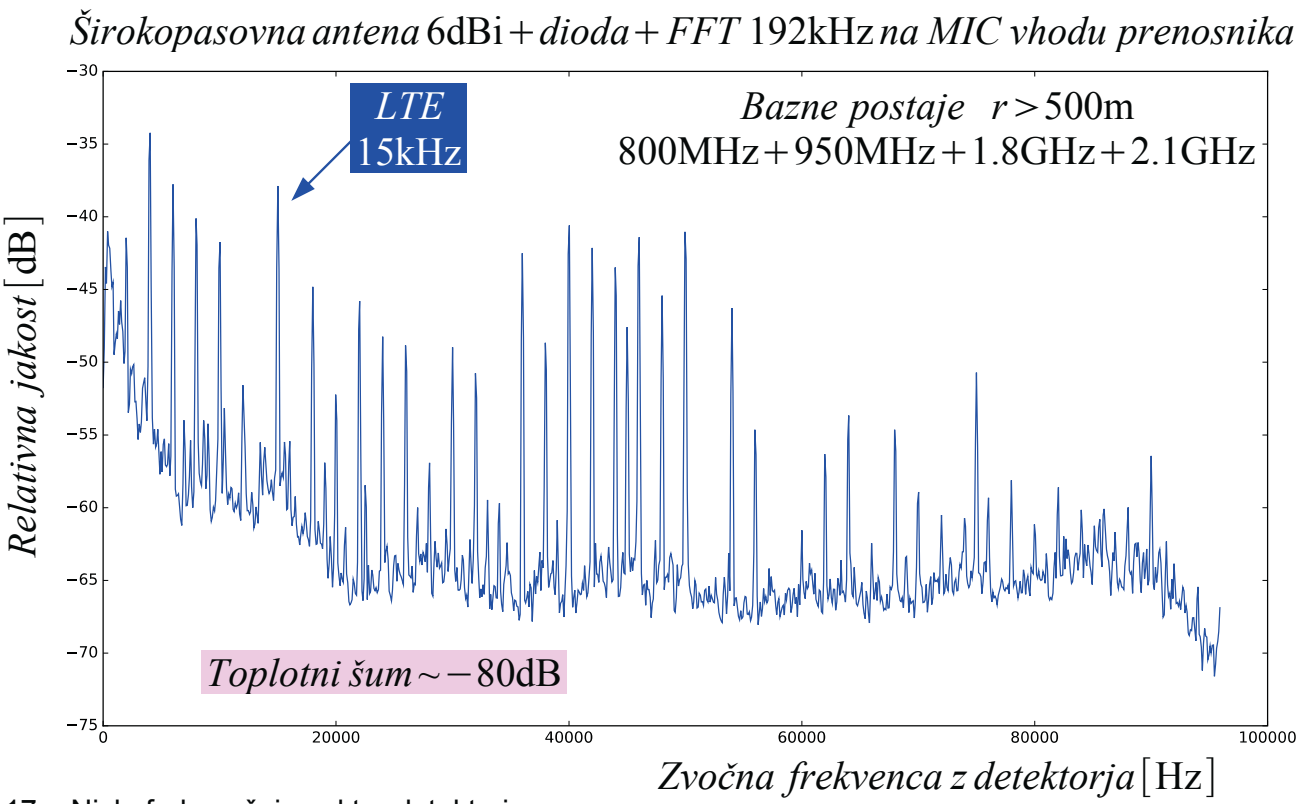








Slika 16 – Antena WiFi AliExpress



Slika 17 − Nizkofrekvenčni spekter detektorja

Pozabljena antena cigara

The forgotten cigar antenna

Matjaž Vidmar

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Katedra za informacijsko komunikacijske tehnologije, Laboratorij za sevanje in optiko

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Povzetek

V prispevku so zajete naslednje teme: razvoj usmerjenih anten, umetni dielektriki, strukture z upočasnjenim valovanjem, izvorni opis cigare (julij 1953), različne izvedbe cigare, Lunohod, James Webb, ruska puška iz Voroneža, antena BDM2 za 2400 MHz, mehanska konstrukcija ruske puške, izmere in prednosti ruske puške, elektromagnetna simulacija ruske puške, "vrtna" antenska merilnica, 23-elementna cigara za 1300 MHz, 33-elementna cigara za 2400 MHz, 58-elementna cigara za 3400 MHz in vzbujanje ruske puške.

Abstract

The following topics are covered in the paper: development of directional antennas, artificial dielectrics, slow wave structures, original cigar description (July 1953), different versions of cigars, Moonwalk, James Webb, Russian rifle from Voronež, BDM2 antenna for 2400 MHz, mechanical construction of Russian rifles, dimensions and advantages of the Russian rifle, electromagnetic simulation of a Russian rifle, "garden" antenna measurement system, 23-element cigar for 1300 MHz, 33-element cigar for 2400 MHz, 58-element cigar for 3400 MHz, and a Russian rifle antenna excitation.

Biografija avtorja

Matjaž Vidmar je doktoriral leta 1992 z naslovom teme »Metoda korekcije ionosferskih pogreškov pri satelitski navigaciji in prenosu časa«. V ZDA je razvijal satelitske oddajnike za organizacijo AMSAT. V sklopu sodelovanja z AMSAT-om je sodeloval pri razvoju komunikacijske in navigacijske opreme za satelit “AMSAT-Phase-3D”, ki je bil uspešno izstreljen v novembru 2000. Profesor Vidmar trenutno poučuje dodiplomske in podiplomske predmete s področja telekomunikacij na Fakulteti za elektrotehniko. Njegovo področje dela je mikrovalovna elektronika, ki obsega področja od letalske industrije do optičnih komunikacij.

Author's biography

Matjaž Vidmar *received his PhD in 1992 from the University of Ljubljana, for developing a single frequency GPS ionospheric correction receiver. Mr. Vidmar is currently teaching undergraduate and postgraduate courses in Electrical Engineering at the University of Ljubljana, where he serves as head of the Radiation and Optics Laboratory (LSO) at the department for Electrical Engineering (FE). His current research interests include microwave and high speed electronics ranging from avionics to optical-fiber communications.*

25. Seminar Radijske Komunikacije

Pozabljena antena cigara

Matjaž Vidmar

LSO, FE, Ljubljana, 2−4.2.2022

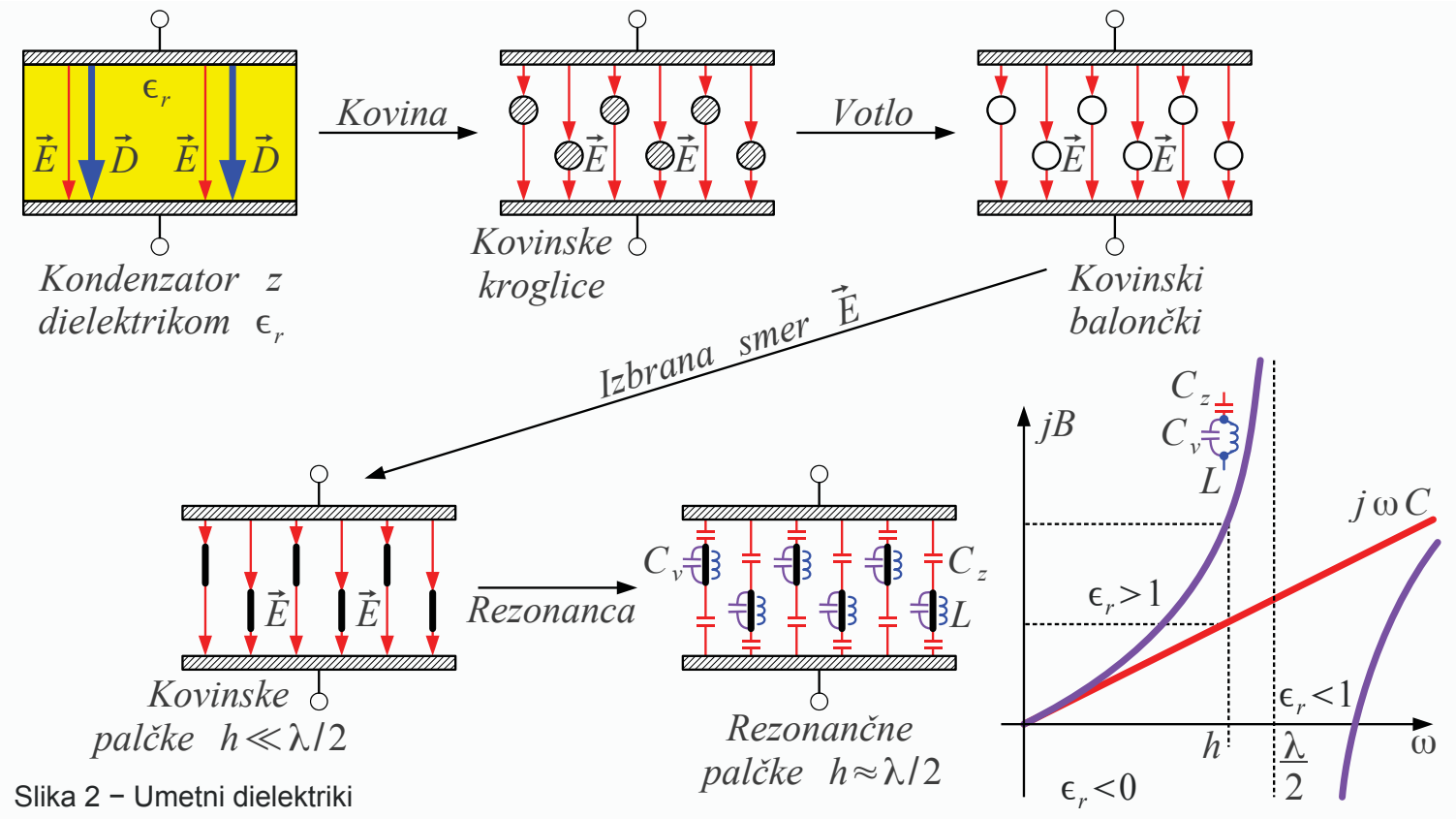
Seznam slik

Slika 1 − Razvoj usmerjenih anten
Slika 2 − Umetni dielektriki
Slika 3 − Strukture z upočasnjenim valovanjem
Slika 4 − Izvorni opis cigare julij 1953
Slika 5 − Različne izvedbe cigare
Slika 6 − Lunohod
Slika 7 − James Webb
Slika 8 − Ruska puška iz Voroneža
Slika 9 − BDM2 za 2400MHz
Slika 10 − Mehanska konstrukcija ruske puške
Slika 11 − Izmere in prednosti ruske puške
Slika 12 − Elektromagnetna simulacija ruske puške
Slika 13 − Vrtna antenska merilnica
Slika 14 − 23el. cigara za 1300MHz
Slika 15 − 33el. cigara za 2400MHz
Slika 16 − 58el. cigara za 3400MHz
Slika 17 − Vzbujanje ruske puške

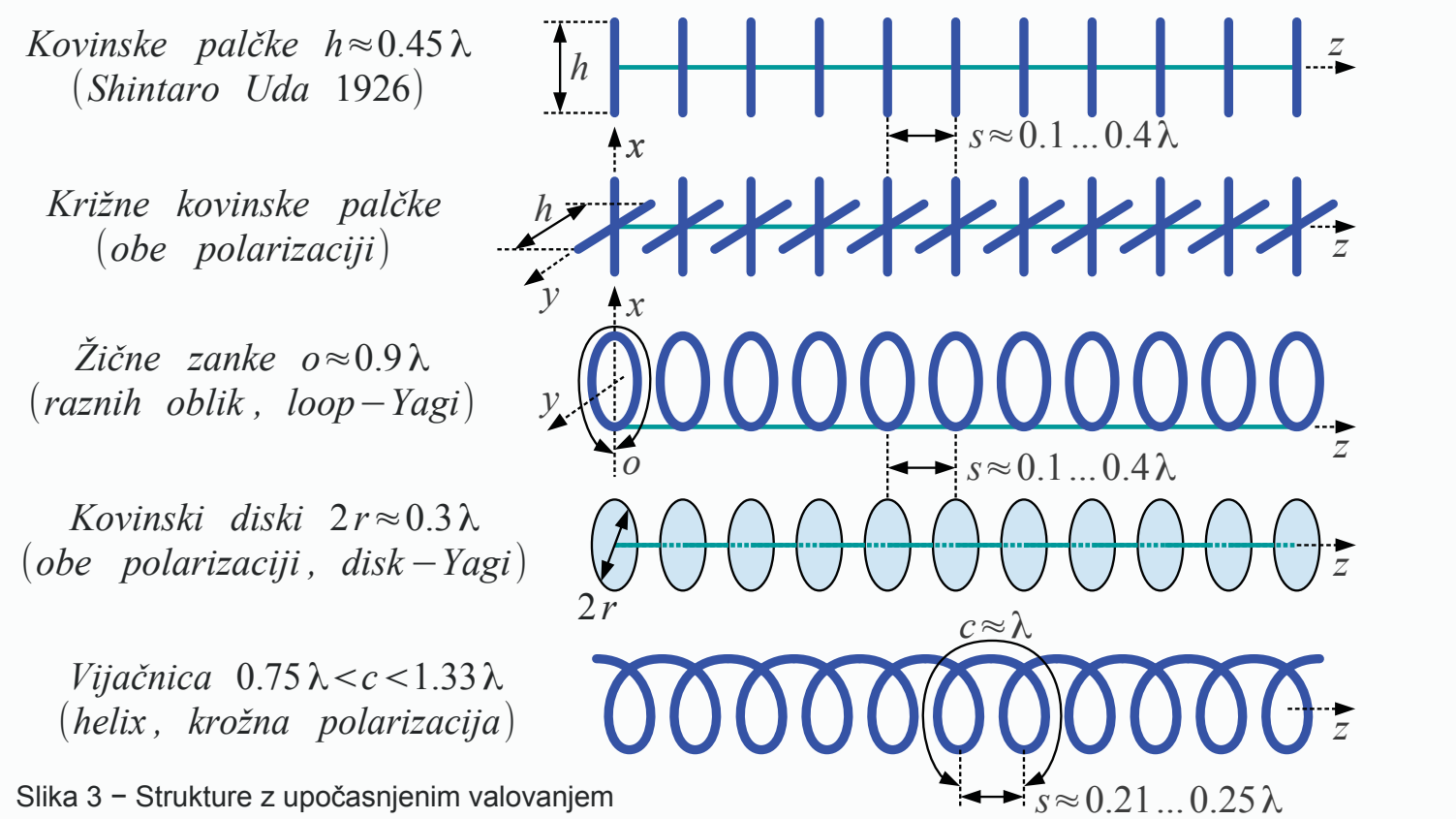
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1886-1889	Heinrich Hertz s poskusi dokaže povezavo med elektromagnetnimi pojavi in svetlobo. Kot usmerjene antene Hertz uporablja „optične“ antene: zbiralna zrcala in leče pri f≈450MHz.
1890-1900	Nikola Tesla, Guglielmo Marconi in množica drugih izumiteljev doseže boljše rezultate dometa pri nižjih frekvencah pod f<100kHz, kjer bi bile „optične” antene nepraktično velike in težke.
1894-1897	Jagadish Chandra Bose izumi prve valovode in valovodne lijake.
1900-1910	Guglielmo Marconi pri poskusih na velike razdalje ugotovi, da je sevanje dolge žice usmerjeno.
1921	Harold Beverage uporabi potujoči val na žici v usmerjeni anteni.
1924	Charles Franklin (Marconijev asistent) izdela prvo veliko antensko skupino.
1926-1928	Shintaro Uda in Hidetsugu Yagi izumita strukturo z upočasnjenim valovanjem iz kovinskih palčk, ki deluje kot zbiralna leča iz umetnega dielektrika v usmerjenih antenah.
1946	John Kraus izumi vijačno anteno (helix), ki uporablja vijačno žico kot umetni dielektrik (zbiralno lečo) za krožno polarizacijo.
1953	J. C. Simon in G. Weill izumita strukturo z upočasnjenim valovanjem iz kovinskih diskov na kovinskem nosilcu za anteno „cigaro“ (poimenovano tudi disk-Yagi). Kovinski nosilec diskov sodeluje v dielektrični leči!
1960	Dwight Isbell razvije logaritmično-periodično anteno.
1974	Hermann Ehrenspeck izumi Short Back-Fire Anteno (SBFA).

Slika 1 − Razvoj usmerjenih anten



Slika 2 − Umetni dielektriki



Slika 3 − Strukture z upočasnjenim valovanjem

Slika 4 – Izvorni opis cigare julij 1953

UN NOUVEAU TYPE D'AERIEN A RAYONNEMENT LONGITUDINAL

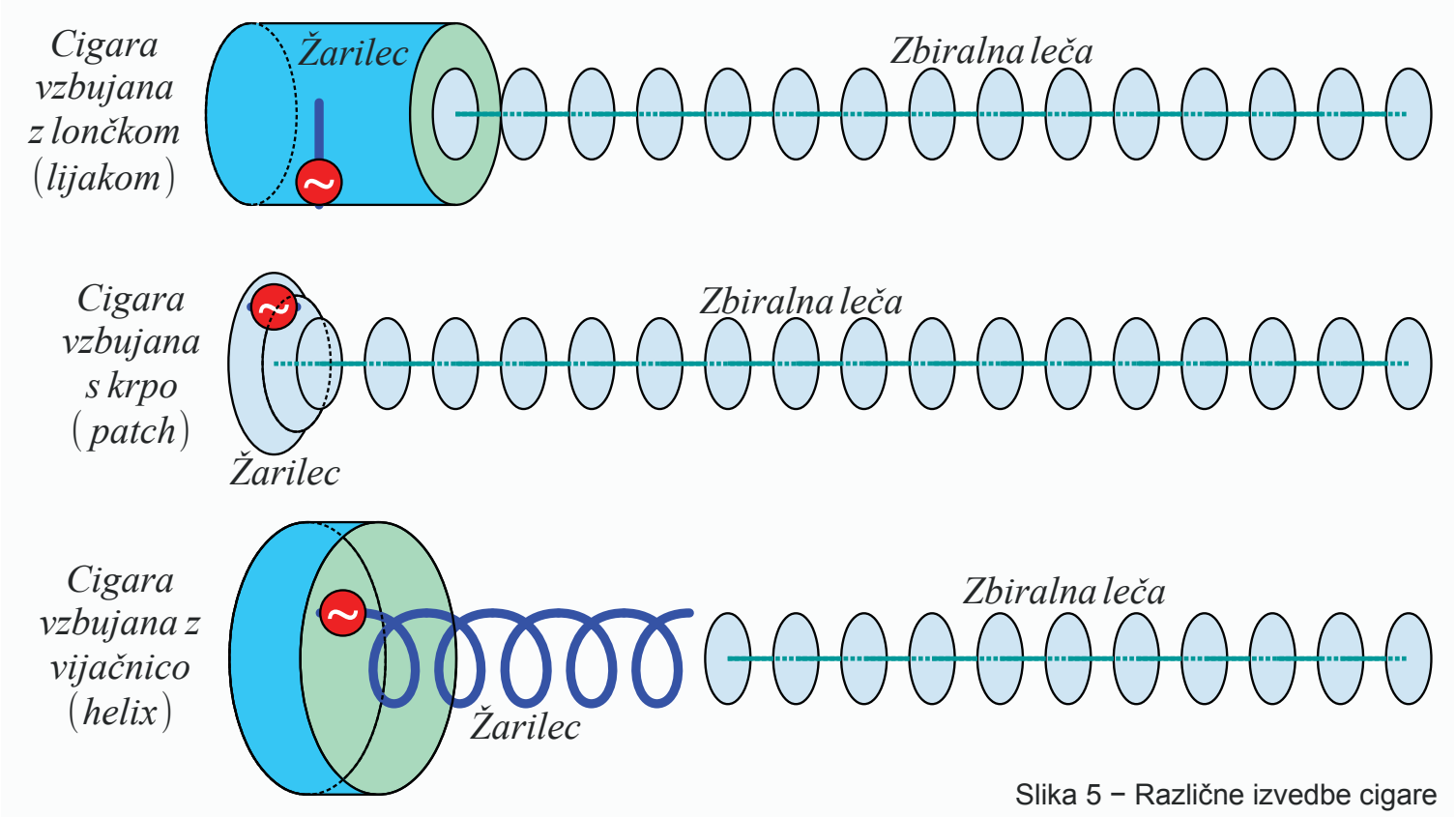
PAR J. C. SIMON ET G. WEILL,
Département Recherches générales,
Centre de Recherches techniques, Compagnie générale de T. S. F.



Fig. 8. — Mesure de phase le long d'une antenne de 80 λ en diélectrique artificiel.

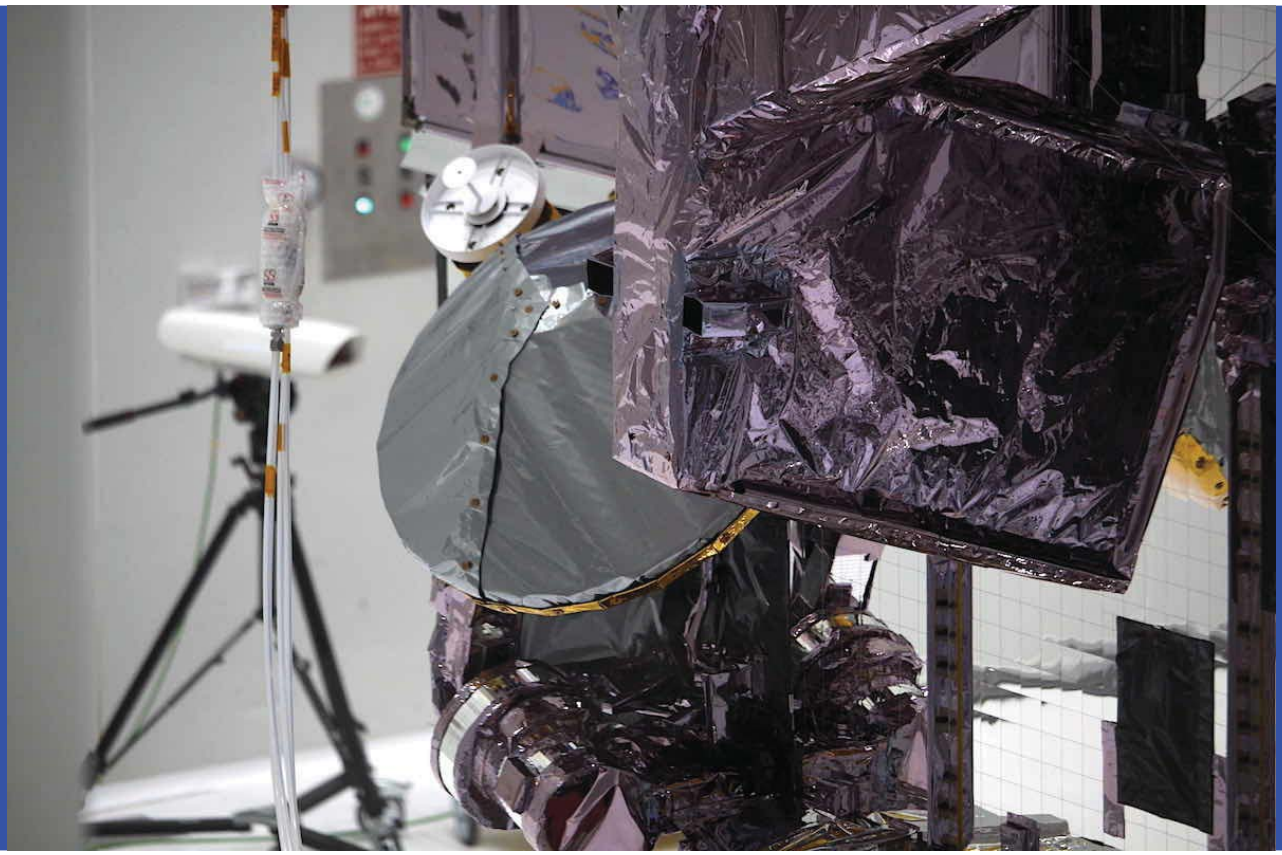


Fig. 15. — Antenne cigare à deux éléments $\frac{L}{\lambda} = \frac{1}{2}$ fonctionnant de 1 700 à 2 000 Mc/s.

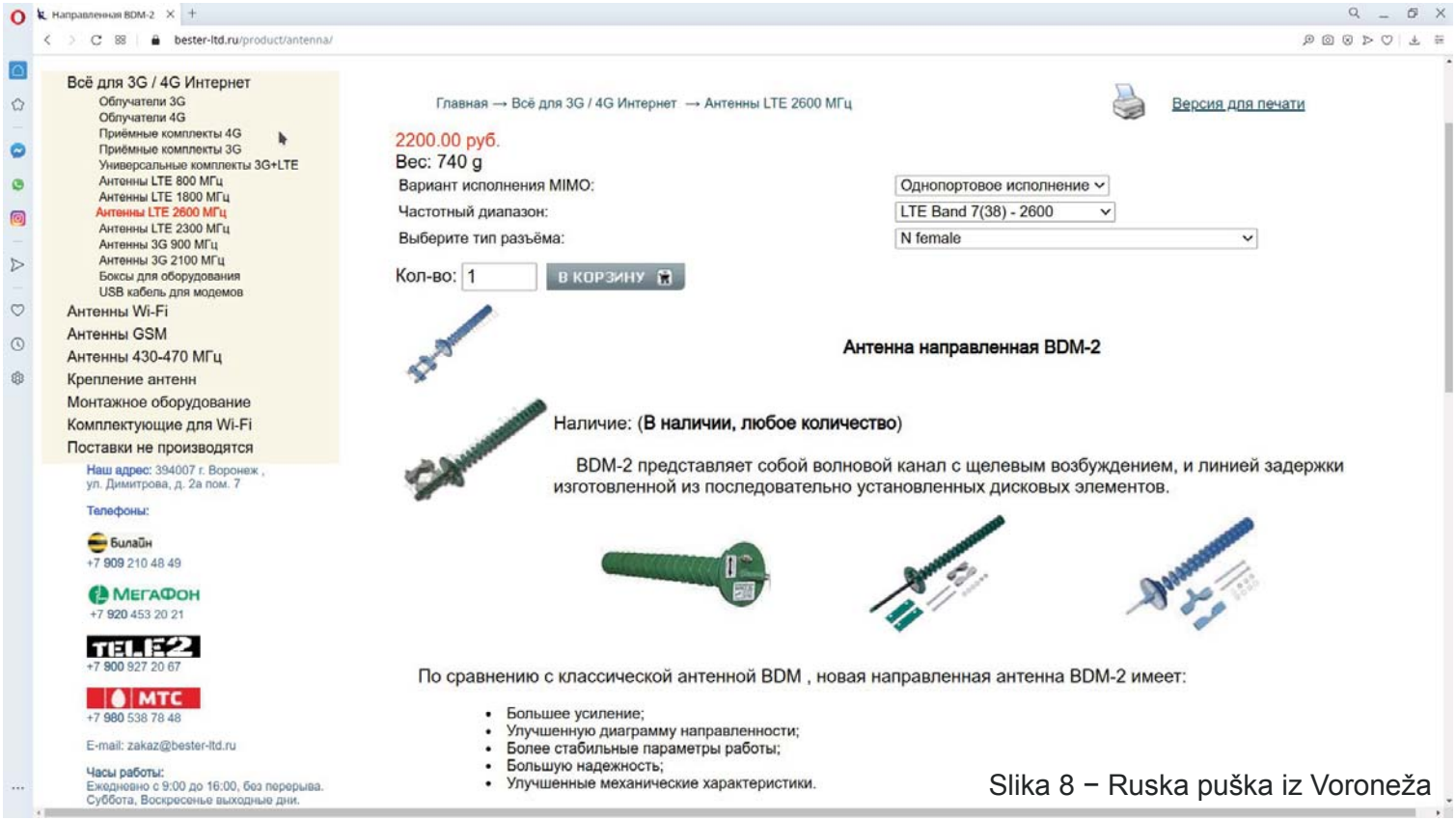


Slika 5 − Različne izvedbe cigare



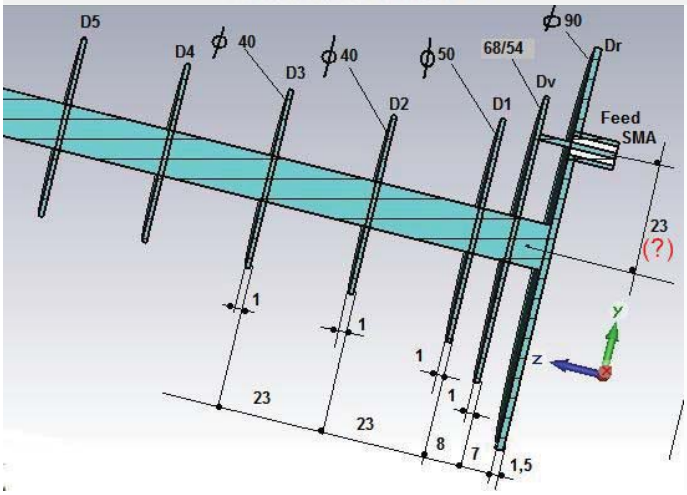


Slika 7 – James Webb



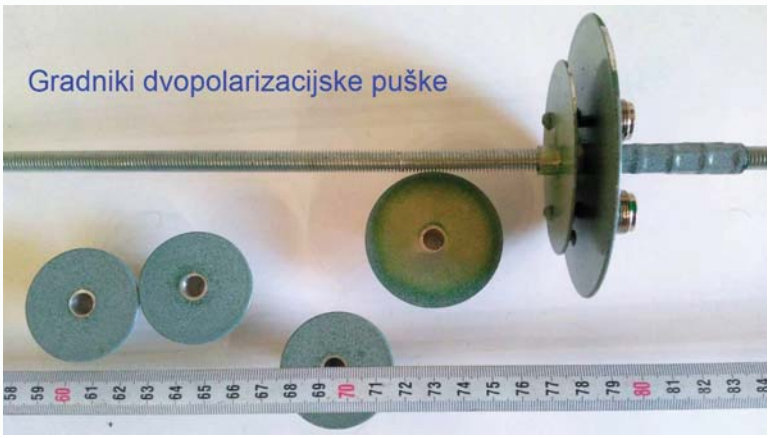
Slika 8 − Ruska puška iz Voroneža

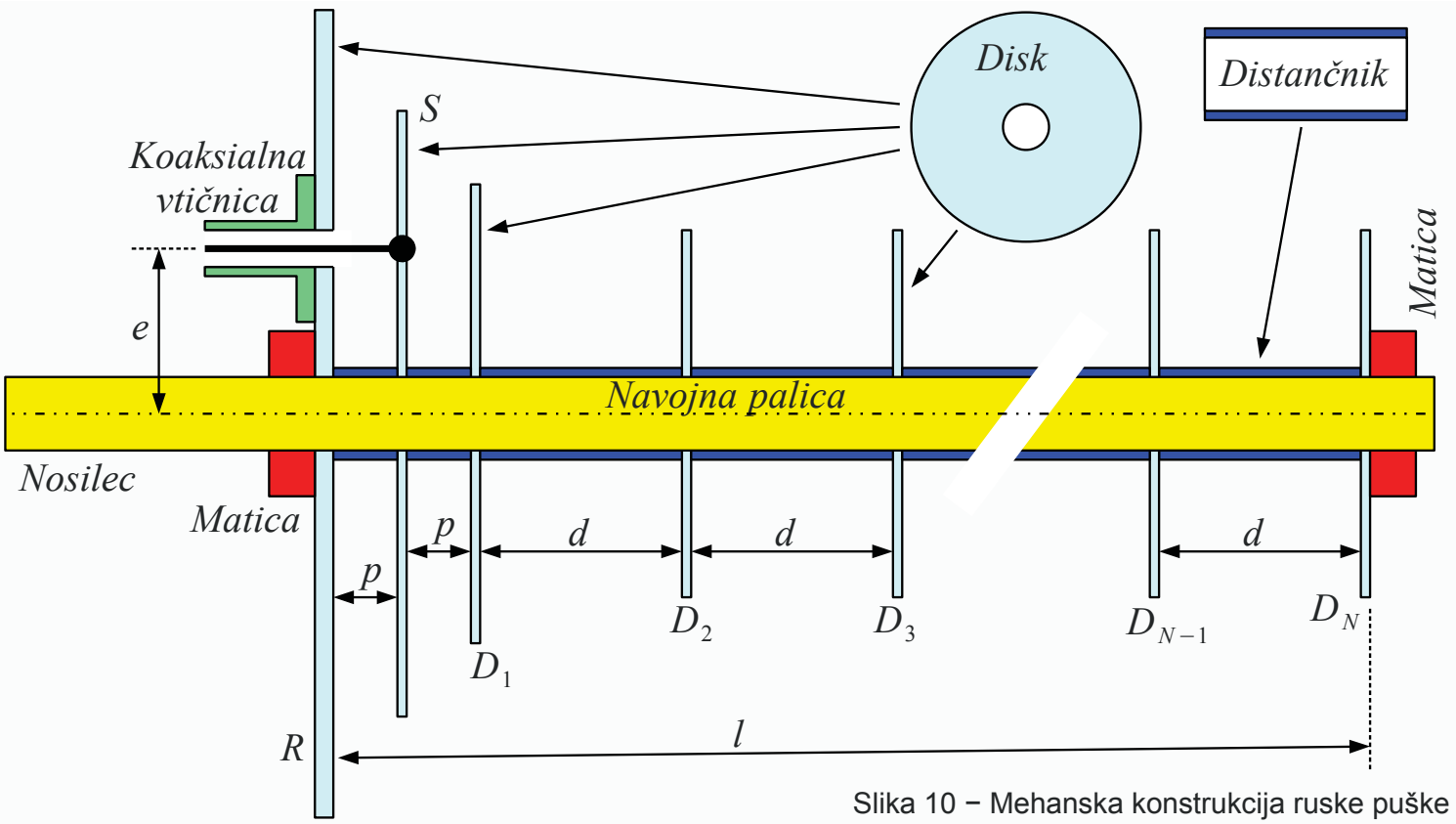




Slika 9 − BDM2 za 2400MHz

https://www.wifi-antennas.com





Slika 10 − Mehanska konstrukcija ruske puške

Inačica		1.3GHz	2.4GHz	3.4GHz
Navojna palica		M10x100cm	M8x82cm	M8x100cm
Dolžina antene	l	90cm~4λ	71cm~6λ	90cm~10λ
Cev za distančnike		12/10mmΦAl	10/8mmΦAl	10/8mmΦAl
Število direktorjev	N	20+1	30+1	55+1
Reflektor	R	166mmΦ 1.5Al	90mmΦ 1.5Al	68mmΦ 1.5Al
Sevalec	S	124mmΦ 1.0Al	68mmΦ 1.0Al	49mmΦ 0.5Ms
Direktor #1	D_1	92mmΦ 1.0Al	50mmΦ 1.0Al	37mmΦ 1.0Al
Vsi ostali direktorji	$D_{2\text{-}N}$	74mmΦ 1.0Al	40mmΦ 1.0Al	28mmΦ 1.0Al
Distančnik med R-S-D1	p	14mm	7mm	5mm
Distančnik med direktorji	d	42mm	22mm	15mm
Ekscentričnost napajanja	e	30mm	18mm	16mm

Prednosti cigare – ruske puške

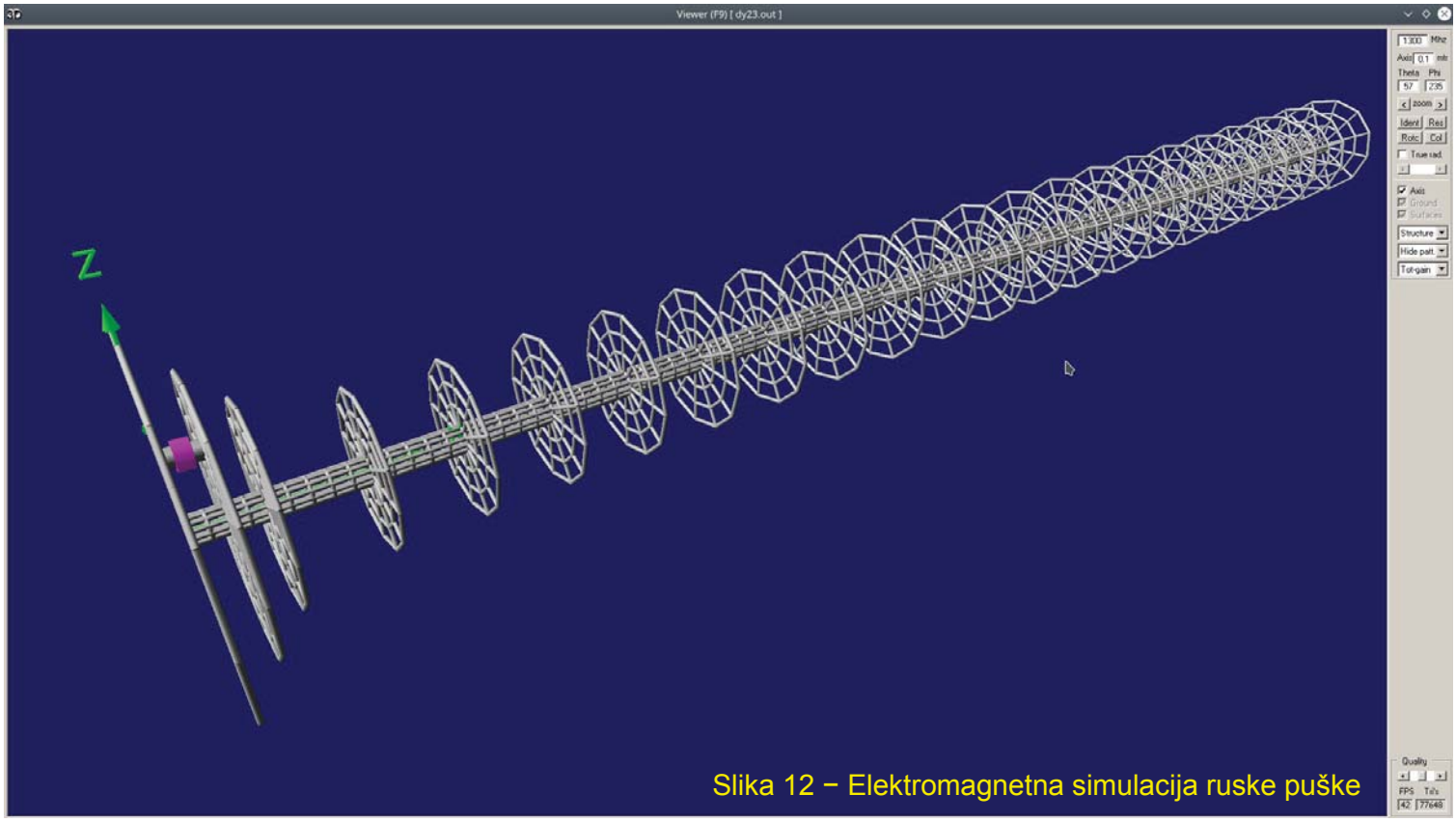
Od vseh struktur z upočasnjenim valovanjem omogočajo diski na okroglem kovinskem nosilcu:

(1) največjo pasovno širino antene
(2) najnižje slabljenje/toplotni šum
(3) največji sevalni izkoristek antene
(4) nosilec električno sodeluje v strukturi
(5) podpirajo poljubno polarizacijo
(6) visoko odpornost na padavine
(7) visoke smernosti do 20dBi in več
(8) ~2dBi večjo smernost od Yagi−Uda primerljivih izmer

Konstrukcija ruske puške omogoča:

(1) preprosto napajanje brez baluna
(2) preprosto prilagoditev impedance
(3) poljubno polarizacijo antene
(4) preprosto dvopolarizacijsko anteno
(5) preprosto mehansko konstrukcijo

Slika 11 − Izmere in prednosti ruske puške



Slika 12 − Elektromagnetna simulacija ruske puške



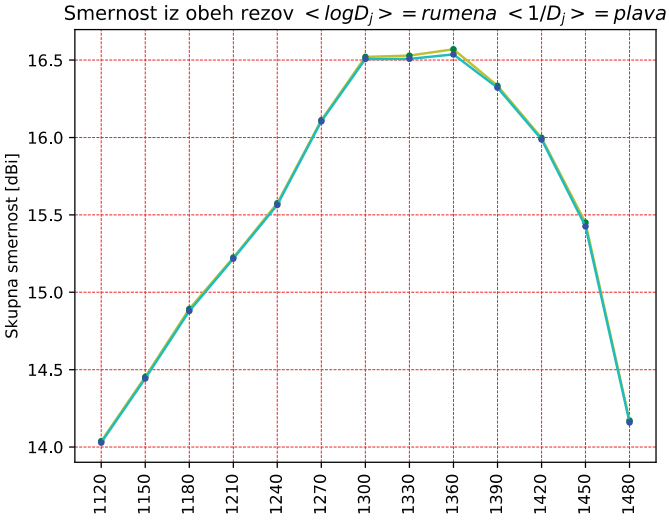
Merilni oddajnik z referenčno anteno

Slika 13 – Vrtna antenska merilnica

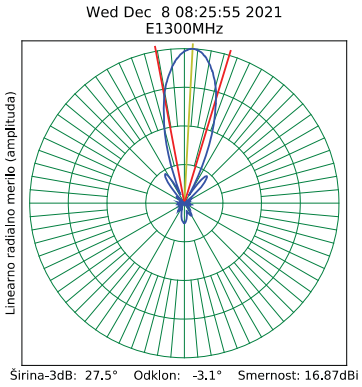
Merjenec na vrtiljaku, merilni sprejemnik in računalnik

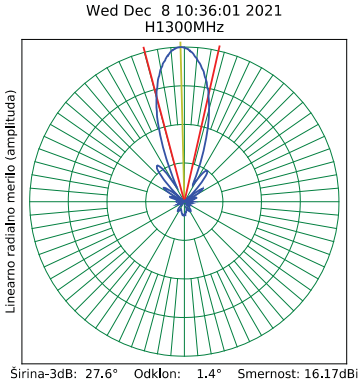




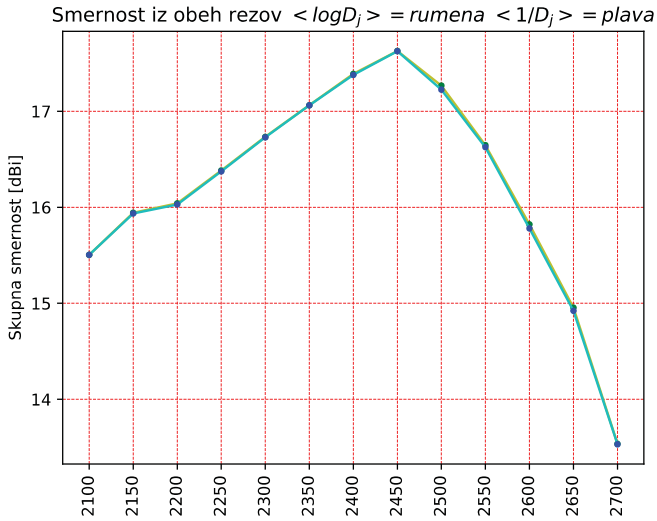


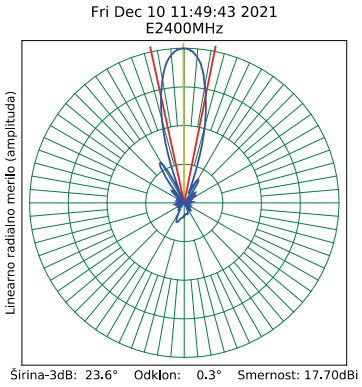
Slika 14 – 23el. cigara za 1300MHz

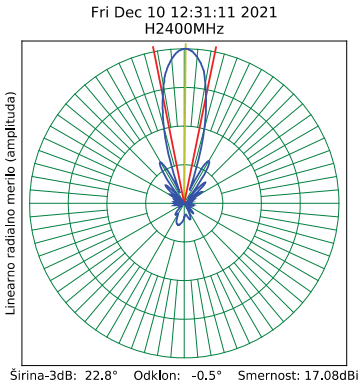






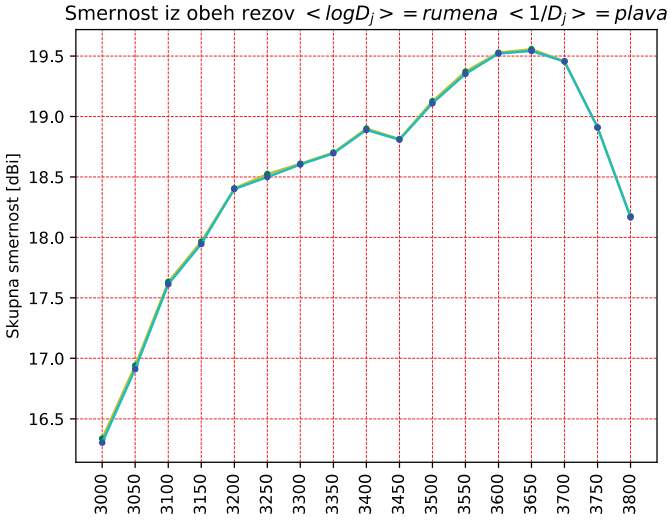


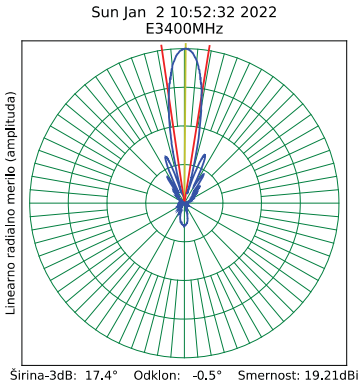


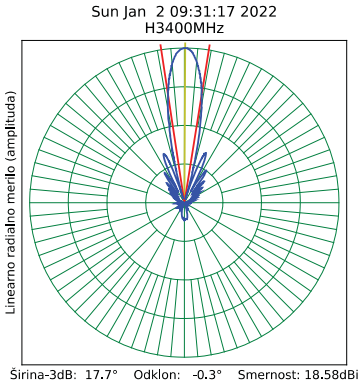


Slika 15 – 33el. cigara za 2400MHz









Slika 16 – 58el. cigara za 3400MHz



Vzbujanje za 2.4GHz VP

Slika 17 – Vzbujanje ruske puške

Vzbujanje za 3.4GHz HP



Starlink - satelitski internet v nizki zemeljski tirnici

Starlink - Satellite internet in Low Earth Orbit

Boštjan Batagelj

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Povzetek

Cilj vseh komunikacijskih satelitskih povezav je, da se za dobrobit človeštva zadovoljijo ogromne komunikacijske potrebe s pošiljanjem signala najboljše kakovosti z najnižjo pasovno širino in močjo ter z uporabo najpreprostejše in najprimernejše strojne opreme. Za doseganje teh ciljev se danes načrtovanje komunikacijskih satelitskih sistemov preusmerja iz geostacionarne tirnice v nižje zemeljske tirnice, kjer se signal najboljše kakovosti izvede z zmanjševanjem verjetnosti napak in zakasnitev. Pri konstelacijskem sistemu majhnih satelitov je ob zasnovi zaželeno, da se zmanjšajo zapletenost in stroški implementacije predlaganega sistema, potrebna prenosna moč, ki se pretvori v razmerje med signalom in šumom, in uporabljeni frekvenčni spekter. V prestavitvi je ovrednoteno satelitsko širokopasovno komunikacijsko omrežje Starlink, ki ga razvija ameriško podjetje SpaceX. Pregledane in komentirane so glavne tehnične značilnosti tega zelo posebnega segmenta širokopasovnih komunikacijskih omrežij, osnovanih na konstelacijskem omrežju tehnologije majhnih satelitov. Glavni namen prispevka je jasno prikazati tehnične lastnosti omrežja Starlink, ki jih podjetje SpaceX običajno ne razkriva podrobno v javno dostopnih predstavitvah.

Abstract

In all links involving communications satellites, the aim is to send the best-quality signal with the lowest bandwidth and power using the simplest and most appropriate hardware. This is for everyone's benefit, because it is necessary to satisfy enormous demands for all types of communications. For the purpose of achieving these targets, the design of communications-satellite systems is being shifted from the geostationary orbit to lower Earth orbits, where the bestquality signal is achieved by minimizing the probability of error and latency. In a small-satellite constellation system, the design minimizes the complexity and the cost of implementing the proposed system, reduces the required transmission power, which translates into signal-to-noise ratio, and narrows the frequency spectrum being used. The presentation evaluates the Starlink-satellite broadbandcommunications network developed by the American company SpaceX. The main technical characteristics of this special segment of broadband-communications networking based on the constellation network of small-satellite technology are reviewed and commented on. The main purpose of the paper is to clearly show the technical characteristics of the Starlink network that SpaceX does not disclose in popular-science presentations.

Biografija avtorja



Boštjan Batagelj je izredni profesor na Fakulteti za elektrotehniko Univerze v Ljubljani in član mednarodnih združenj IEEE in OSA. Raziskovalno delo opravlja v Laboratoriju za sevanje in optiko na katedri za informacijsko komunikacijske tehnologije, kjer se med drugim ukvarja z fizičnim nivojem optičnih prenosnih in dostopovnih telekomunikacijskim omrežji vključno s konvergenco radijskih sistemov in elementov.

Author's biography

Bostjan Batagelj *is an associate professor at the University of Ljubljana, Faculty of Electrical Engineering and a member of the international organizations IEEE and OSA. As a researcher he works in the Radiation and Optics Laboratory in the Information and Communications Technology Department. His current research interests include work on the physical layer of optical transport and optical access networks, including the convergence with radio systems and components.*

25. seminar radijske komunikacije

SRK 2022
2.-4. februar 2022
srk.fe-uni.lj

Starlink - satelitski internet v nizki zemeljski tirnici

izr. prof. dr. Boštjan Batagelj

Univerza v Ljubljani
Fakulteta za elektrotehniko

Katedra za IKT
LSO Laboratorij za sevanje in optiko

Ljubljana, 3. februar 2022

Kazalo vsebine:

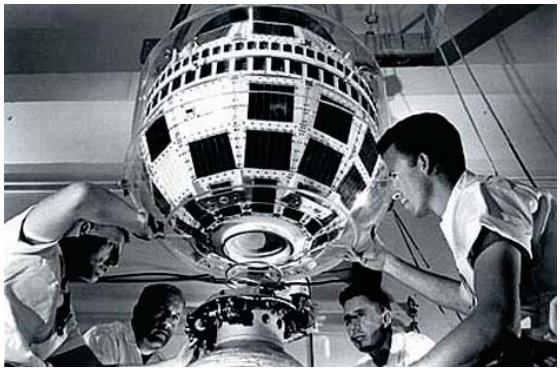
- cilj telekomunikacij
- od Telstarja do satelitskih omrežji
- Starlinku konkurenčni projekti
- premagovanje ovir interesnih skupin
  - ogorčeni astronomi in naravovarstveniki
  - visoko tveganje za nezgode na Zemlji in v vesolju
  - trn v peti lastnikom fiksnih omrežij
- premagovanje tehnoloških ovir z inovativnimi tehnološkimi dosežki
  - nizka cena poletov
  - nov ionski pogon
  - cenejša masovna serijska proizvodnja
  - hitre nadgradnje v omrežju
  - nizke zakasnitve v omrežju
  - inovativna sledilna antena
  - inovativni pristop povezovanja uporabnikov
  - inovativne povezave s svetlobnimi laserskimi signali
- pričakovane globalne spremembe

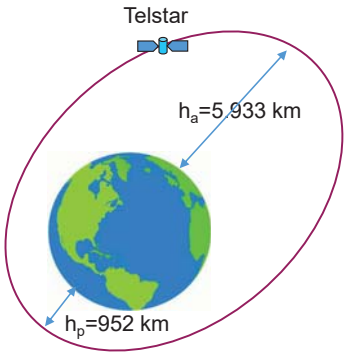
Kaj je naloga telekomunikacij?

- Cilj telekomunikacij je poslati signal najboljše kakovosti z najmanjšo porabo moči in pasovne širine s pomočjo najenostavnejše strojne opreme.
- Načrtovalske zahteve za satelitske komunikacije so zelo ostre, tako na strani uporabnikov, kot tudi v vesolju.

Prvi aktivni komunikacijski satelit – Telstar

- ob 4:35 (zjutraj), 10. julij 1962 ga NASA izstreli v Cape Canaveral, Florida
- izdelala ga je ekipa v Bell Telephone Laboratories
- velikost 87 cm, teža 77 kg





Premer sprejemne antene na Zemlji 49 m

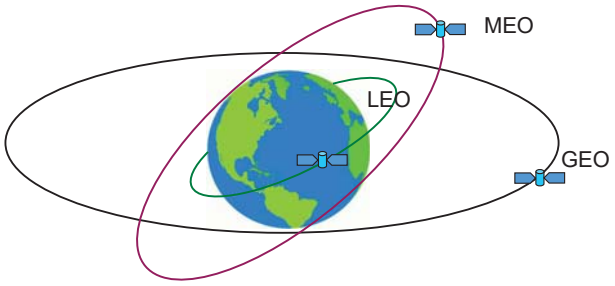


- 12 telefonskih zvez prek Atlantika
- uporaba samo 20 min na znotraj 2½ urnih obhodnih časov
- poskusni prenos televizijskega signala
- uporaba frekvenčne modulacije (FM) signala

vir: http://www.youtube.com/watch?v=uKH-GijnAGk&feature=player_embedded#at=1514

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Višina tirnic umetnih satelitov



R_Z=6378 km

nizka zemeljska tirnica *(nizkozemeljska tirnica)*	Low Earth Orbit (LEO)	od 100 km do 2.000 km
srednja zemeljska tirnica	Medium Earth Orbit (MEO)	od 2.000 km do 36.000 km
geostacionarna tirnica	Geostationary Orbit (GEO)	36.000 km (35.786 km)
visoka zemeljska tirnica	High Earth Orbit (HEO)	od 36.000 km navzgor 50.000 km

- Nad 50.000 km:
  - vpliv težnosti drugih nebesnih teles ni več zanemarljiv (Luna, Sonce)
  - zakasnitve signala so velike
- Geostacionarni sateliti so zelo dragi (nekajkrat dražji od nosilne rakete).
- Podoceanski optični kabli so od satelitov povsem prevzeli promet med kontinenti, ker je optično vlakno 10 000-krat bolj zmogljivo kot satelit.

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Starlinku konkurenčni projekti

- Globalstar (Qualcomm) **delujoči** LEO sateliti (na višini 1420 km) za satelitsko telefonijo in podatkovne komunikacije z omejeno pasovno širino. Deluje na omejenih območjih z zemeljskimi vozlišči. https://www.globalstar.com
- Iridium (Motorola) **delujočih** 76 LEO satelitov za globalno telefonijo. Sateliti (na višini 781 km) v šestih različnih tirnicah pokrivajo tudi zemeljske pole. Imajo madsatelitske radijske zveze na 23 GHz. https://www.iridium.com
- O3b Networks (lastnik SES S.A., financiral tudi Google) **delujočih** osem MEO satelitov (na višini 8063 km) za telefonske in podatkovne storitve (na voljo samo mobilnim operaterjem in ponudnikom internetnih storitev).
- Teledesic (lastnik Microsoft) propadel poskus LEO satelitov v 90-ih letih. vir: "Teledesic: a global broadband network" https://ieeexplore.ieee.org/document/682221
- O3b mPOWER (lastnik SES S.A. in Microsoft za zemeljske postaje Azure Orbital) v MEO.
- Kuiper Systems (lastnik Amazon) **načrtuje** 3236 satelitov v LEO.
- OneWeb (bivši WordVu v lastništvu Google) **načrtuje** 648 LEO satelitov (na višini 1200 km) za globalni internet. Po finančnih težavah v 2020 začne 2021 z izstrelitvami in ima sedaj **delujočih** 394 satelitov. Na voljo je mobilnim operaterjem in ponudnikom internetnih storitev. https://oneweb.net https://en.wikipedia.org/wiki/OneWeb_satellite_constellation
- Kepler Communications **načrtuje** LEO satelite za širokopasovni globalni internet (Kanadski star-up)
- LeoSAT, ki je načrtoval cca. 100 satelitov v LEO je propadel 2019. https://en.wikipedia.org/wiki/LeoSat
- Orbcomm **delujoči** LEO sateliti za satelitski IoT M2M (29 delujočih LEO satelitov) https://www.orbcomm.com/
- SkyBridge (lastnik Alcatel) propadel projekt za satelitski internet.
- ViaSat **delujoči** štirje sateliti v geostacionarni tirnici za internetni promet. https://www.viasat.com

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Pričetki projekta Starlink

- Starlink je globalno satelitsko komunikacijsko omrežje, ki ga razvija ameriško podjetje SpaceX.



(Space Exploration Technologies Corporation)

Januarja 2015 v Seattlu lastnik podjetja SpaceX Elon Musk na odprtju podružnice SpaceX Seattle prvič predstavi satelitski projekt Starlink.
https://www.youtube.com/watch?v=AHeZHyOnsm4

STARLINK https://www.starlink.com/

- Ambiciozni projekt bo v vesolju vzpostavil globalno satelitsko internetno omrežje, ki bo
  - sposobno prenesti večino (cilj je 50%) internetnega prometa na dolgih razdaljah in
  - okrog 10% lokalnega internetnega prometa nekega (ruralnega) območja.

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Utirjenje satelitov



22. februar 2019	2 satelita
24. maj 2019	60 satelitov
11. november 2019	60 satelitov
7. januar 2020	60 satelitov
29. januar 2020	60 satelitov
17. februar 2020	60 satelitov
18. marec 2020	60 satelitov
22. april 2020	60 satelitov
18. maj 2020	60 satelitov
⋮	
6. januar 2022	49 satelitov
19. januar 2022	49 satelitov
29. januar 2022	49 satelitov

izstreljenih 2042
(1848 delujočih v tirnicah)

- Nosilna raketa Falcon 9 (značilna po ponovni uporabi).
- Po vstavitvi v tirnico sateliti letijo skupaj, potem se razpršijo na različne položaje v tirnicah nad Zemljo.

vir: Starlink Statistics, Jonathan's Space Pages, https://planet4589.org/space/stats/star/starstats.html
vir: List of Starlink launches, Wikipedia, https://en.wikipedia.org/wiki/List_of_Starlink_launches

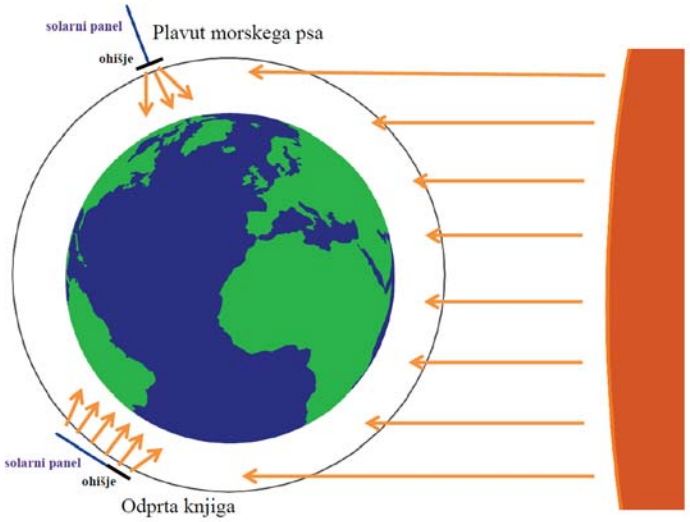
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Večerne lučke na nebu



- Kolona svetlih satelitov, potujočih čez večerno nebo.
- Prvih 60 satelitov (24. maj 2019) je bilo zelo vidnih in je povzročilo zgražanje pri astronomih, ki so projekt označili kot bizaren, saj naj bi imel negativne posledice za prihodnost astronomskih raziskav.





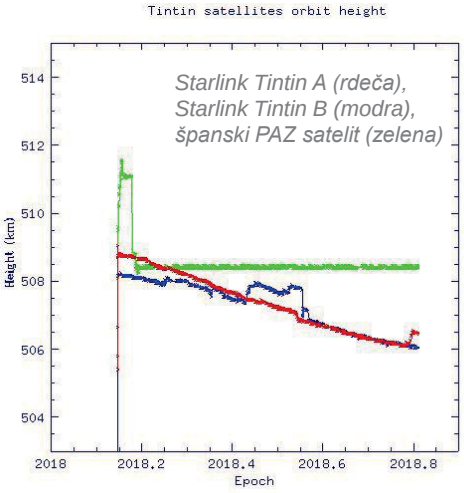
- Sateliti so vidni, ko proti Zemlji odbijejo sončno svetlobo.
- Sateliti v nizkih tirnicah so vidni le zvečer in zjutraj, oddaljeni sateliti so vidni tudi ponoči.

- Ukrep je bil temen premaz na spodnji strani satelita, ki zmanjša odsev.

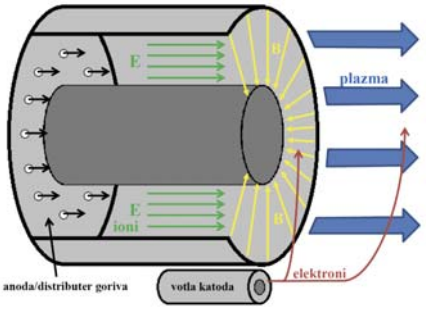
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Višina satelitov Starlink

- Sprva je SpaceX zaprosil ameriško Zvezno telekomunikacijsko komisijo (Federal Communications Commission - FCC) za dovoljenje za izstrelitev 4.425 satelitov v tirnice na višini med 1110 in 1325 kilometri.



- Poskusna satelita Tintin A in Tintin sta bila izstreljena 22. 2. 2018 in postavljena na višino 509 km.
- Preizkus kriptonskih (Kr) ionskih pospeševalnikov je bil uspešen, vendar se satelita nista povzpela više.



- SpaceX se odloči za novo tirnico na višini 550 km, ker:
  - bodo sateliti sami padali (samoočiščujoča tirnica),
  - imamo manjšo zakasnitev,
  - se število satelitov zmanjša.

vir: “SpaceX wants to fly some internet satellites closer to Earth to cut down on space trash“,
https://www.theverge.com/2018/11/9/18016962/spacex-internet-satellites-space-debris-trash-orbit-closer-earth-distance-atmosphere

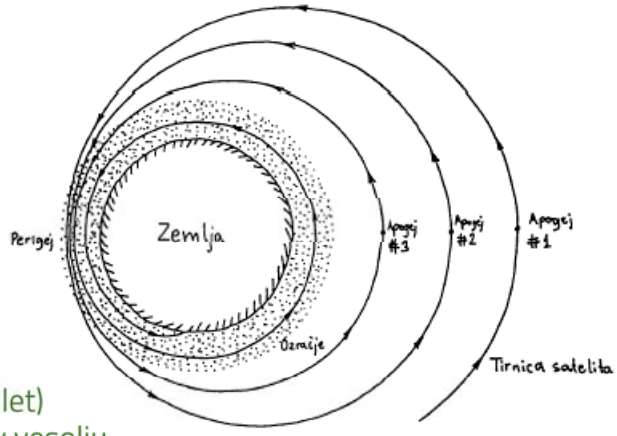
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Motnje tirnice zaradi trenja z ozračjem

- Trenje z Zemljinim ozračjem se pozna pri satelitih, ki se nahajajo pod 1.000 km.
- Učinek trenja je močno odvisen od razmerja med presekom (površino) in maso satelita.
- Debelina Zemljinega ozračja je odvisna od aktivnosti Sonca (11 letna perioda). https://en.wikipedia.org/wiki/Solar_cycle
- Trenje z ozračjem se odraža kot:
  - zmanjševanje hitrosti satelita v perigeju,
  - zniževanje apogeja.

$$v = \sqrt{\frac{\mu}{a}} = \sqrt{\frac{3{,}986 \cdot 10^{14}\ \mathrm{m^3/s^2}}{(550 + 6378) \cdot 10^3\ \mathrm{m}}} = \underline{\underline{7585\ \mathrm{m/s}}}$$

- Na koncu satelit zaradi velikega trenja zgori v ozračju na višini okoli 100 km.



- Starlinkov satelit (386 kg) bo ob koncu življenjske dobe (6 let) v celoti zgorel in s tem ne bo ogrožal nikogar na Zemlji in v vesolju.
- Kesslerjev sindrom je teoretični scenarij, ko je gostota objektov v nizki Zemljini tirnici tako velika, da lahko en trk povzroči verižni pojav uničenja številnih satelitov in s tem ustvari še več vesoljskih smeti.

Tveganje nezgode

https://spectrum.ieee.org/tech-talk/aerospace/satellites/the-odds-that-one-of-spacexs-internet-satellites-will-hit-someone



- Sestava prvih Starlink satelitov je zaradi
  - SiC laserskih zrcal,
  - vztrajnikov iz nerjavečega železa,
  - ionskega pospeševalnika iz titana in železa,
- imela riziko za človeško žrtev 1:18.200, kar je nad ESA in NASA zahtevami, ki znašajo 1:10.000.

- FCC je marca in junija 2017 izračunal skupno tveganje za človeško žrtev.

11.927 satelitov ÷ 6 let = 1.987 satelitov / leto ÷ 365 dni= 5,4 satelita / dan

skupno število satelitov

življenjska doba satelita

vsakih 6 let bo ranjen ali ubit en zemljan!

- SpaceX se je branil s tem, da vsak dan na zemljo pade med 62 in 242 meteoritov težjih od 10 g.
- Po sestanku med SpaceX in FCC (marec 2019) je SpaceX obljubil preoblikovanje satelitov tako, da v celoti izgorijo v ozračju (mogoče je bil to razlog za znižanje mase iz 386 kg na 260 kg).

https://spectrum.ieee.org/tech-talk/aerospace/satellites/spacex-claims-to-have-redesigned-its-starlink-satellites-to-eliminate-casualty-risks

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Starlink.com https://www.starlink.com/



- Delovanje je bilo načrtovano in se je začelo leta 2020 (ZDA in Kanada).
- Sledijo preostali deli sveta, v naslednjem letu tudi Slovenija.
- Za ameriško združenje optičnih širokopasovnih omrežji (NTCA) je Starlink močna konkurenca. Podjetje SpaceX je namreč za opremljanje 10% belih lis v ZDA, kar znaša 640.000 lokacij, od ameriškega regulatorja FCC dobilo 886 milijonov dolarjev.

https://www.delo.si/novice/znanoteh/starlink-moti-astronome-a-tudi-operaterje/


Starlink moti astronome, a tudi operaterje

Internetno omrežje *Kaj bo omrežje satelitov na nizki zemeljski tirnici prineslo običajnim gospodinjstvom in kaj velikim ponudnikom*

1378

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ping

	Ljubljana
Amsterdam	29.066ms
Copenhagen	35.433ms
Dallas	136.918ms
London	33.125ms
Los Angeles	160.055ms
Moscow	58.833ms
Munich	11.978ms
New York	113.982ms
Paris	43.723ms
Rome	24.702ms
Stockholm	47.315ms
Tokyo	228.498ms
Toronto	105.743ms
Vienna	5.951ms
Zagreb	12.775ms

https://wondernetwork.com/pings

Svetlobni signal po optičnem vlaknu z lomnim količnikom n=1,5 prepotuje od Ljubljane do Amsterdama (1250 km) v času

$$t = \frac{L}{\frac{c_0}{n}} = \frac{1250\ \text{km}}{2 \cdot 10^8\ \text{m/s}} = 4{,}17\ \text{ms}$$

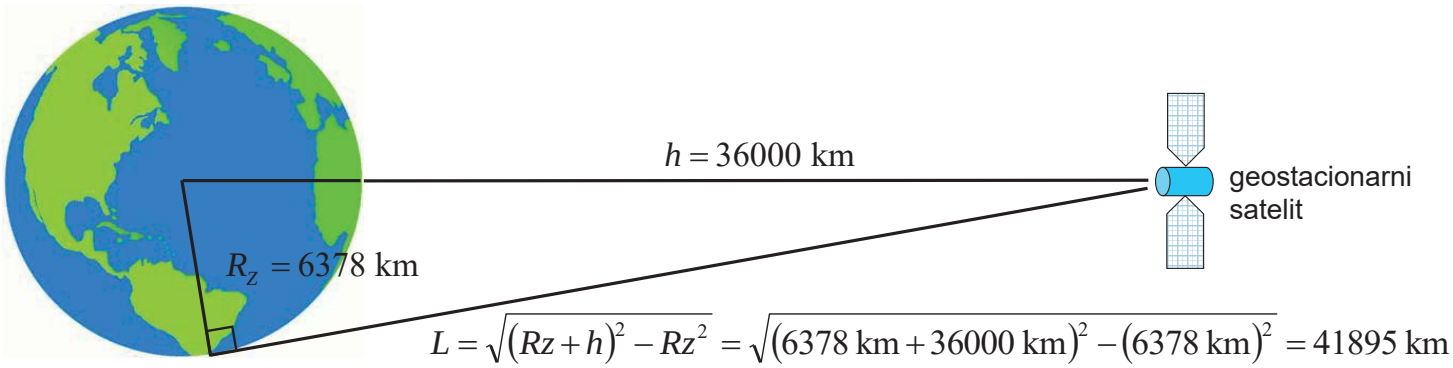
Ljubljana – Amsterdam – Ljubljana

$$2t = \underline{\underline{8{,}3\ \text{ms}}}$$

Procesiranje signala v telekomunikacijskih napravah predstavlja bistven del zakasnitve signala.

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Zakasnitve do geostacionarnega satelita



Zakasnitev za opazovalca, ki ima geostacionarni satelit v nadglavišču (zenitu):

$$t_{zenit} = \frac{h}{c_0} = \frac{36000\ \text{km}}{3 \cdot 10^8\ \text{m/s}} = 120\ \text{ms} \qquad 2t_{zenit} = 240\ \text{ms}$$

Zakasnitev za opazovalca, ki ima geostacionarni satelit na obzorju (horizontu):

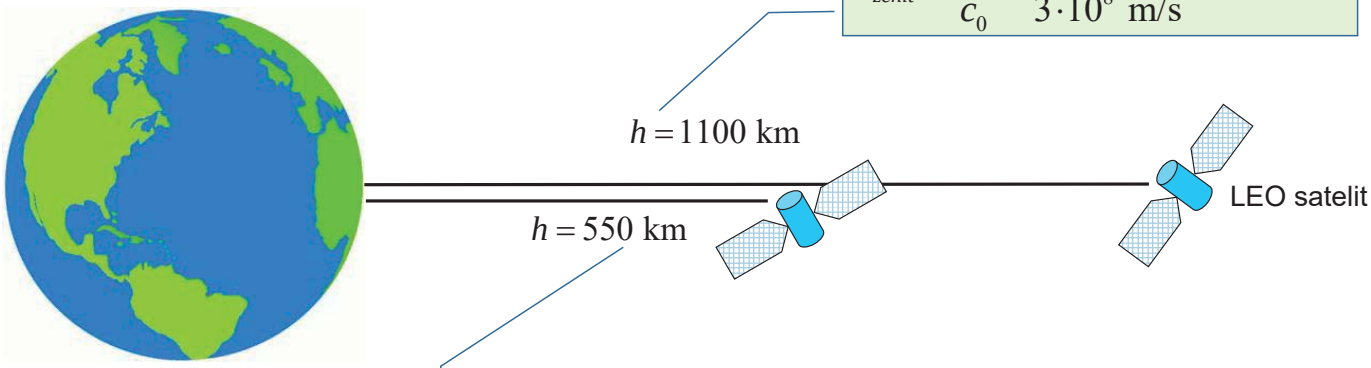
$$t_{horizont} = \frac{L}{c_0} = \frac{41895\ \text{km}}{3 \cdot 10^8\ \text{m/s}} = 140\ \text{ms} \qquad 2t_{horizont} = 280\ \text{ms}$$

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Zakasnitve do LEO satelita

Zakasnitev za opazovalca, ki ima geostacionarni satelit v nadglavišču (zenitu):

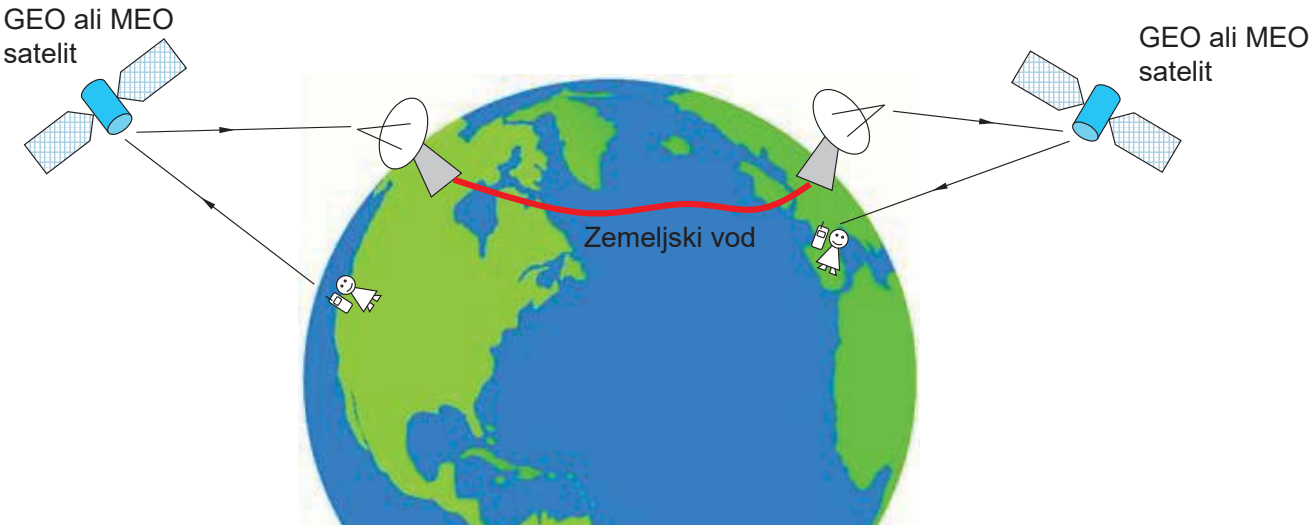
$$t_{zenit} = \frac{h}{c_0} = \frac{1100\ \text{km}}{3 \cdot 10^8\ \text{m/s}} = 3,7\ \text{ms}$$



$$t_{zenit} = \frac{h}{c_0} = \frac{550\ \text{km}}{3 \cdot 10^8\ \text{m/s}} = 1,8\ \text{ms}$$

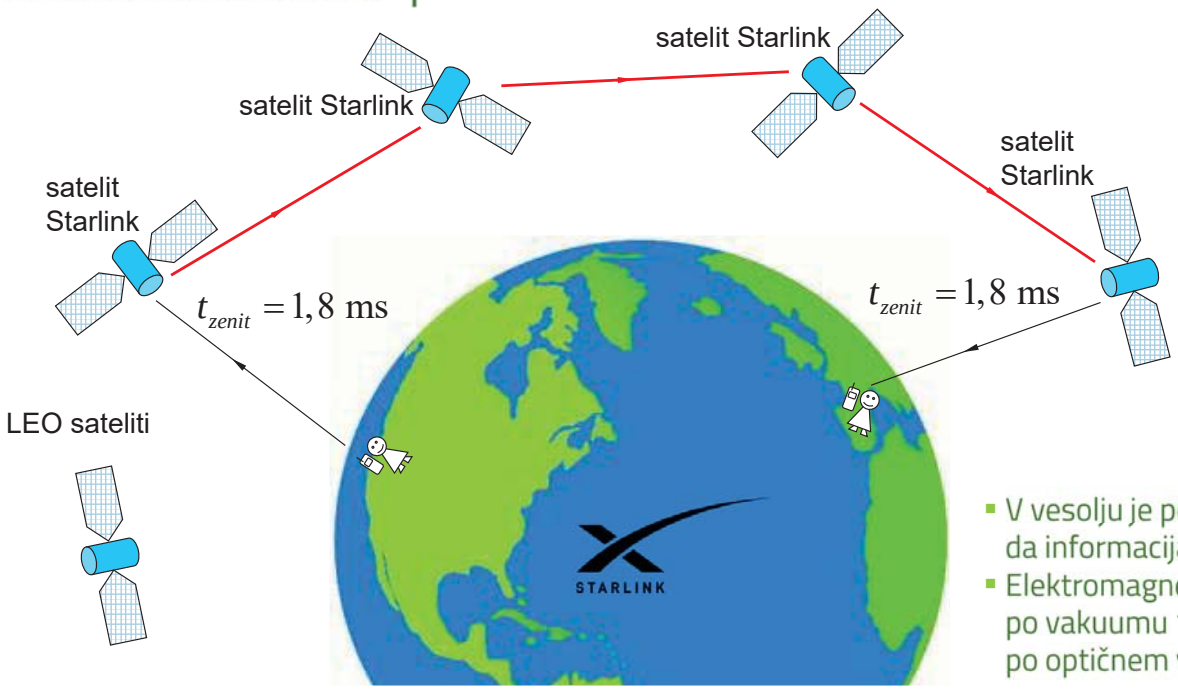
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Zakasnitve pri omrežju brez medsatelitskih povezav



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Zakasnitve pri omrežju z medsatelitskmi povezavami



- V vesolju je potrebno **manj vozlišč**, da informacija prispe na cilj.
- Elektromagnetno valovanje potuje po vakuumu 1,5-krat hitreje, kot po optičnem vlaknu.

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Primerjava zakasnitev v optičnem in LEO satelitskem omrežju

- Uporaba optičnega vlakna z najkrajšo razdaljo med A in B

$$t_{AB} = \frac{L}{\frac{c_0}{n}} = \frac{nL}{c_0}$$

- Uporaba Starlinka s satelitom v zenitu in najkrajše medsatelitske povezave med A in B

$$t_{AB} = \frac{L}{c_0} + 2\frac{h}{c_0}$$

$$t_{AB} = \frac{nL}{c_0} = \frac{L+2h}{c_0}$$

$$nL = L + 2h$$

$$L(n-1) = 2h$$

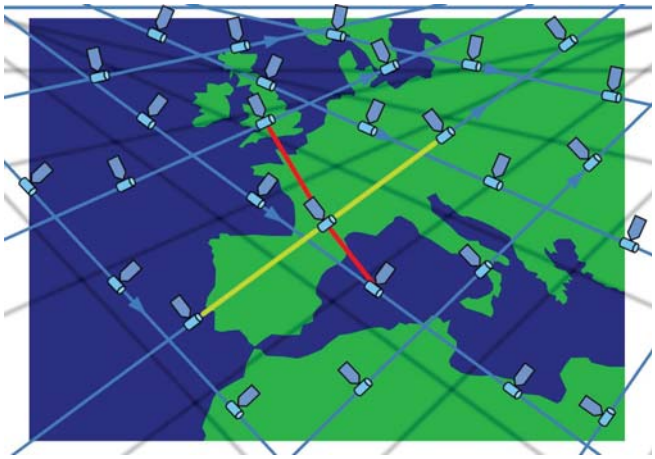
$$L = \frac{2h}{(n-1)} = \frac{2 \cdot 550 \text{ km}}{(1,5-1)} = \frac{1100 \text{ km}}{0,5} = 2200 \text{ km}$$

- Na dolge razdalje bo hitreje preko satelita Starlink v LEO, kot preko direktnega optičnega vlakna.
- Za natančen izračun je potrebno upoštevati:
  - Realne razdalje med sateliti (glej članek prof. Mark Handley "Delay is Not an Option: Low Latency Routing in Space") https://dl.acm.org/doi/10.1145/3286062.3286075
  - Zakasnitve v optičnih vozliščih, ki lahko predstavljajo povišanje zakasnitve za več kot 50%.

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Vesoljski segment

- medsatelitske zveze

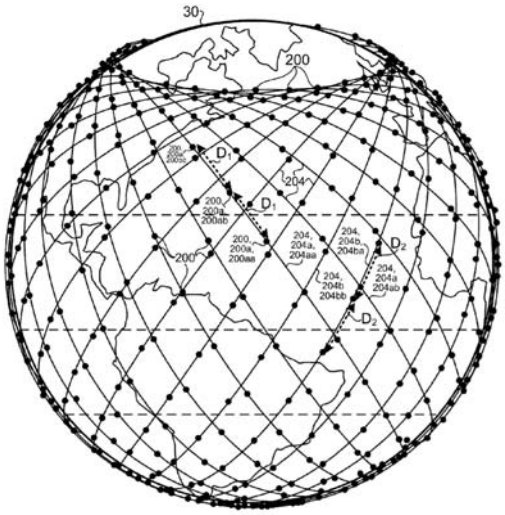


- obhodni čas

$$T = 2\pi\sqrt{\frac{a^3}{\mu}} = 2\pi\sqrt{\frac{(550 \text{ km} + 6378 \text{ km})^3}{3,986 \cdot 10^{14} \text{ m}^3/\text{s}^2}} =$$

$$= 5.738 \text{ s} = 95,6 \text{ min} = 1 \text{ ura } 35,6 \text{ min}$$

- 22 satelitov v vsaki od 72 tirnic.



- Patent „Satellite constellation"

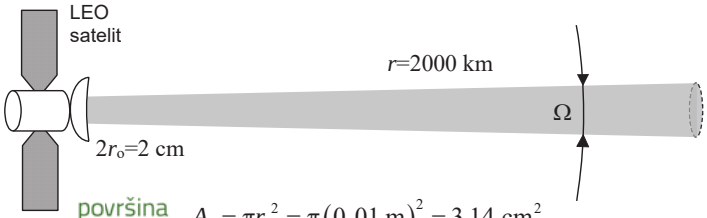
https://patents.google.com/patent/US9973267B2/en

https://www.maxval.com/blog/featured-technologies-starlink-constellation/

Optična medsatelitska zveza

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- Za komunikacijo med satelitoma na razdalji 2000 km se uporablja optična zveza v praznem prostoru (angl. free-space optic – FSO) na valovni dolžini 1550 nm. Svetloba izhaja iz oddajnika s premerom zrcala 2 cm.



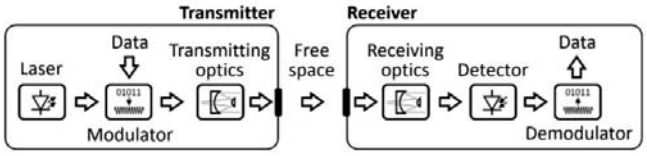
površina oddajnika $A_o = \pi r_o^2 = \pi (0{,}01\ \text{m})^2 = 3{,}14\ \text{cm}^2$

prostorski kot $\Omega = \frac{4\pi}{D_o} = \frac{4\pi}{1{,}6 \cdot 10^9} = 7{,}6 \cdot 10^{-9}\ \text{srd}$

$A_S = r^2 \Omega = (2 \cdot 10^6\ \text{m})^2 \cdot 7{,}6 \cdot 10^{-9}\ \text{srd} = 3 \cdot 10^4\ \text{m}^2$ osvetljeno območje

$2r_S = 2\sqrt{\frac{A_S}{\pi}} = 2\sqrt{\frac{30000\ \text{m}^2}{\pi}} = 197\ \text{m}$

smernost oddajnika $D_o = \frac{4\pi}{\lambda^2} A_o = \frac{4\pi}{(1550\ \text{nm})^2} \cdot 3{,}14\ \text{cm}^2 = \underline{\underline{1{,}6 \cdot 10^9}}$



vir: Carrasco-Casado A., Mata-Calvo R. (2020) Space Optical Links for Communication Networks. In: Mukherjee B., Tomkos I., Tornatore M., Winzer P., Zhao Y. (eds) Springer Handbook of Optical Networks. Springer Handbook. Springer, Cham. https://doi.org/10.1007/978-3-030-16250-4_34



- 1,7 Tbit/s preko 10,4 km z "on-off-keying" leta 2016
- 13,16 Tbit/s preko 10,4 km z 16-QAM leta 2017

vir: https://www.dlr.de/kn/en/desktopdefault.aspx/tabid-8112/13915_read-35337

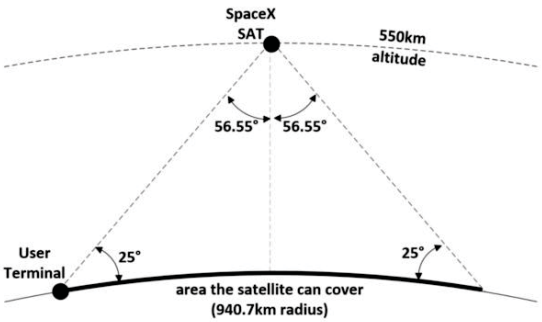
vir: https://www.tesat.de/products

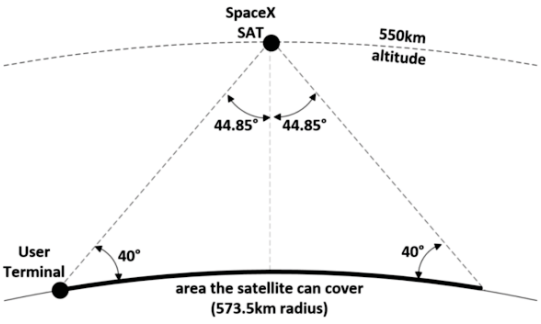
Geografsko pokrivanje satelita Starlink na višini 550 km

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$v = \sqrt{\frac{\mu}{a}} = \sqrt{\frac{3{,}986 \cdot 10^{14}\ \text{m}^3/\text{s}^2}{(550 + 6378) \cdot 10^3\ \text{m}}} = \underline{7585\ \text{m/s}}$

$T = 2\pi\sqrt{\frac{a^3}{\mu}} = 2\pi\sqrt{\frac{(550\ \text{km} + 6378\ \text{km})^3}{3{,}986 \cdot 10^{14}\ \text{m}^3/\text{s}^2}} = 1\ \text{ura}\ 35{,}6\ \text{min}$

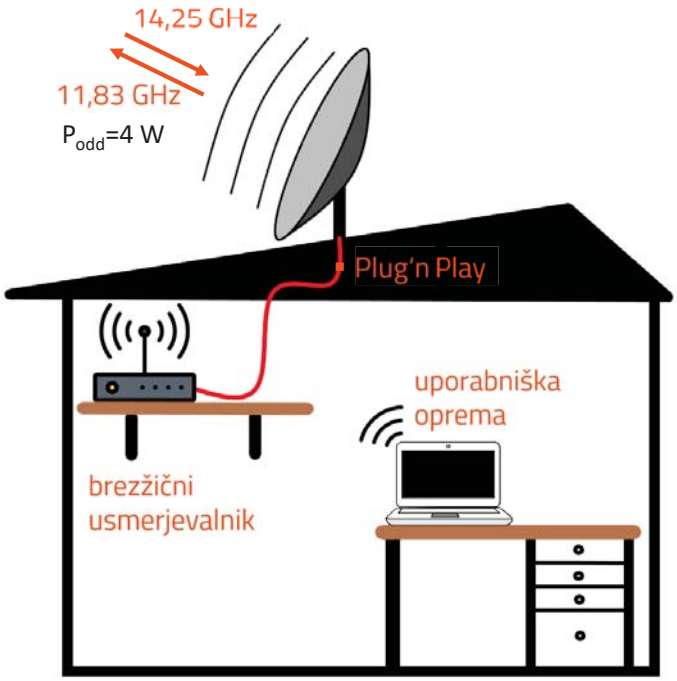




- satelit je uporabniku na razpolago slabih 5 minut
- maksimalno zakasnitev do satelita znaša 3,75 ms

- satelit je uporabniku na razpolago slabe 3 minute

Zemeljski segment





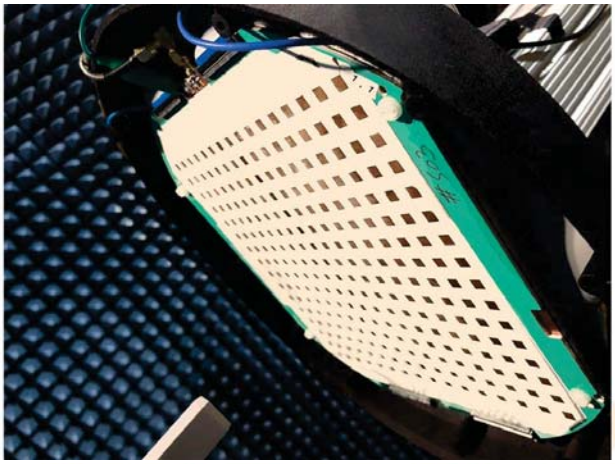
- satelitski krožnik premera 48 cm



- mehansko vrtenje na grobo
- fino električno krmiljenje antenskega snopa

Terminal sistema Starlink

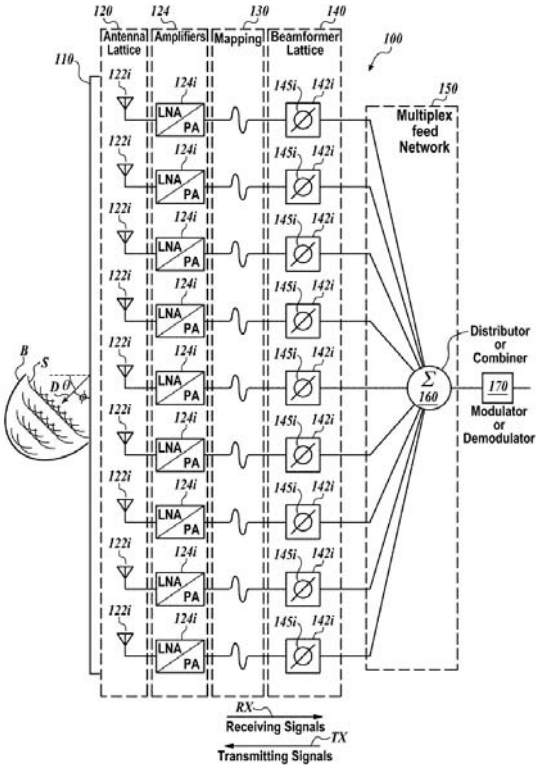
- antensko polje s faznimi sukalniki



- antensko skupino tvori več kot 200 elementov

Uni-Dimensional Steering of Phased Array Antennas
https://patents.google.com/patent/US10770790B1/en

Beamformer lattice for phased array antennas
https://patents.google.com/patent/US20190253125A1/en



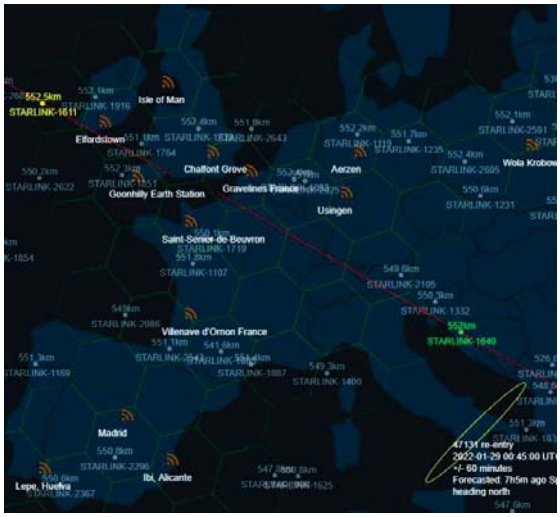
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Zemeljske postaje

- Zemeljski prehod (angl . gateway)
- 26,5 – 40 GHz







https://satellitemap.space

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Zaključki

- Večino globalnega internetnega prometa bo nemogoče prevzeti.
- Starlink ne bo primeren za gosto poseljena področja (priznava Elon Musk), ker si zmogljivost enega satelita deli preveč uporabnikov.
- Zakasnitve v omrežju niso resen problem:
  - Sateliti so na nizki tirnici (bližnje kot Stuttgard).
  - Hitrost EM valovanja je večja, kot po optičnem vlaknu.
  - Na vmesni poti bo manj vozlišč kot pri optičnem omrežju. Sateliti ne bodo delovali kot klasična vozlišča na Zemlji, ki pridelajo veliko zakasnitve na račun usmerjanja paketa. Usmerjevalni algoritmi bodo vnaprej poznani.
- Starlink bo reševal tudi ozko grlo v sedanjem omrežju, ki so zadnji metri do uporabnika.
- Starlink bo globalno internetno omrežje, ki bo prevladujoče (dominantno) v svojem segmentu.
- Odpirajo se tudi nove možnosti uporabe satelitov Starlink (določanje položaja s pomočjo Dopplerjevega pojava).

Komunikacijske tehnologije IoT

IoT communication technologies

Boštjan Snoj

A1 Slovenija

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Povzetek

Za komunikacije med napravami v internetu stvari je na voljo več različnih radijskih tehnologij. Vsaka ima lahko svoje prednosti in slabosti. Izbor je močno odvisen od namena uporabe in naših zahtev. V ospredje bomo postavili tehnologije NB-IoT, LTE-M in prihajajoči NR-RedCap, ki jih pri zagotavljanju povezljivosti uporabljamo mobilni operaterji. Pogledali si bomo tehnološke razlike med njimi, kako jih umestiti v različne načine uporabe in kako primerne za prihodnost so obstoječe tehnologije in delujoče rešitve, ter katere so nove tehnologije, ki širijo obzorja povezovanja IoT naprav. Za marsikatero podjetje je radijski del IoT napravic novo področje, ki ga težje obvladujejo. V ospredje ponovno prihaja znanje o načrtovanju in izdelavi strojne opreme (HW), saj specifične zahteve uporabe zahtevajo prilagojeno oblikovanje napravic. Kako se spopadamo z njimi? Kaj vse nam ponujajo zaledni sistemi, da nove IoT napravice kar najhitreje lahko spravimo v uporabo? Kako smo omejeni s podatki in na kaj moramo misliti v procesu, ko prehajamo iz koncepta v produkcijsko fazo?

Abstract

Several different radio technologies are available for communication between devices in the world of Internet of Things. Each can have its advantages and disadvantages. The choice strongly depends on the purpose of use and our requirements. We will focus on NB-IoT, LTE-M and the upcoming NR-RedCap technologies used by mobile operators to provide connectivity. Differences between them are crucial to properly place them in different use cases. Major question is also how future proof are existing technologies already. What bring new technologies that expand the usability of IoT world? Radio part of IoT devices is a new area of development for many companies. Know-how about hardware design for radio devices is a must in IoT world. How do we face that fact? What do back-end systems offer us to get new IoT devices up and running as quickly as possible? How limited are we with amount of data and what do we need to think about in the process moving to production phase?

Biografija avtorja



Boštjan Snoj je vodilni ekspert na področju interneta stvari v podjetju A1 Slovenija. Od leta 2000 deluje na področju telekomunikacij. Ima večletne izkušnje na razvojnem in integracijskem področju fiksnih in mobilnih komunikacij, vezane na projekte v tujini. Nekaj let bil del razvojne ekipe, ki je razvijala telekomunikacijske produkte za Siemens Communications. Kasneje je prešel v sektor za podporo in integracije telekomunikacijskih rešitev. V zadnjem

času se ukvarja s tehnologijami IoT na področju mobilnih komunikacij.

Author's biography

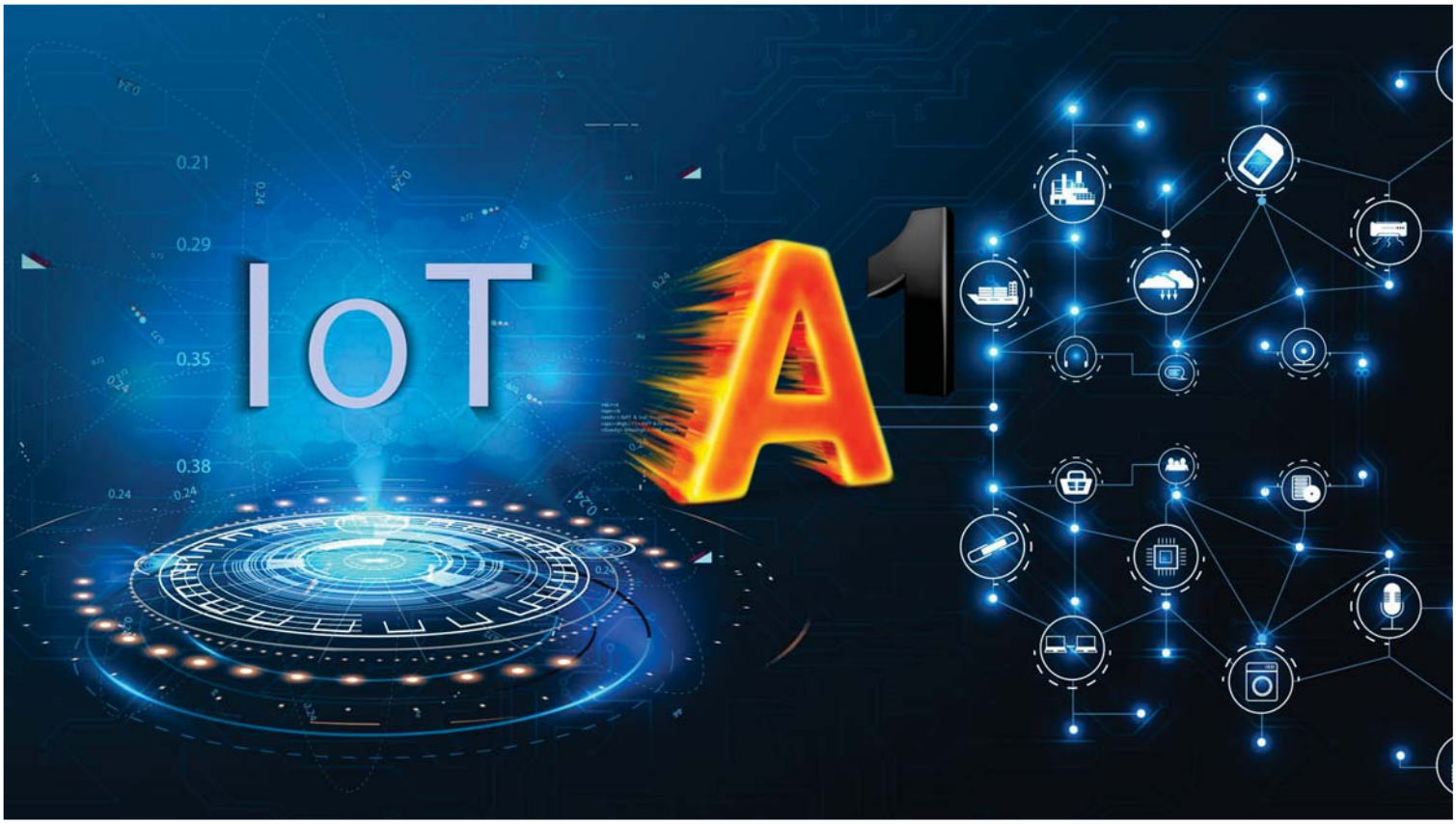
Bostjan Snoj *is Lead Internet of Things Expert (IoT). He has been working in telecommunications sphere since 2000. He gained years of experience in telecommunication software development and solution integration for fixed and mobile communications, related to projects abroad. He was part of the development team that developed telecommunications products for Siemens Communications for several years. Later he moved to the solutions support and integration sector. Currently he is working on mobile IoT technology at A1 Slovenia.*



IoT Radio Communication Technologies

Boštjan Snoj

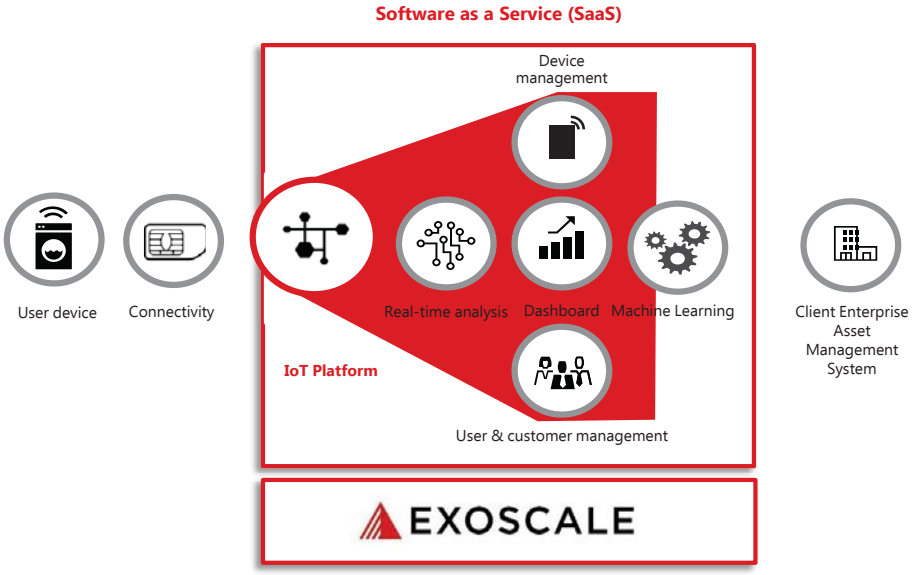
▪ A1 Slovenia

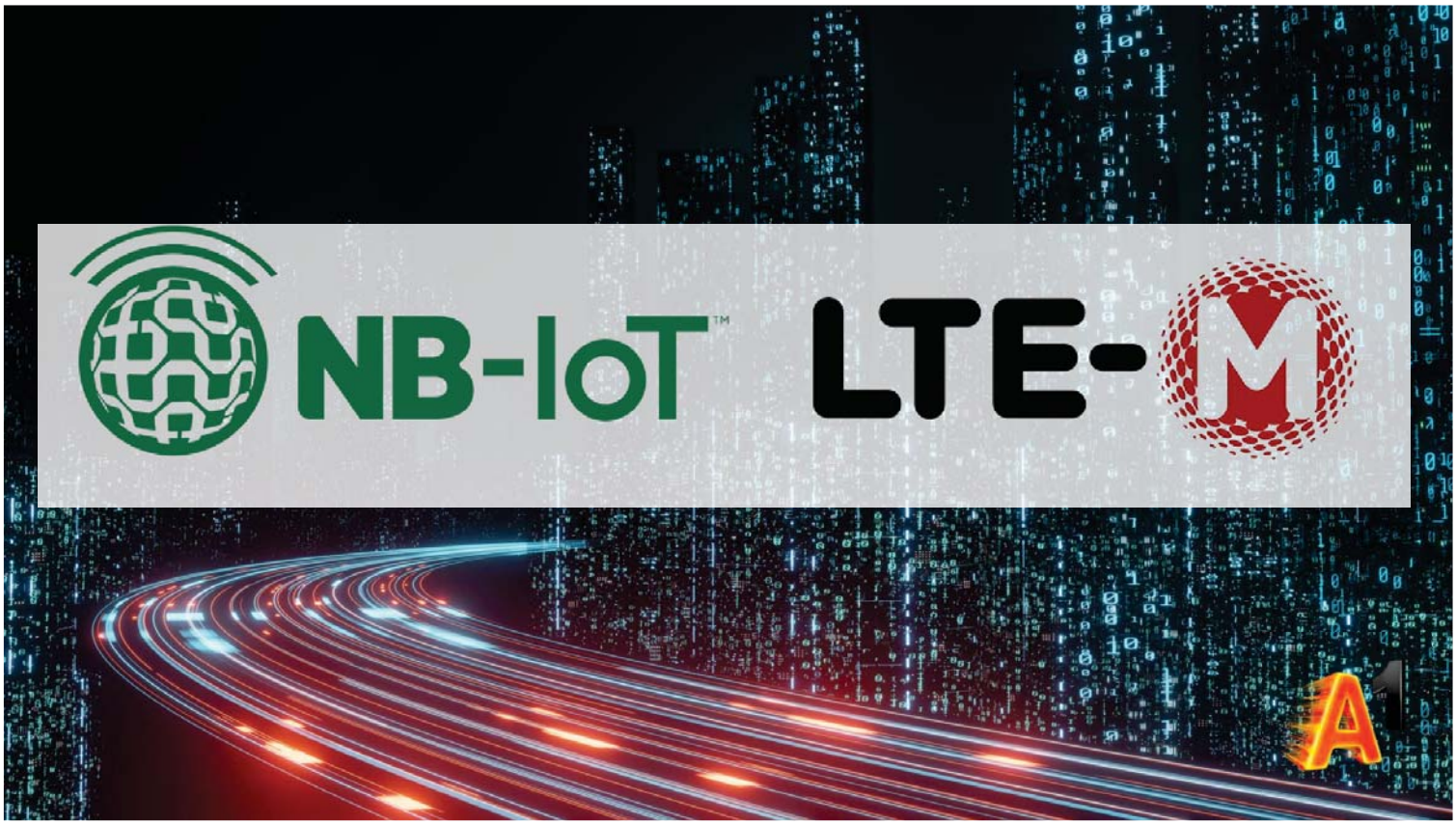




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A1 Digital Stack

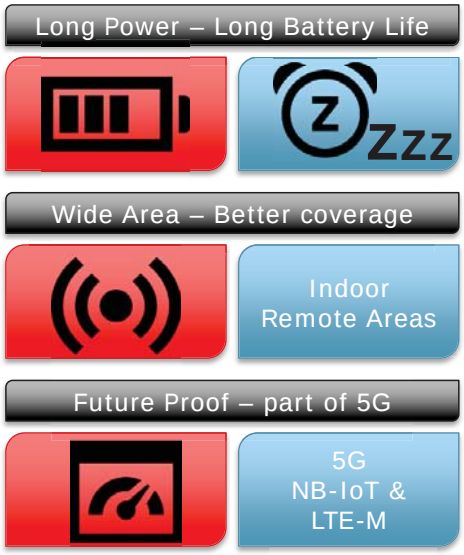


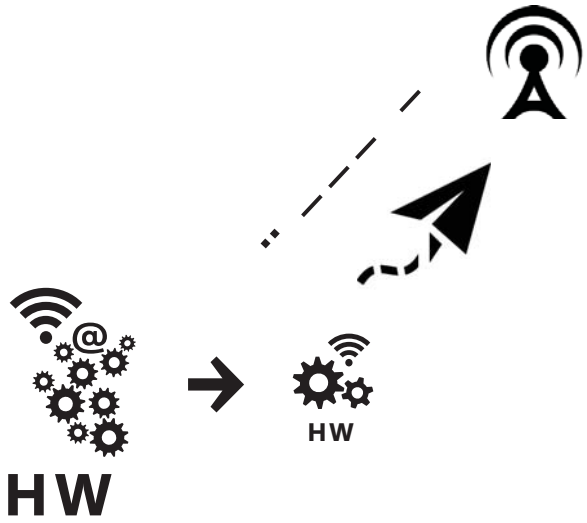

NB-IoT
LTE-M


2G
3G
4G
5G
6G
MOBILE
NETWORK
Future is in
„RedCap“

IoT Radio Communication Technologies

Key benefits of NB-IoT and LTE-M





IoT Radio Communication Technologies

Basic definitions, what are NB-IoT and LTE-M

- Cellular IoT: 2G, 3G, 4G, NB-IoT, LTE-M
- NB-IoT and LTE-M are both cellular technologies standardized by 3GPP,
- both are developed for Low Power Wide Area Network (LPWAN) type of devices,
- usually battery powered (Low Power),
- having in mind longer range and deeper in-house penetration (Wide Area),
- both are part of 4G technology,
- and will continue to be the basic IoT technologies in the 5G (future proof).

- From cost perspective: low price because of low module complexity.
- Both inherit privacy and security policy to which we are used to from LTE.
- Number of IoT devices foreseen tens of billions till 2025

IoT Radio Communication Technologies

Basic definitions, what are NB IoT and LTE-M

- Both are suitable technologies for M2M solution development,
- are designed for low data transfer rates,
- used to operate in hard reaching areas / environments,
- replacing 2G and 3G technologies.
- Both use operator‘s licensed spectrum,
- which can guarantee QoS,
- 3GPP Release 14 compliant in A1 network (feature reach).

Looks like they are mirror image one of the other? Right?

- Let‘s find key differences among all common features.

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Voice over LTE and SMS

	NB-IoT	LTE-M
VoLTE	No	Yes (Provider specific)
SMS	Yes	Yes
Mobility support	No	Yes
Bands	B3, B20	B3, B20
In-house penetration	Excellent	Good

- VoLTE If needed it will be available at A1 network.
- Mobility: no handover for NB IoT!

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Transfer Rate and Bandwidth

	NB-IoT	LTE-M
Bandwidth	180kHz	1,4MHz
Speed DL	<100kbps	300kbps
Speed UL	<100kbps	370kbps

- Use Case dependant! Think about how to reduce amount of data to transfer!

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Key differences between NB-IoT and LTE-M

- Network

	NB-IoT	LTE-M
Number of Connections	Max every 15min	No limit
Connection mode	Half Duplex	Full Duplex
Latency	1s – 60s	50-100ms
Standard IP protocols	No	Yes
Need for special protocols	Yes	No need

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Functions

	NB-IoT	LTE-M
Static IP V4	Yes	Yes
S2S VPN	Yes	Yes
Private Radius	Yes	Yes
IP V6 support	Available soon in A1 network	Available soon A1 network

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Functions

	NB-IoT	LTE-M
Remote control	Yes/No (UC dep.)	Yes
Firmware updates	No	Yes
Grow with UCs	No	Yes

- Remote control for some non critical actions available in NB-IoT.
- Small speed and protocol specific requests in NB-IoT restrict FW upgrades.
- Since no updates available, it is not possible to grow with Use Cases

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Reference Signals Received Power (RSRP)

	NB-IoT	LTE-M
RSRP Excellent Signal Strength	>-90 dBm	>-85 dBm
RSRP Good Signal Strength	-90 dBm to -105dBm	-86 dBm to -100 dBm
RSRP Fair Signal Strength	-106 dBm to -116 dBm	-101 dBm to -112 dBm
RSRP Poor Signal Strength	-117 dBm to -121 dBm	-113 dBm to -120 dBm
RSRP Dead Signal Strength	<-122 dBm	<-121 dBm

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Reference Signal Received Quality (RSRQ)

	NB-IoT	LTE-M
RSRQ Excellent Signal Quality	>-9 dB	>-9 dB
RSRQ Good Signal Quality	-9 dB to -12 dB	-9 dB to -12 dB
RSRQ Fair to Poor Signal Quality	<-13 dB	<-13 dB

IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

- Functions

	NB-IoT	LTE-M
First focus - Europe	Yes	
Secondary focus - Europe		Yes
First focus – North America		Yes
Secondary focus - North America	Yes	
First focus - Asia	Yes	
Secondary focus - Asia		Yes

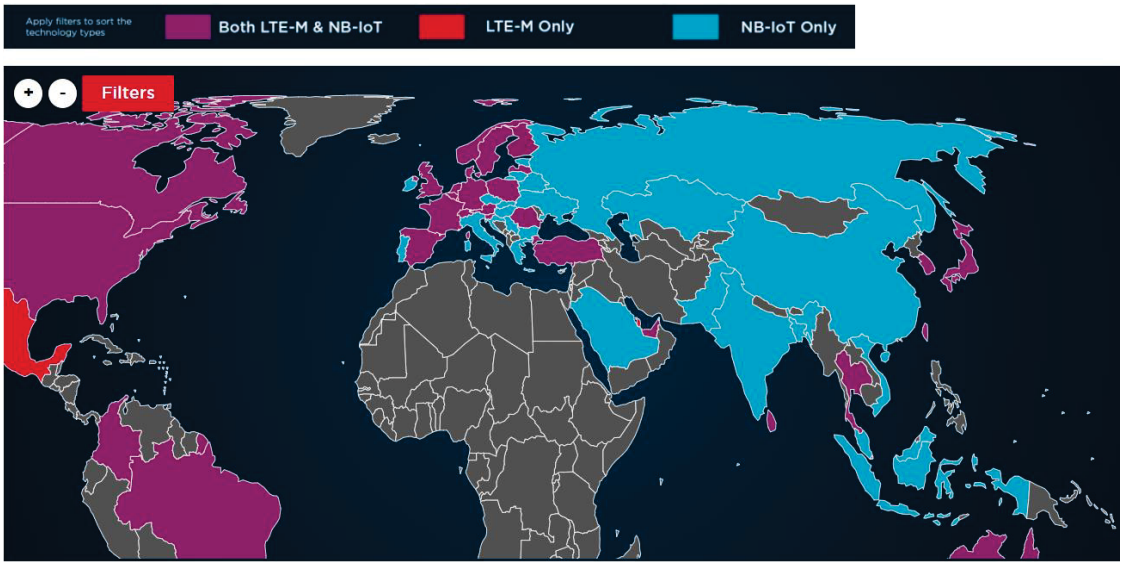
IoT Radio Communication Technologies

Key differences between NB-IoT and LTE-M

	Firmware update	Grow with use case	Indor penetrat.	Remote controll	Voice available	Battery life	Mobility support	Price
LTE-M	•••	•••	••	•••	•••	••	•••	••
NB-IoT	•	•	•••	••		•••	•	•••

IoT Radio Communication Technologies

Mobile IoT Deployment Map (source: GSMA, Jan 2022)



Source: https://www.gsma.com/iot/deployment-map

IoT Radio Communication Technologies

Typical mistake when deciding NB-IoT or LTE-M
TCP for NB-IoT

- **Using TCP protocol for NB-IoT technology**
  - NB-IoT in theory supports both TCP and UDP protocols. But this is misleading!
  - NB-IoT facts:
    - High Latency
    - Half Duplex connection
    - UE attach delays
  - TCP facts:
    - sensitive to delays
    - Sensitive to packet losses during data transmission
    - Slower than UDP
- Solution:
  - If retransmission of lost packets on transport layer is absolutely necessary, than consider moving to LTE-M.
  - Use UDP (and resolve the packet loss on application level if needed).
- A1 measurement: UDP packet loss <1%, TCP packet loss can become quickly over 90%

IoT Radio Communication Technologies

Typical mistake when deciding NB-IoT or LTE-M

- **Server side on UE over NB-IoT technology**
  - It is not battery friendly solution (draining batteries, no deep sleep possible)
  - Delays over the network may result in packet loss during high buffer loads in network
- Solution:
  - Move to LTE-M
  - Redesign the application to have a client on UE side



IoT Radio Communication Technologies

Typical mistake when deciding NB-IoT or LTE-M

- **Sending data in short intervals over NB-IoT**
  - NB-IoT facts:
    - Slow speed
    - Latency
    - No retransmission of lost packets is possible on transport level
  - Data may be generated faster, than we are possible to flush them over NB-IoT
- Solution:
  - Move to LTE-M.
  - Redesign the application not to be so brutal sending data.



IoT Radio Communication Technologies

Good practice



- Use appropriate protocols if working on NB-IoT:
  - CoAP (UDP)
  - (CoAP)/LWM2M (UDP)
  - MQTT-SN (designed to use UDP)
- Reboot:
  - There is a lot of Software running inside User Equipment. Therefore there is no guarantee, that code is bug-free. Consider periodical rebooting if there is a large number of IoT devices with no management option.
- Fall back:
  - Detect abnormal SW behaviour and enable fall-back scenario (wake up in minimal maintenance mode)
- Antenna design:
  - Antenna design is underestimated. Antenna with high gain, optimal radiation diagram is half of a success in harsh RF conditions.

IoT Radio Communication Technologies

Conclusion

- LTE-M will emerge faster and faster since it is easier for application development and maintaining, having always the door open for easy new Use Cases introduction.
- NB-IoT is here now and that is the fact. Since it was available prior to LTE-M in EU, it has a bit of advantage in terms of commercial progress . NB-IoT will stay mainly for the simple applications on larger scale. For example sensors and meters, where functional requirements are firmly defined at the beginning of the project, and are not subject to change and where deeper in-house penetration and wider range is absolutely necessary.
- Think about your Use Case and use appropriate technology. After deploying thousands of IoT devices, there is no way back! Consider even supporting both technologies for the same Use Case.

IoT Radio Communication Technologies

NR-RedCap

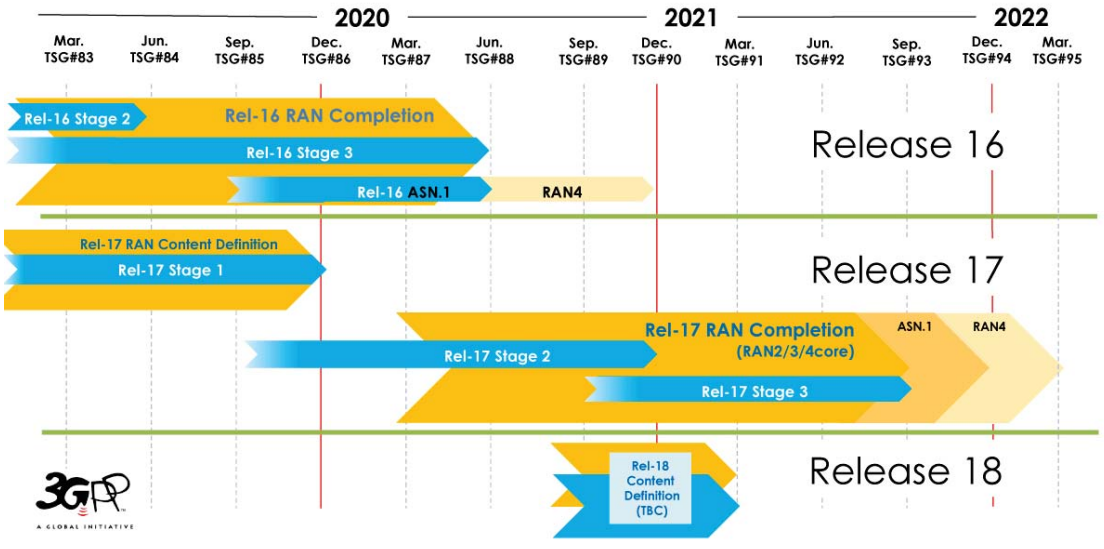


- RedCap = Reduced Capability
- It was first included in one of the 3GPP Release 17 Study Item: "Low complexity NR devices" in June 2019.
- Data transmission rate at least no slower than the LTE Cat-1 standard

IoT Radio Communication Technologies

Release 17, new dates

Source 3GPP: https://www.3gpp.org/images/articleimages/Releases/graphic_version3_SP-200222.jpg



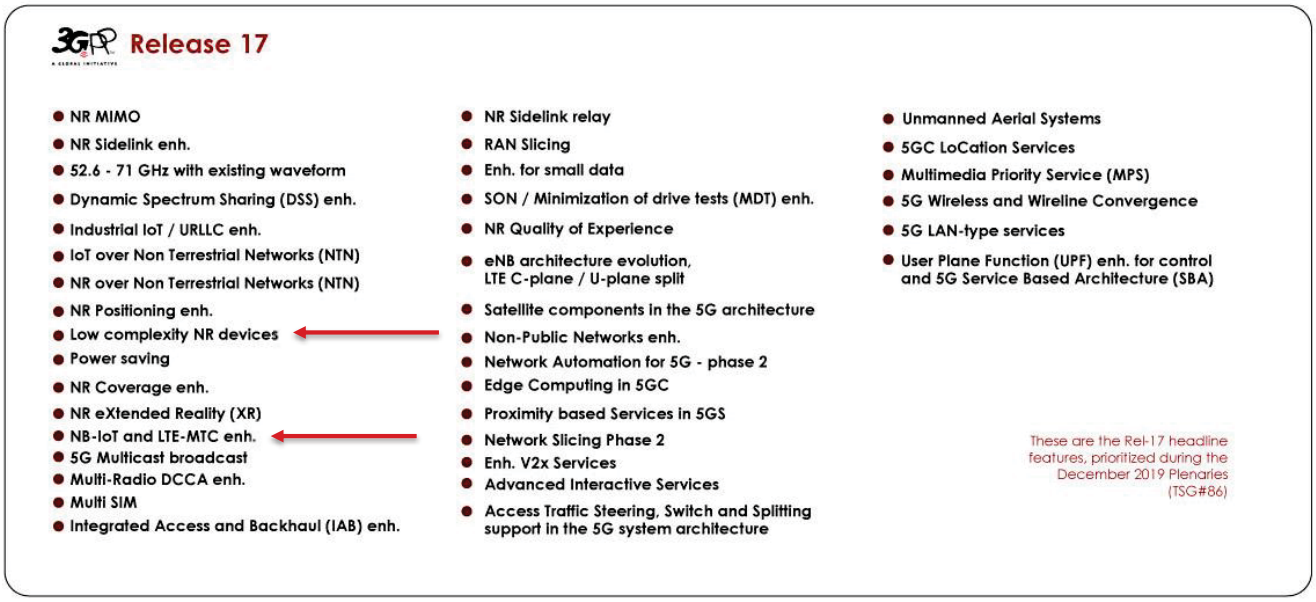
Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

© 3GPP 2020

IoT Radio Communication Technologies

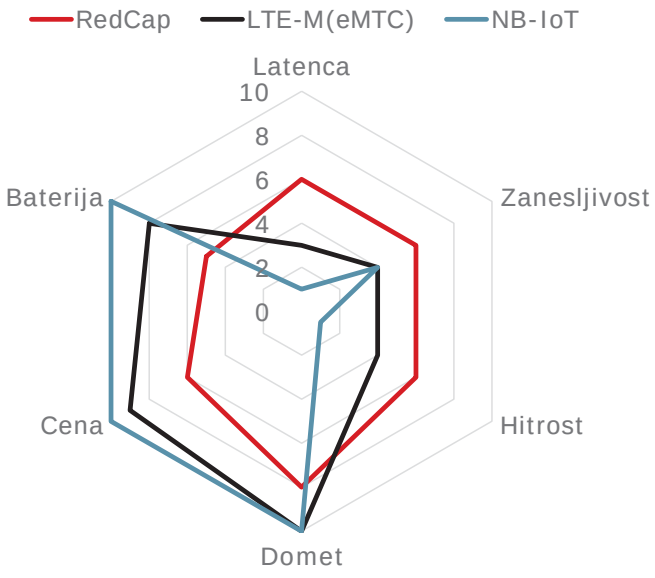
Release 17 - Functionalities

vir: 3gpp https://www.3gpp.org/images/articleimages/Releases/rel_17_v2.jpg



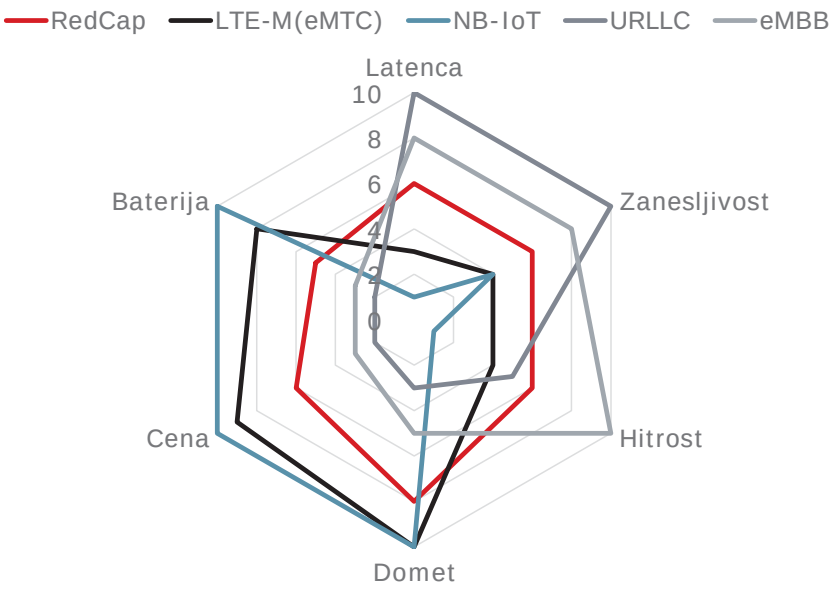
IoT Radio Communication Technologies

Spider Diagram RedCap, LTE-M, NB-IoT



IoT Radio Communication Technologies

Spider Diagram RedCap, LTE-M, NB-IoT



IoT Radio Communication Technologies

RedCap missing elemnt



- Industrial sensors – need for low latency (5-10ms): pressure sensors, motion sensors, accelerometers, and actuators
- Surveillance cameras: smart cities, factories
- Wearables: smartwatches, rings, e-health related devices, and medical monitoring devices

IoT Radio Communication Technologies

A1 IoT Platform - Cumulocity

CUMULOCITY IoT



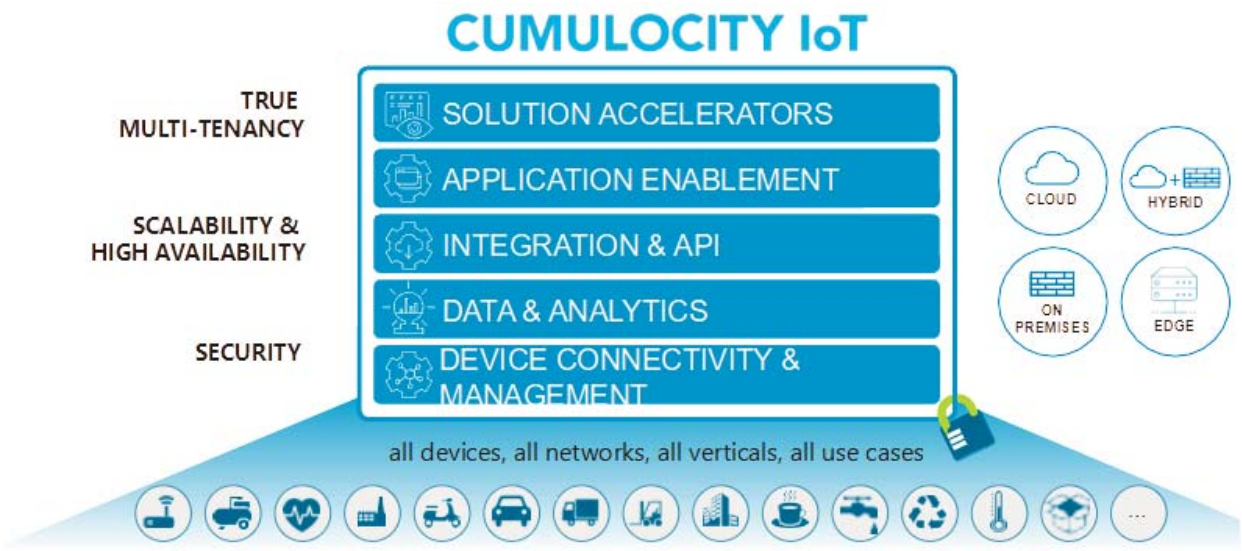
- Welcome to the stress-free IoT platform! Cumulocity IoT was built from the ground up to be open, rapid to deploy and distributed. You can connect any "thing" and get started in minutes. Simplify with one architecture—from the edge to cloud and on-premises. Monitor and respond to IoT data in real time. No coding needed!



IoT Radio Communication Technologies

A1 IoT Platform - Cumulocity

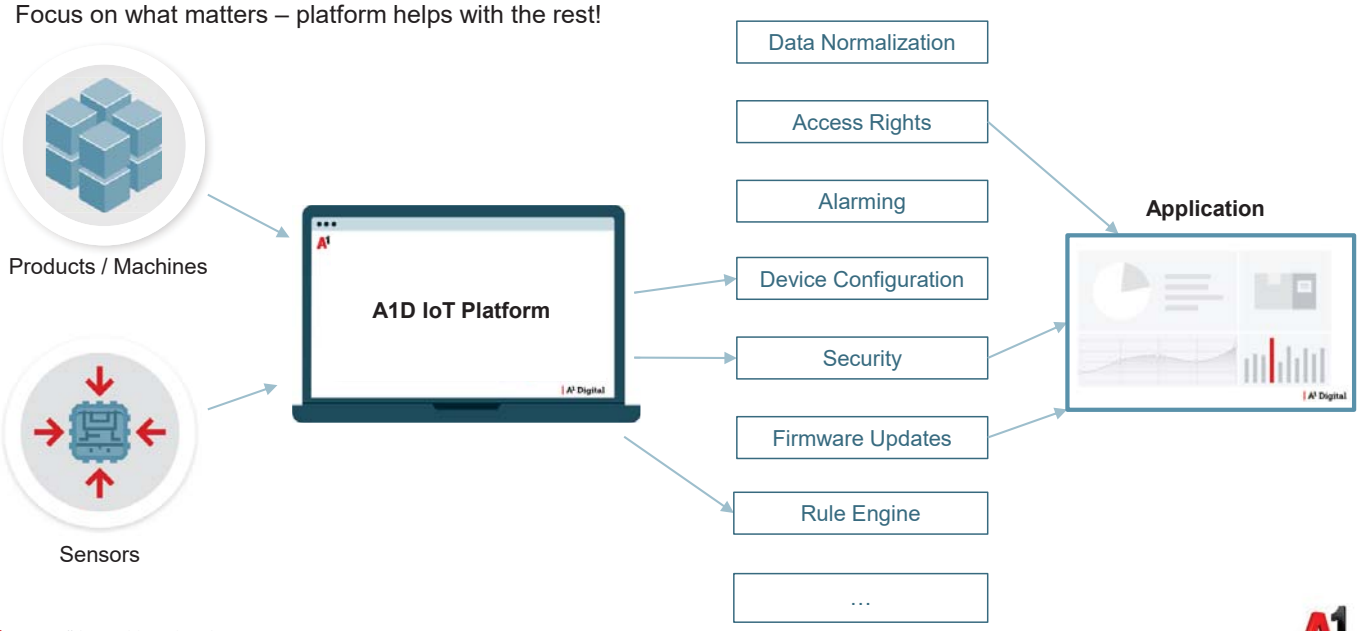
CUMULOCITY IoT



IoT Radio Communication Technologies

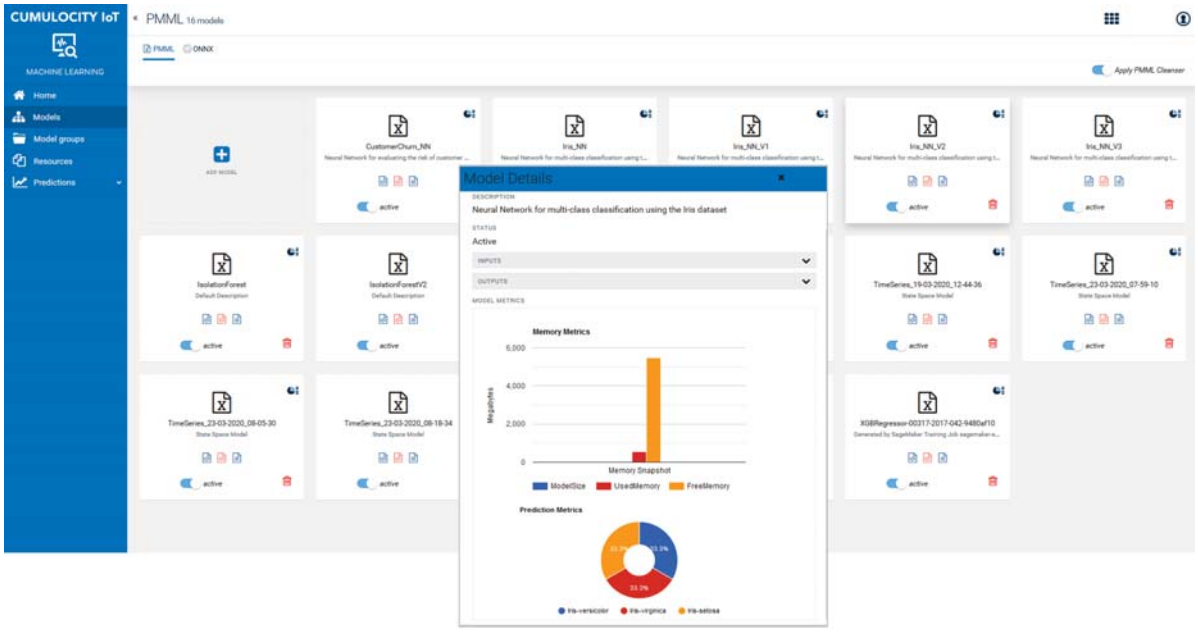
A1 IoT Platform - Cumulocity

- Focus on what matters – platform helps with the rest!



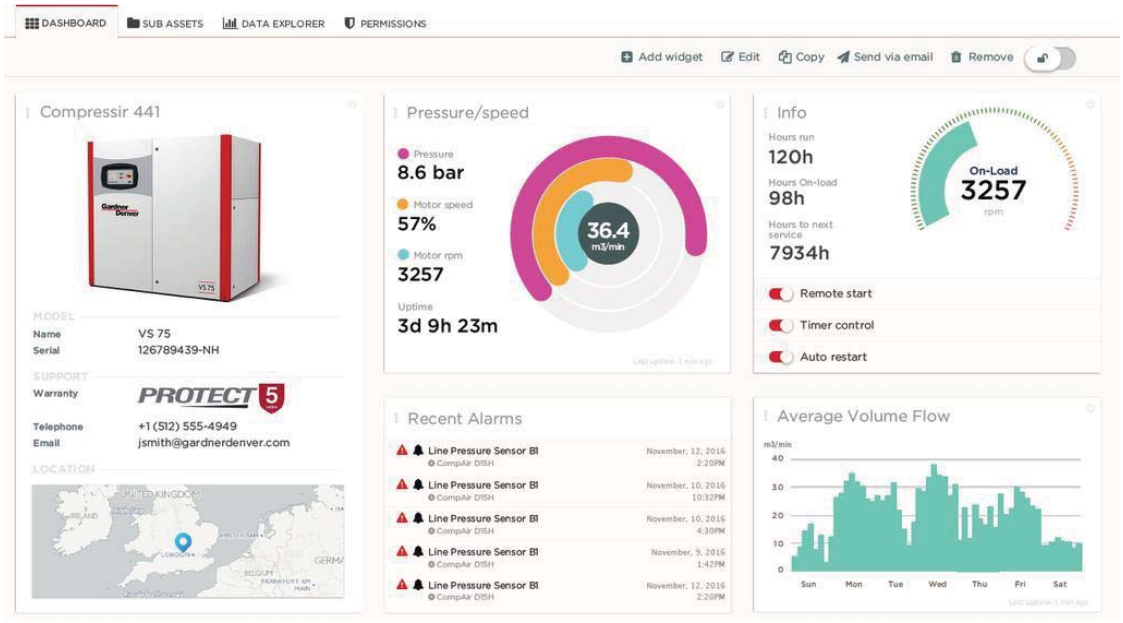
IoT Radio Communication Technologies

A1 IoT Platform - Cumulocity



IoT Radio Communication Technologies

A1 IoT Platform - Cumulocity



IoT Radio Communication Technologies

A1 Machine Learning Platform



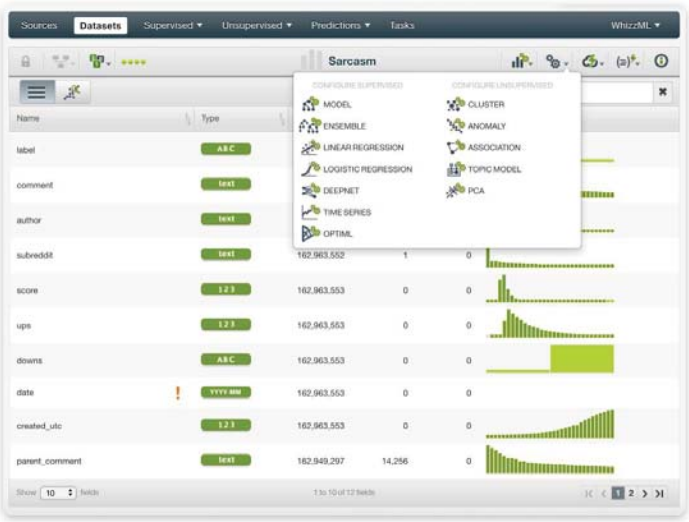
IoT Radio Communication Technologies

Comprehensive Machine Learning Platform

BigML provides a selection of robustly-engineered Machine Learning algorithms proven to solve real world problems by applying a single, standardized framework across your company.

Supervised Learning: classification and regression (trees, ensembles, linear regressions, logistic regressions, deepnets), and time series forecasting.

Unsupervised Learning: cluster analysis, anomaly detection, topic modeling, association discovery, and Principal Component Analysis (PCA).



IoT Radio Communication Technologies

Interpretable & Exportable Models

All predictive models on BigML come with an interactive visualization and explainability features that make them interpretable. They can be exported and used to serve local, offline predictions on any edge computing device or be instantaneously deployed as part of distributed, real-time production applications.

Interpretable: Visualizations such as Partial Dependence Plots effectively generate and display thousands of model predictions at a glance while Prediction Explanations and Field Importances shed light on factors driving individual predictions.

Exportable: BigML models are fully exportable via JSON PML (and PMML) and can be used from all popular programming languages. This means you can seamlessly plug your models into your web, mobile or IoT applications or services such as Google Sheets, Amazon Echo, Zapier, and more.



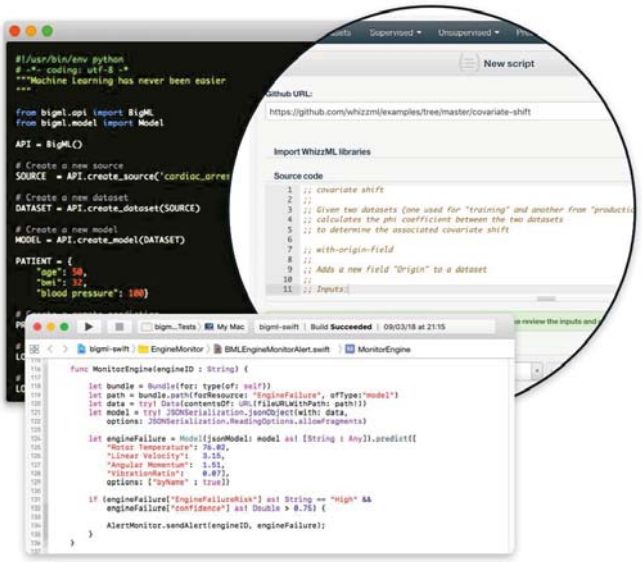
IoT Radio Communication Technologies

Programmable & Repeatable

As an "API-first" company, BigML brings every new feature first to the REST API. Bindings & libraries are available for all popular languages, including Python, Node.js, Ruby, Java, Swift, and more.

Reproducible: BigML's granular record keeping and transparency are crucial to meet regulatory and audit compliance requirements yet are often completely overlooked in other Machine Learning tools.

Traceable: All resources on BigML are immutable and stored with a unique ID and the creation parameters, which enables you to track any Machine Learning workflow at anytime.



IoT Radio Communication Technologies

Automation

Rapidly bring your predictive modeling tasks to production through effective automation. BigML turns the difficult, time-consuming work of hand-tuning models or executing complex workflows into one-click menu options or single API calls.

OptiML: Automatic optimization for model selection and parameterization of classification and regression algorithms saves you a lot of time by creating and evaluating hundreds of models to find the best performing ones.

WhizzML: A domain-specific language for automating complex workflows, implementing high-level Machine Learning algorithms, and easily sharing them with others.

Scriptify: Convert your workflows into reusable scripts in a single click.



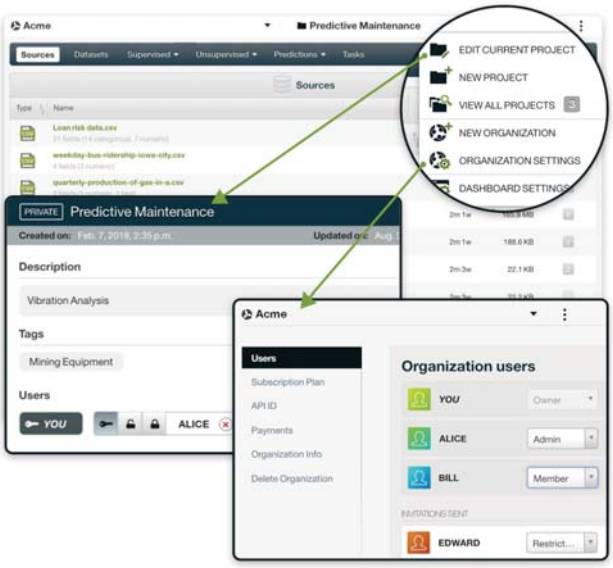
IoT Radio Communication Technologies

Collaboration

Share your Machine Learning resources using granular team and project management capabilities. BigML is a transparent, collaborative platform for all members of your organization, from analysts and developers, to engineers and executives.

Organizations: Effectively adopt Machine Learning across your entire corporate structure. With BigML organizations, the Dashboard is a shared workspace where users can access the same projects and resources with specific roles and permissions.

Projects: All resources in an organization exist within projects, which can be public or private. Assign user permissions according to the needs of each project, allowing other members to manage, create, or simply view resources.



IoT Radio Communication Technologies

Flexible Deployments

Have tons of data? Need to provide access to everyone in your organization? Don't fret, all your bases are covered on BigML with options for multi-tenant and single-tenant versions on the cloud or on-premises. BigML can be ported to any cloud provider or to a Virtual Private Cloud, with fully-managed and self-managed versions.

BigML Lite: Fast track to value for companies ready to implement their first production use cases.

BigML Enterprise: Full-scale access for companies ready to adopt Machine Learning across departments.

Auto-scalable: All deployment methods utilize BigML's smart infrastructure that automatically adjusts resources to seamlessly meet computational needs in the most cost effective manner.



IoT Radio Communication Technologies

Hardware – Antenna is the most important part

Cellular Antennas

QUECTEL

	LTE (4G)	5G	5G (Mid-High Bands)
Internal/ Embedded	YC0001AA YC0002AA YC0003AA YC0017BA YF0022AA YFCA002AA	YP0009CA YF0020AA 5G SMD YC0018 YF0002AA YF0002DA	YP0009AA YP0009BA YF0017AA YF0017BA YF0002BA YF0002CA
External-Direct Mount	YCN001AA YE0002AA YE0013AA YGL001AA	YE0001BA YE0003AA YE0007AA YE0025AA	5G mmWave YM0012AA RA510TRWAA-N00-NNNNA
External-Cabled	YB0010AA YB0016AA YE0006AA YE0010AA YE0021AA YE0029AA	YE0027AA YE0028AA YE0037AA YXH001AA	
External-Cabled Combo	YB0015AA (LTE + GNSS + Wi-Fi) YB0031AA (LTE +GNSS) YB0033AA (LTE x 2 + GNSS)	YB0006AA (7in1) YB0007xx (5Gx4)	

IoT Radio Communication Technologies

Hardware – Antenna is the most important part

Customized Antenna Technologies

QUECTEL

LDS (Laser Direct Structuring)

- The prevailing antenna manufacturing technology on the market
- High design flexibility but double-curved surface not possible
- SMT component integration possible
- Can be more expensive than FPC and Sheet Metal
- Short design cycle (Samples with 7 days turnaround after design)



FPC (Flexible Printed Circuit)

- Traditional antenna manufacturing technology
- Cost-effective
- Can be integrated with spring contacts for ease of assembly
- Limited layout complexity
- Cost between that of Sheet Metal and LDS
- Sample manufacturing cycle time in 7 days

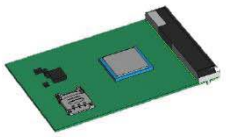
Sheet Metal

- The most capable 3D antenna manufacturing technology on the market
- Design flexibility guaranteed
- Antenna volume and RF performance improved
- Conformal geometric designs with chassis
- Low assembly cost
- High yield
- Higher tooling cost than that of FPC and LDS

IoT Radio Communication Technologies

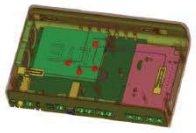
Hardware – Antenna is the most important part

Customized Antenna Design Process



Concept

- Architecture Review
- Antenna Placement
- Antenna Layout



ME Design

- Antenna Design
- Gerber File Review
- Antenna System Design & Optimization



Sample

- Engineering Sample
- Antenna Integration
- Noise Debugging
- Performance Optimization



Test

- RF Test
- OTA Test



Manufacture & Deliver

- Assembly Production
- Manufacture Test
- Packaging and Supply

IoT Radio Communication Technologies

Hardware – Most Popular Module

BG95 Series Specifications 1



23.6 mm × 19.9 mm × 2.2 mm

Cat M1/Cat NB2/EGPRS

Package: 102-pin LGA

Supply Voltage ①: 2.6–4.8 V, typ. 3.3 V (BG95-M1/-M2)
3.3–4.3 V, typ. 3.8 V (BG95-M3/-M5/-M6/-MF)
3.2–4.2 V, typ. 3.8 V (BG95-M4)

Data Rate:

- LTE Cat M1: Max. 588 kbps (DL), Max. 1119 kbps (UL) (Half Duplex)
- LTE Cat NB2: Max. 127 kbps (DL), Max. 158.5 kbps (UL)
- EGPRS: Max. 296 kbps (DL), Max. 236.8 kbps(UL)
- GPRS: Max. 107 kbps (DL), Max. 85.6 kbps (UL)

Protocols: PPP/ TCP/ UDP/ SSL/ TLS/ FTP(S)/ HTTP(S)/ MQTT/ LwM2M/ CoAP/ IPv6

Functions: Data/ VoLTE/ GNSS/ DFOTA/ NITZ/ PING/ Jamming Detection/ Triangle Location

Interfaces: (U)SIM/ eSIM ②/ UART/ USB/ I2C/ PCM/ ADC/ GPIO/ GRFC/ Antenna

Power Consumption (Typical): 3.9 μA @ PSM (USB and UART disconnected), BG95-M3

** means under development*
① please refer to the hardware design manual for more specific requirements on power supply voltage.
② eSIM is reserved and not included by default.

IoT Radio Communication Technologies

IoT Hardware for Devices



Give Away SRK 2022 !!

Thank you!

POSKENIRAJ KODO IN SI
SPRAVI KONTAKT TELEFON

Boštjan Snoj
Lead Internet of Things Expert (IoT)
@ bostjan.snoj@A1.si
A1 Slovenija, d. d.
Ameriška ulica 4
SI - 1000 Ljubljana

Primerjava arhitekturnih nivojev 4G/VoLTE in 5G/VoNR

Comparison of 4G/VoLTE and 5G/VoNR architectural levels

Božo Mišović

ZENLAB, d. o. o.

bozo.misovic@zenlab.si

Povzetek

Pogosto pozabljamo, da je je naš mobilni žepni računalnik („pametni telefon“), ki ga nosimo naokoli, še vedno v uporabi tudi kot „telefon“, ki je namenjen pogovorom. Prvotna brezžična mobilna omrežja so bila dizajnirana za prenos govora, kot je bil na primer analogni NMT450 (govor/1Kbps). Kasneje so se razvili digitalni javni mobilni sistemi, ki se še danes uporabljajo tudi za kritične aplikacije v realnem času. To so 2G (SMS/10Kbps), 3G (Video/64Kbps), 4G (1Gbps), 5G (10Gbps), kmalu pa lahko pričakujemo tudi 6G (1Tbps). Zgrajena mobilna omrežja so prilagojena ključnim in zanesljivo nadzorovanim, visoko kvalitetnim in robustnim govornim storitvam.

Abstract

We often forget that the mobile computer we carry around in our pockets is still referred to as a 'phone'. Wireless networks were first designed for voice, and it remains a critical real-time application today. Building a network that can adapt is crucial in managing reliable, high-quality and robust mobile voice services.

Biografija avtorja

Božo Mišović je leta 1977 diplomiral na Fakulteti za elektrotehniko v Ljubljani, smer Telekomunikacije. Prvo delovno razmerje je nastopil v podjetju Iskra Elektrozveze, na področju domače proizvodnje naprav za data prenos - modemi. V času tržne transformacije podjetij je pomagal pri ustanovitvi podjetja Smartcom, kot tehnični direktor in nadaljeval deset let v podjetju SRC.SI, kot vodja programa za WAN komunikacije. Delo je nadaljeval v podjetju Mobitel (zdaj Telekom Slovenije), kjer je opravljal delo tehničnega strokovnjaka. Od leta 2001 je deloval na uvajanju tehnologij GPRS/UMTS/HSPA/LTE. Od leta 2015 deluje kot zunanji svetovalec v podjetjih Projekt IP, EIMV, Stelkom in sedaj Zenlab.

Author's biography



Božo Mišović *graduated at the Faculty of Electrical Engineering, University of Ljubljana in 1977. His first employment was at Iskra Elektrozveze in 1976. He helped to set-up the new data communications company Smartcom, where he worked as technical director. In 1992, he joined company SRC.SI as WAN support manager where he worked on Novel, Microsoft and Cisco equipment. In 2001 he started to work in company Mobitel (current Telekom Slovenije) on GPRS/UMTS/HSPA/LTE support. He retired in 2015 and then continued working in companies Projek IP, EIMV, Stelkom, and Zenlab as external associate for mobile networks.*

Arhitekturni nivoji 4G/VoLTE vs 5G/VoNR

Božo Mišović
IP Svetovalec za brezžične tehnologije, ZENLAB d.o.o.

Marjana Senčar Srdič
Vodja tehnologij interneta stvari in inovacij, A1 Slovenija d. d.

SRK 2022, Ljubljana

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Brezžične govorne tehnologije:

Draft for internal discussion

Mogoče pogosto pozabimo, da je je naš mobilni žepni računalnik („pametni telefon"), ki ga nosimo naokoli, še vedno uporabljan kot „telefon"/pogovorno! Prvotna brezžična mobilna omrežja, so bila dizajnirana za prenos govora, kot je bil analogni NMT450/govor/1Kbps in novo dizajnirani digitalni javni mobilni sistemi, za danes kritične real-time aplikacije; 2G/SMS/10Kbps, 3G/Video/64Kbps, 4G/1Gbps, 5G/10Gbps, 6G/1Tbps,…. Zgrajena mobilna omrežja so prilagojena ključnim in zanesljivo nadzorovanim, visoko kvalitetnim in robustnim govornim servisom!



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Mobilni telefoni 1G/2G/3G/4G:

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Draft for internal discussion

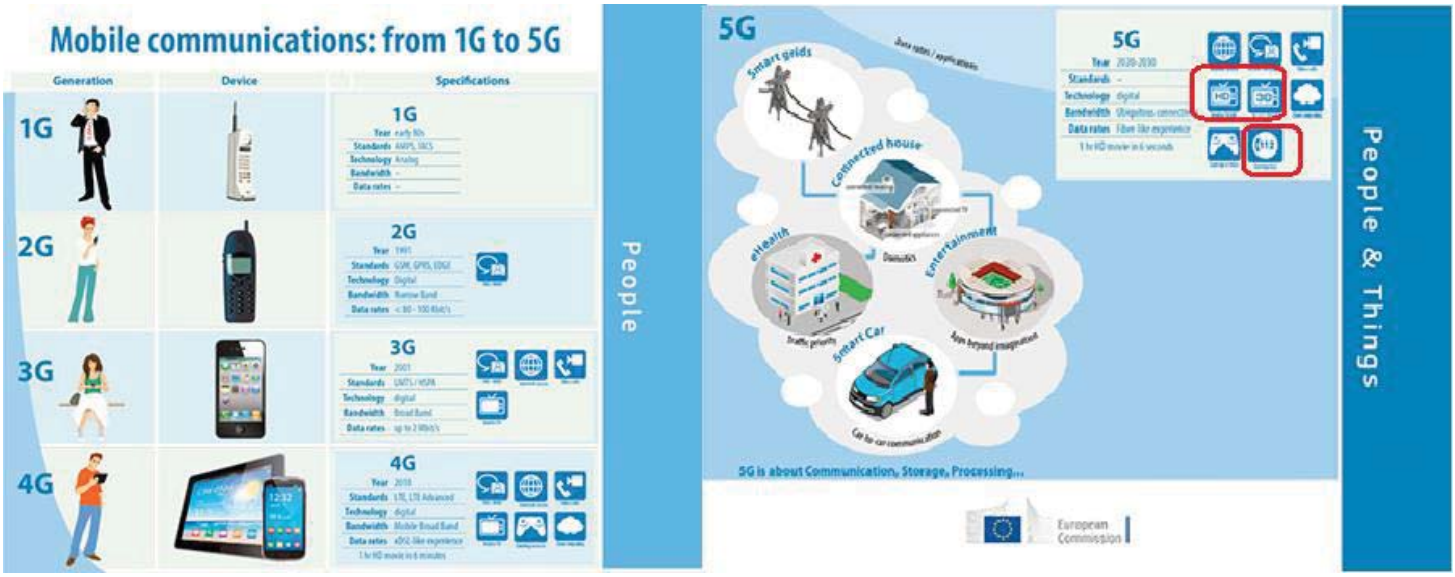


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5G storitve vs 1G/2G/3G/4G:

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Draft for internal discussion

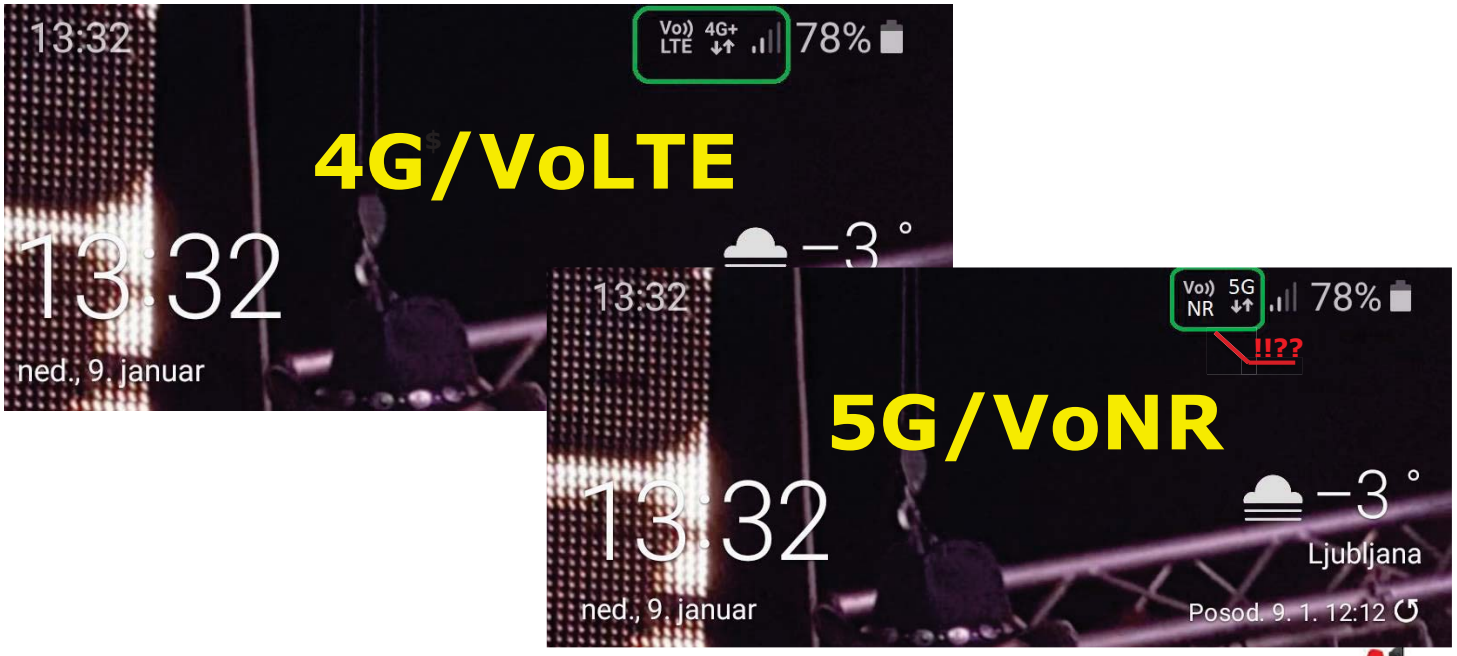


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4G/VoLTE & 5G/VoNR:

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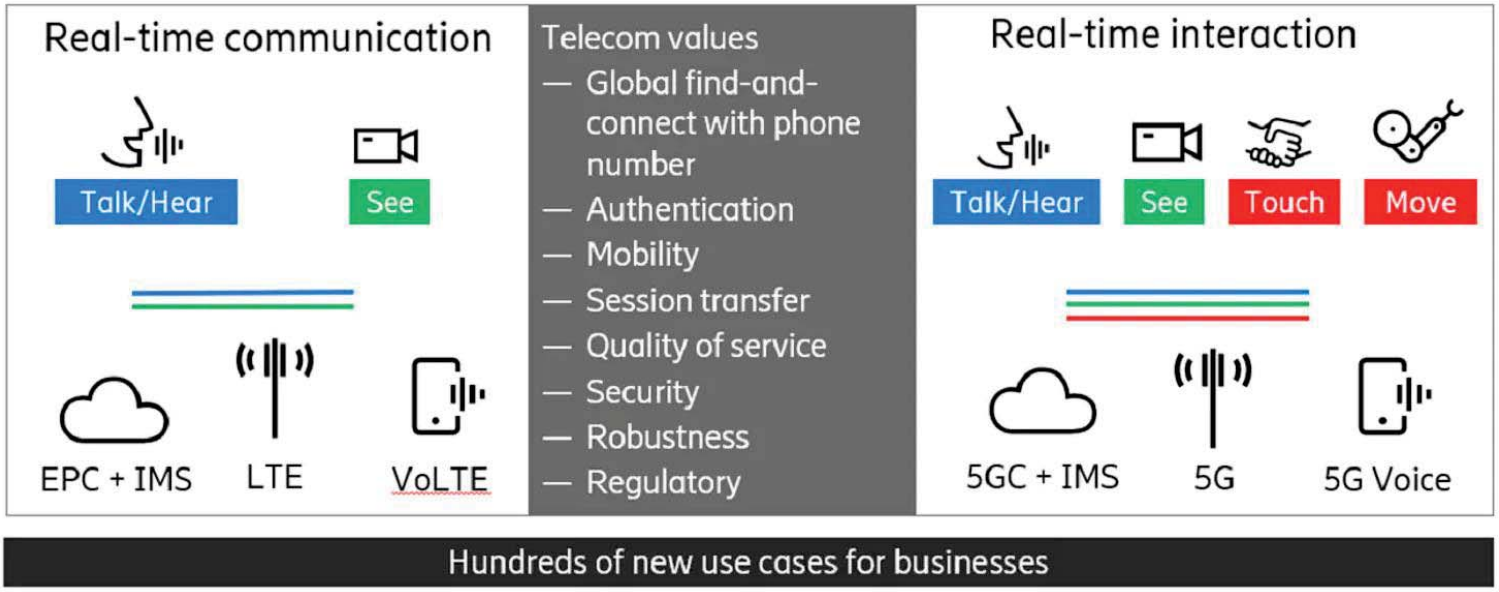


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5G vs 4G Interaktivna komunikacija:

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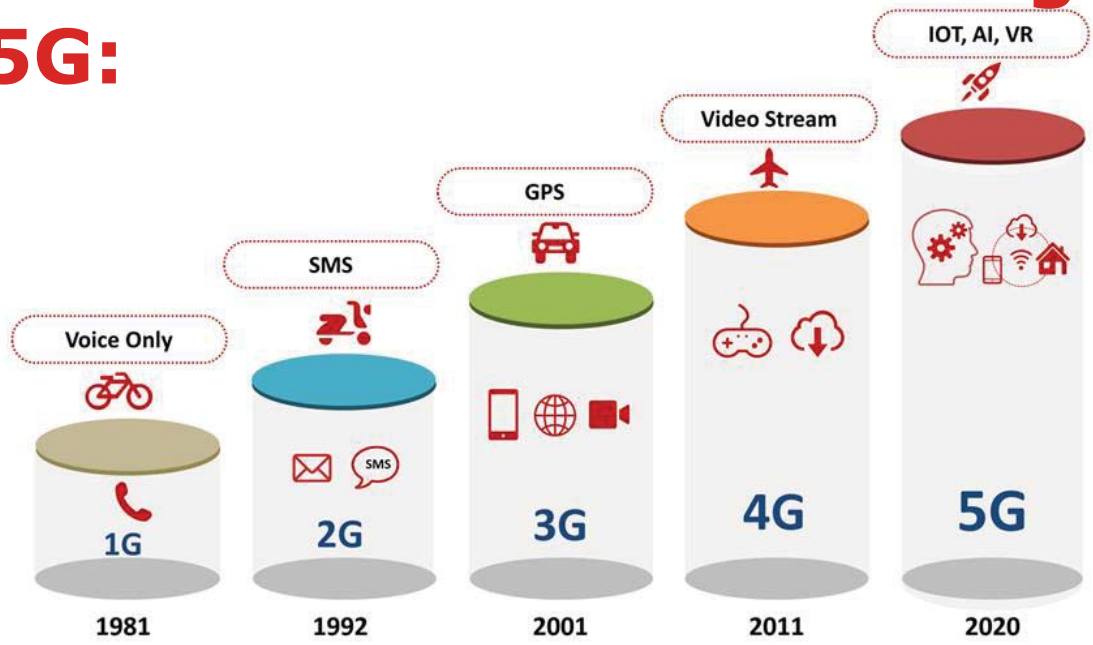
or internal discussion



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Zgodovina mobilnih tehnologij do 5G:

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Draft for internal discussion

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Pogovorni scenarij 4G in 5G:

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LTE	NSA	SA → LTE (EPS FB)	SA
			
VoLTE	VoLTE	VoLTE	VoNR
Voice call starts and ends in LTE	Voice call starts and ends in LTE while in EN-DC	UE is redirected to LTE with voice call	Voice call starts and ends in SA
Same IMS Service and Audio/Video codecs			

Draft for internal discussion

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Draft for internal discussion

Primerjava tehnologij; 1G/2G/3G/4G/5G:

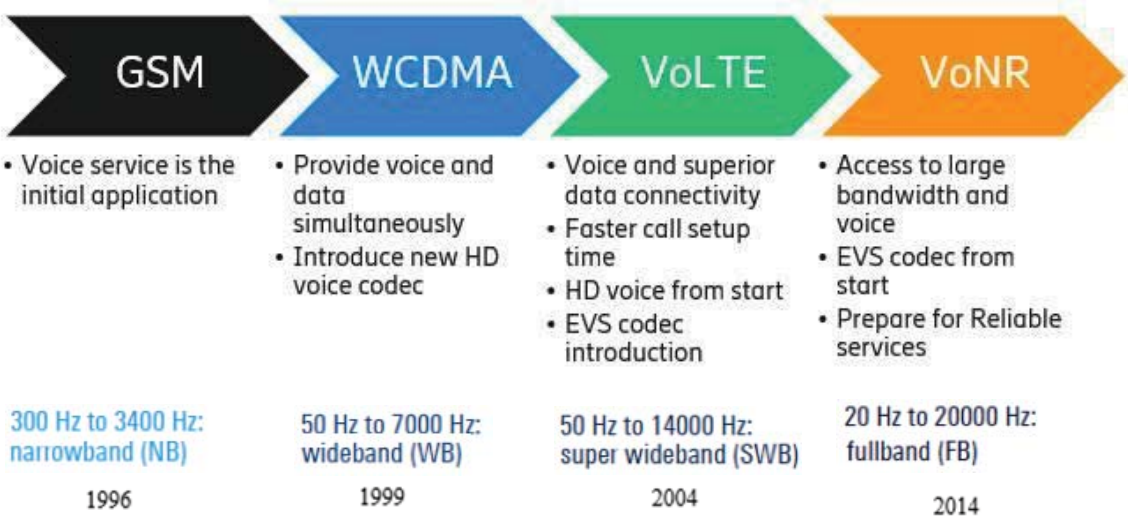
Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2014/2015
Bandwidth	2kbps	14-64kbps	2mbps	200mbps	>1gbps
Technology	Analog cellular	Digital cellular	Broadbandwidth/ cdma/ip technology	Unified ip &seamless combo of LAN/WAN/WLAN/PAN	4G+WWWW
Service	Mobile telephony	Digital voice,short messaging	Integrated high quality audio, video & data	Dynamic information access, variable devices	Dynamic information access, variable devices with AI capabilities
Multiplexing	FDMA	TDMA/WCDMA	WCDMA	WCDMA	WCDMA
Switching	Circuit	Circuit/circuit for access network&air interface	Packet except for air interface	All packet	All packet
Core network	PSTN	PSTN	Packet network	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal& Vertical	Horizontal& Vertical

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Draft for internal discussion

Nadgradnje ; 2G/3G/4G/5G:



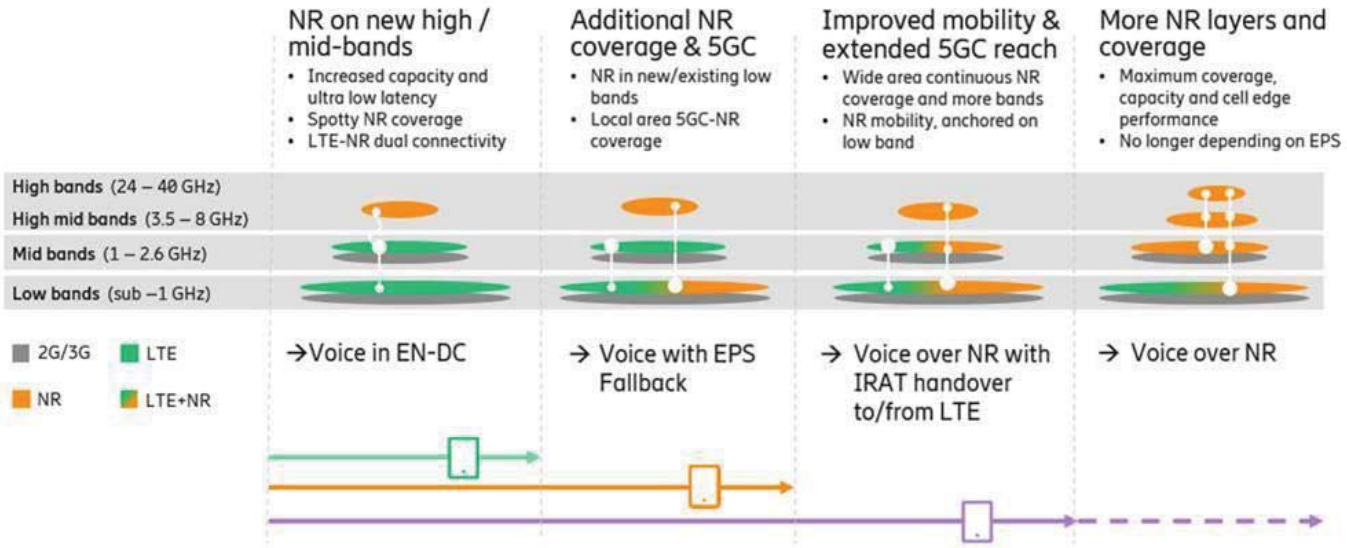
EVS is the **first 3GPP conversational codec offering up to 20 kHz audio bandwidth**

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Draft for internal discussion

Prehodi v VoNR:



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Draft for internal discussion

EVS kodek VoNR Rel15:

Below table shows all versions of TS 26.441 3GPP TS 26_series 26.441

ID	Specification	Size (KB)	Publish Date	Release
1	26441-g00.zip	440.1	2020-07-21 12:27:00	
2	26441-f00.zip	438.75	2018-06-22 19:18:00	Release 15
3	26441-e00.zip	482.19	2017-03-17 23:04:00	
4	26441-d00.zip	481.36	2015-12-13 15:36:00	
5	26441-c10.zip	535.58	2014-12-22 20:54:00	
6	26441-c00.zip	535.47	2014-09-23 09:40:00	
7	26441-200.zip	997	2014-09-22 11:14:00	
8	26441-100.zip	634.89	2014-06-16 12:07:00	

EVS/Enhanced Voice Services

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Draft for internal discussion

(CS)Circuit Switching vs (PS) Packet Switching:

Circuit Switching	Packet Switching
Circuits traffic only for voice	Data traffic and VoLTE
Dedicated wires for communication between the nodes	The communication is done using a shared wire
Circuits travel using the same course	Packets travel individually
Circuits need and book the entire bandwidth	Circuits need only the bandwidth they use and they don't book any
It consumes a lot of bandwidth	It doesn't waste bandwidth

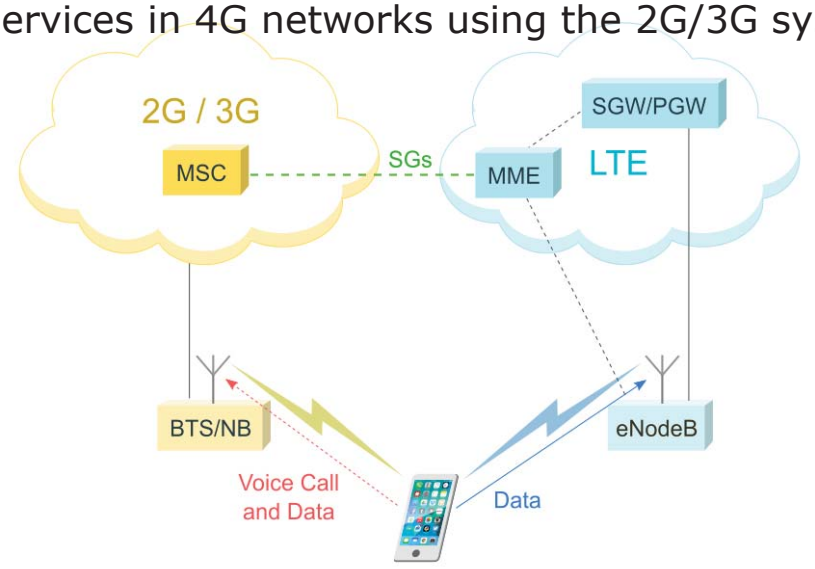
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CSFB klici na/iz 4G/LTE v 2G/3G:

CSFB (Circuit Switch Fallback) is a technology that supports voice and SMS services in 4G networks using the 2G/3G systems.



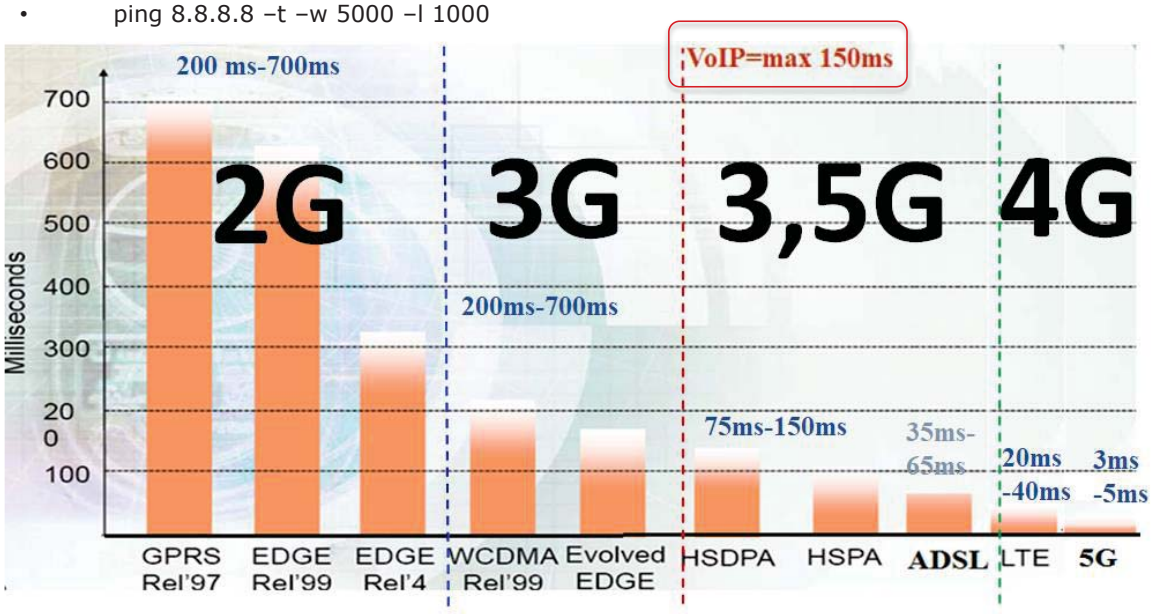
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Meritve RTT kasnitev:

- ping 8.8.8.8 –t –w 5000
- ping 8.8.8.8 –t –w 5000 –l 1000

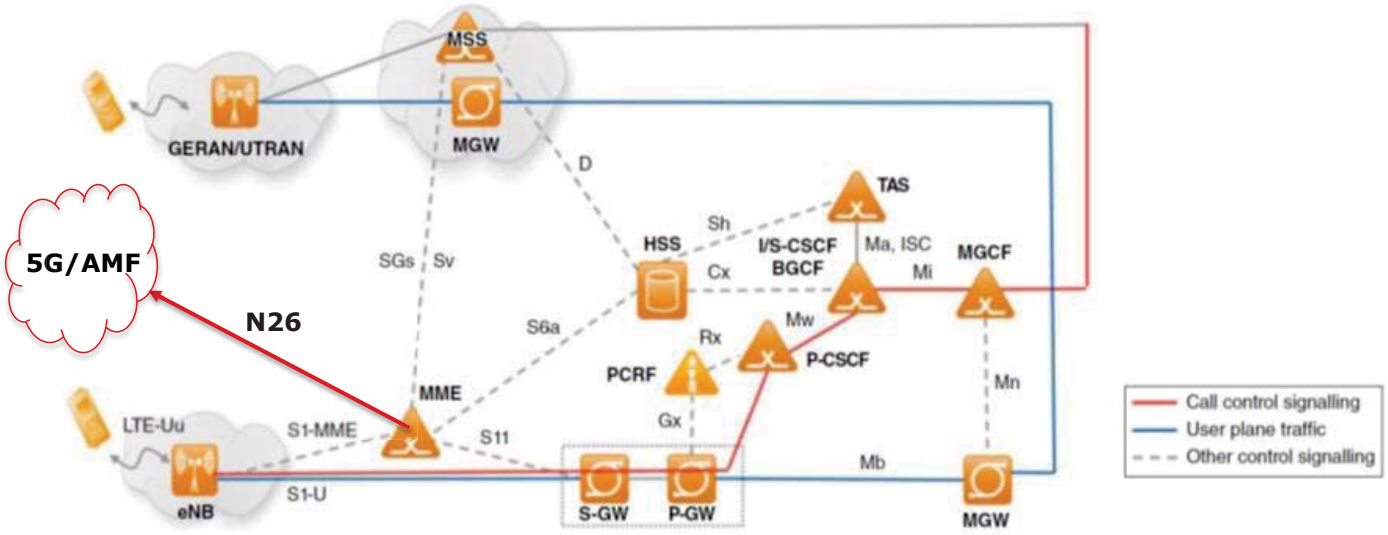


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Arhitektura LTE omrežja:

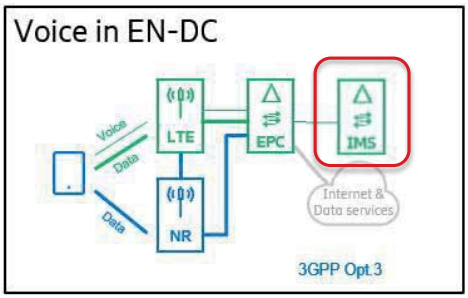


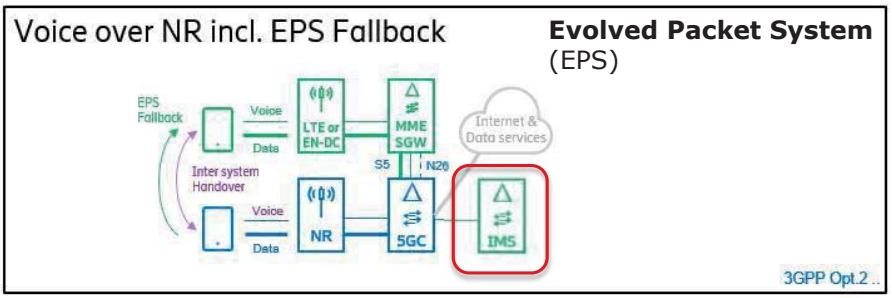
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4G/5G/3GPP govorna arhitektura:

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Voice in EN-DC

- Voice over LTE while using NR as a data boost
- IMS is not even aware of EN-DC

EPS Fallback

- NR for data but falling back to voice and data over LTE or EN-DC during voice call
- Used before NR supports and is dimensioned for voice

Voice over NR

- Using NR for voice and data
- Seamless mobility between 5GS and EPS using Inter-system handover
- NR supporting voice features and dimensioned for voice coverage

5G EN-DC/Evolved-Universal Terrestrial Radio Access-New Radio-Dual Connectivity
je predstavljen v 3GPP release 15!!!

Architecture

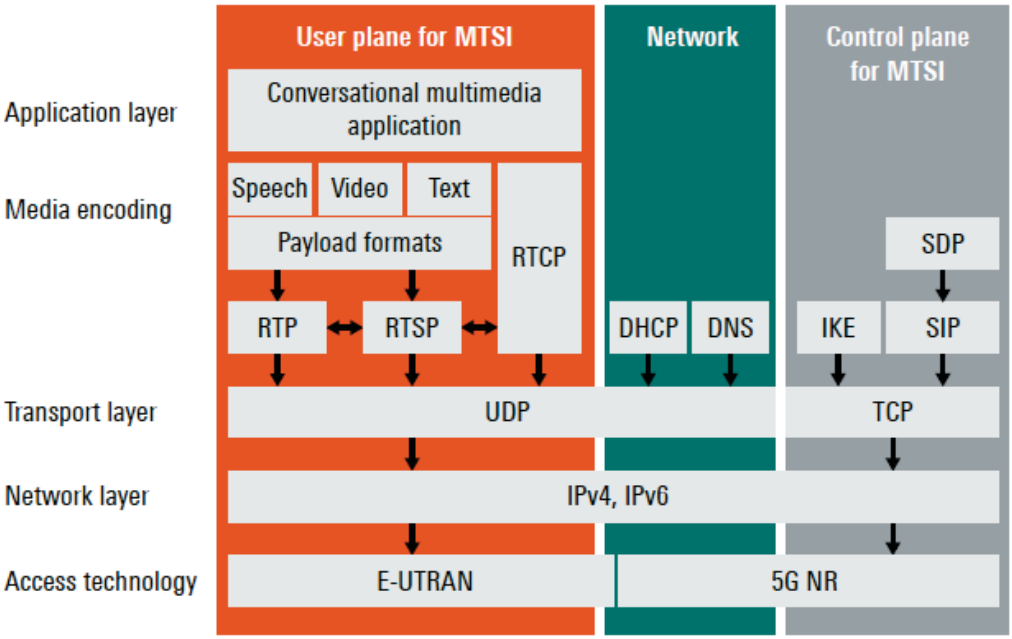
- EPC and 5GC with N26 interworking and SMF + UPF supporting S5
- Same architecture for EPS fallback and voice over NR

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Protokolni nivoji 4G in 5G:

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VoLTE karakteristike:

- VoLTE ima boljši spektralni izkoristek kot GSM in WCDMA
- Časovno hitrejšo klicno strukturo vzpostavitve klicev
- Optimizirana in zmanjšana poraba baterije
- Izogibanje prekinitvam in degradaciji data servisov, kot so zaznavni v Switch Fall Back klicnem načinu
- VoLTE omogoča izboljšani QoS, glede na CS tehnologije
- Neločljivo povezano HD VoLTE podporo

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VoLTE zahteve:

- Mobile Network Operator (MNO) VoLTE podpora:
  - IMS (IP Multimedia Subsystem)
  - QoS v radijskem in transportnem omrežju
  - eNB konfiguracija
- User Equipment (UE) VoLTE podpora:
  - UE lahko podpira zmožnost grupnega zaznavanja (Feature Group Indications); RLC UM, TTI snopa, Semi Persistent Sheduling, SRVCC, cDRX
  - UE ponudniki omogočajo (firmware) VoLTE nadgradnjo za posamezne modele telefonov za določene države
- SIM kartice zagotavljajo VoLTE klice:
  - v odgovornost Operaterjem

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VoLTE omrežne zahteve:

- IMS- IP Multimedia Subsystem; center govornega jedrnega omrežja
- Pomen entitet:
  - CSCF – Call Session Control Function, funkcija krmiljenja klicne seje
  - AS - Aplikacijski strežnik
- Med operativne funkcionalnosti:
  - BGCF - Breakout Gateway Control Function.
  - MGCF - Media Gateway Control Function
  - IMS-MGW - IMS Media Gateway Function
  - SGW - Signalling Gateway Function
- Podporne funkcionalnosti:
  - SEG – Security Gateway
- Plačevanje

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VoLTE IMS protokoli:

- VoLTE uporablja dva standardna protokola; SIP/SDP in RTP:
  - **SIP – Session Initial Protocol**, popularen protokol za kreiranje modificiranje in zaključevanje multimedijskih sej, zlasti pri protokolarnem pogovarjanju sej, med dvema uporabnikoma.
  - **SDP – Session Description Protocol**, protokolarno pogovarjanje multimedijskih značilnosti, med oddajnikom in sprejemnikom (kode, adrese, porti, formati, zahteve pasovnih širin pri vzpostavitvi sej).
  - **RTP – Real-Time Transport Protocol**, , ki poteka preko UDP nosilcev medijskega niza, s statističnem zbiranjem podatkov podanih medijskih povezav, vključno s izgubami paketov, tresenjem, RTT kasnitvami in QoS nadzorom podatkovne govorne povezave

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VoLTE IMS protokoli/primeri izpisov:

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```
Sip Message = SIP/2.0 183 Session Progress
Via: SIP/2.0/TCP [2001:568:fc2f:5ad8:0:34:4222:a201]:8902;branch=z9hG4bK3279891221
To: <tel:2363308163;phone-
context=ims.mnc220.mcc302.3gppnetwork.org>;tag=h7g4Esbg_p65549t1595014080m787189c3170103174s1_666007836-
1226930242
From: <sip:+16478840624@ims.mnc220.mcc302.3gppnetwork.org>;tag=3443992759
Call-ID: 3443992747_2268474104@2001:56f:fc2f:5ad8:0:34:4222:a201
CSeq: 222767274 INVITE
Contact: <sip:sgc_c@[2001:568:FFF0:201::C]:5061;transport=tcp>
Record-Route: <sip:[2001:568:FFF0:201::C]:5061;transport=tcp;lr>
Require: 100rel
RSeq: 2
Server: Ericsson MTAS - CXP9020729/8 R19F12
Supported: timer
Content-Type: application/sdp
Content-Length: 381
Feature-Caps: *;+g.3gpp.srvcc
Allow: REGISTER, REFER, NOTIFY, SUBSCRIBE, INFO, PRACK, UPDATE, INVITE, ACK, OPTIONS, CANCEL, BYE
```

SIP

```
v=0
o=- 822819063 667786426 IN IP6 2001:568:FFF0:201::C
s=-
c=IN IP6 2001:568:fff0:16::27
t=0 0
m=audio 3308 RTP/AVP 97 96
b=AS:42
a=rtpmap:97 AMR/8000
a=fmtp:97 mode-set=7; mode-change-period=2; mode-change-capability=2; max-red=0
a=rtpmap:96 telephone-event/8000
a=fmtp:96 0-15
a=ptime:20
a=maxptime:40
a=silenceSupp:off - - - -
a=sqn: 0
a=cdsc:1 image udptl t38
```

SDP

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CSFB vs VoLTE:

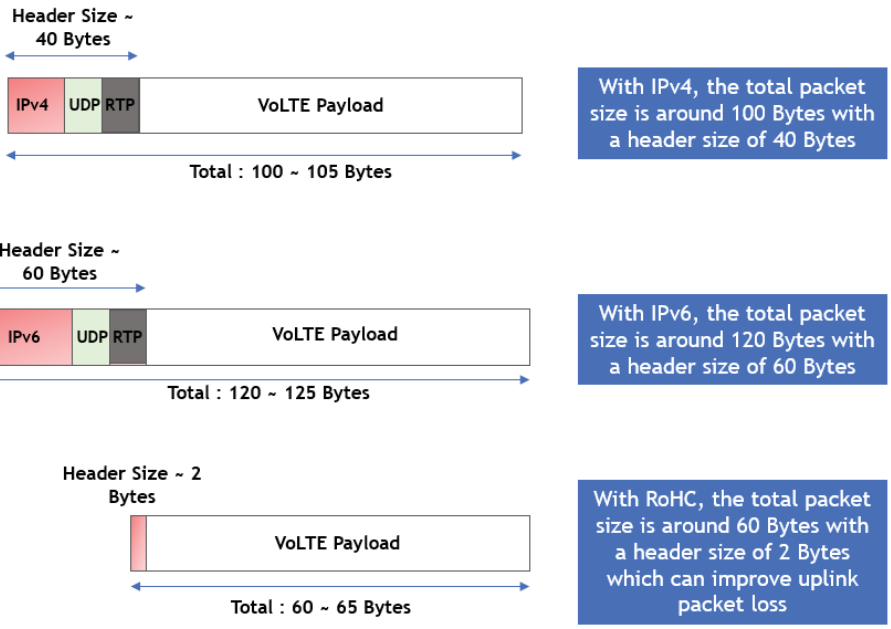
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Feature	CSFB	VoLTE
Easy of Deployment	Challenging, but not as difficult as VoLTE	Numerous major challenges to overcome
Economic Considerations	Minor	Major
LTE Coverage Requirements	Low	High
Call Setup Time	Approx. 3-7 secs	Approx. 2-4 secs
Voice Quality	Acceptable	HD Voice
Lifespan	2G and 3G limited life	IMS forms basis for 5G voice and beyond

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VoLTE RoHC (Robust Header Compression:



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VoLTE QoS:

- Prenos govora je občutljiv na izgubo podatkov (URL), kasnitve in tresenje (jitter). Zmogljivost sistema end-to-end QoS podpore je ključnega pomena za omogočanje kvalitetnega VoLTE prenosa pogovorov, brez čezmerne prekoračene degradacije.

- QCI (QoS – Class Identifier) je mehanizem v mobilnem omrežju, ki omogoča ustrezen QoS za specifičen EPS nosilce. Mobilno omrežje zazna QCI za vsak tip EPS nosilca (signalizacija, podatki, volte) da zagotovi ustrezen QoS za vsak servis; ki klasificira različne tipe nosilcev informacij kot različne QoS klase. Vsaka od QoS klas vsebuje GBR (Guaranted Bit Rate), non-GBR (non- Guaranted Bit Rate), prioritete dostave paketov, kasnitve paketov in hitrosti izgub napčnih paketov

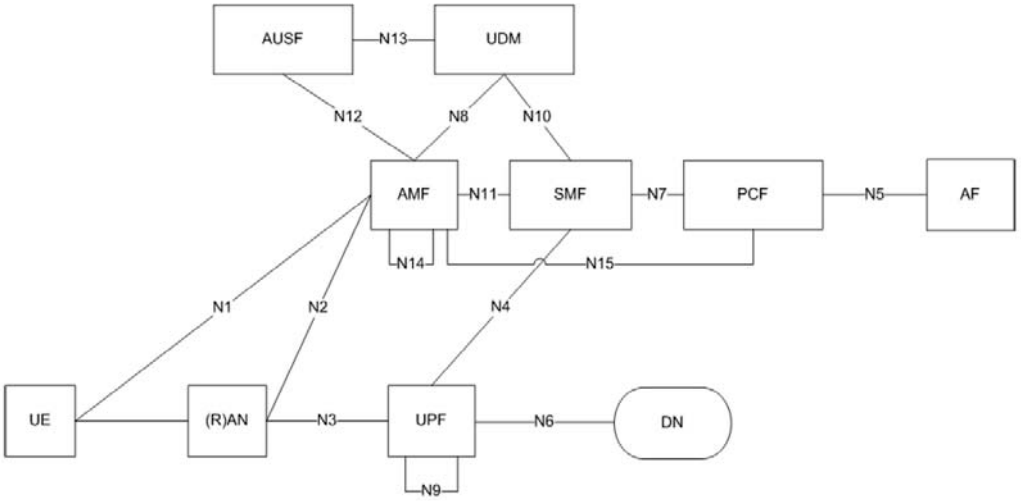
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Arhitektura 5G_GTP:

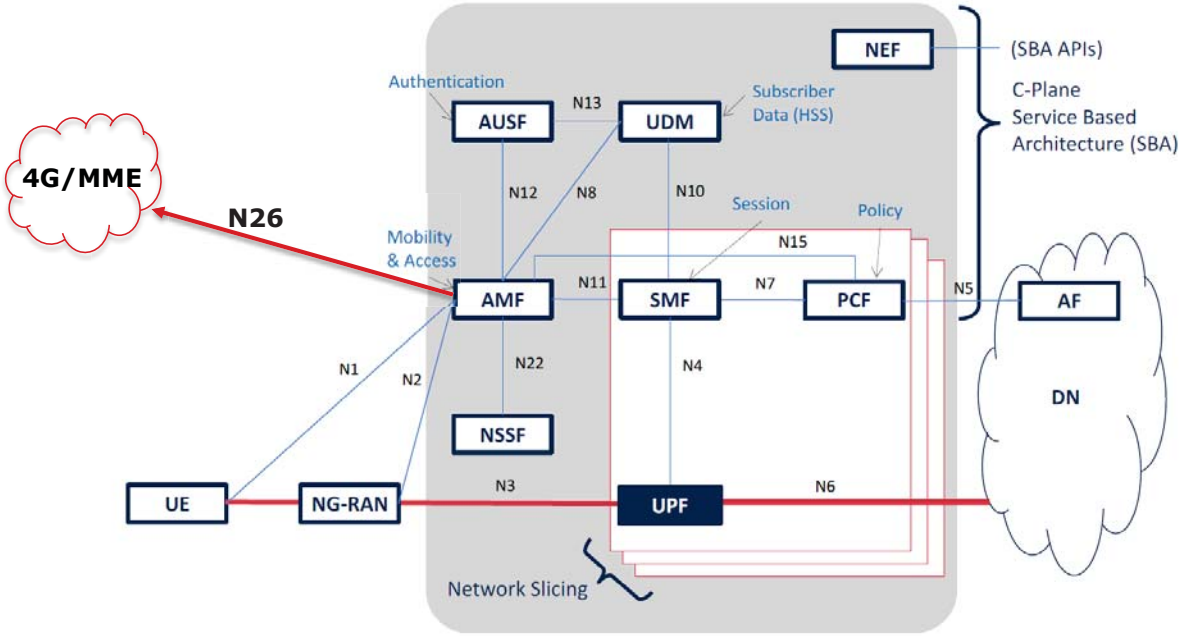


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5G RAN arhitektura:

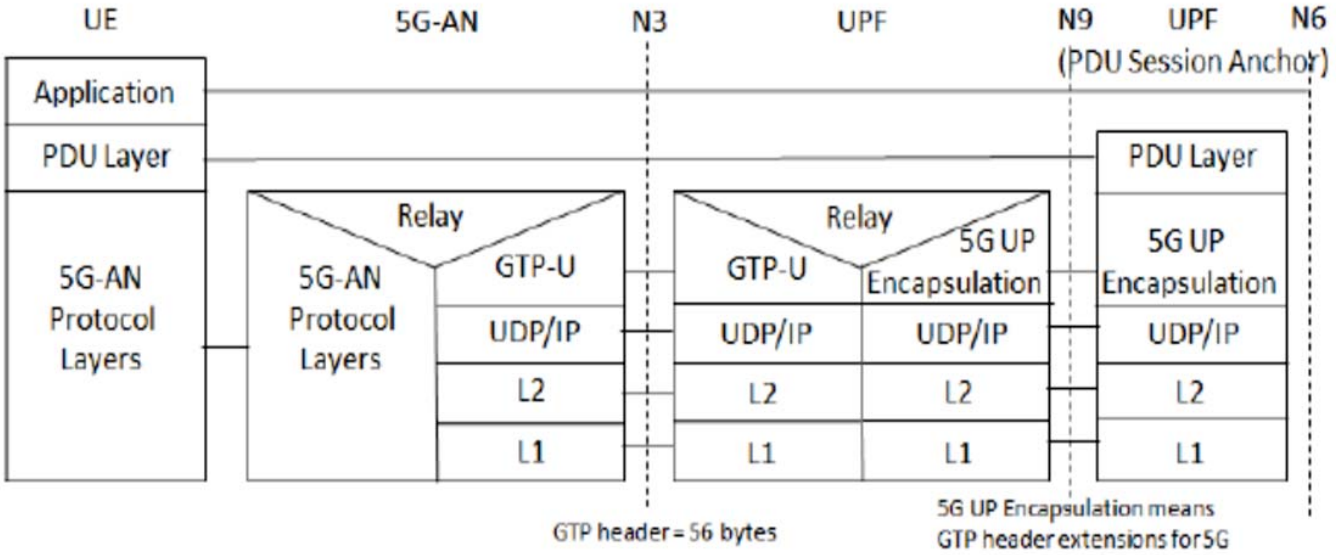


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Protokolni sklad 5G_GTP:

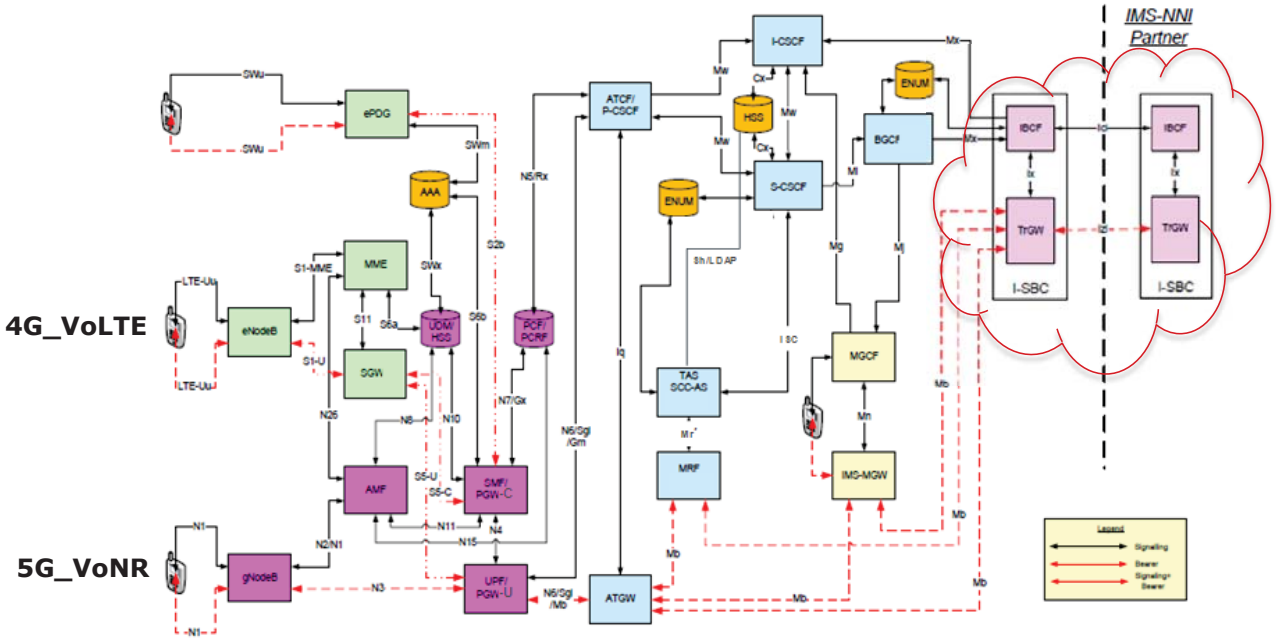


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4G/5G/IMS roaming arhitektura:



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N26 medspoj => 4G/VoLTE – 5G/VoNR „Fallback" kasnitve:

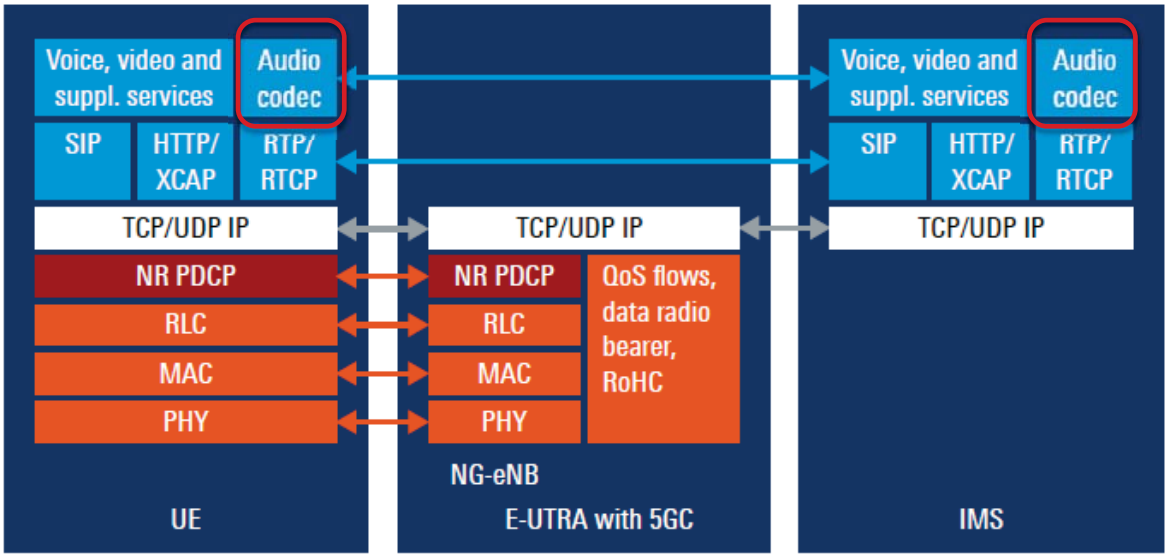
Test case	Type of Voice call	Observations
Mobility	5G (VoNR) to 4G (VoLTE) mobility	With N26 interface voice interruption time is ≈ 70ms Without N26 interface, the interruption time is ≈ 700ms (recommended limit for a voice call = 300ms)
Call set up	Originating 5G (EPS-FB) to 4G (VoLTE) Originating 5G (VoNR) to 4G (VoLTE)	With EPS-FB, the Call Setup Time is ≈ 1s more than with VoNR (with N26) and still slightly increased without N26 (+ 0,5s).

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Pogovorni servisi v 5G arhitekturi:

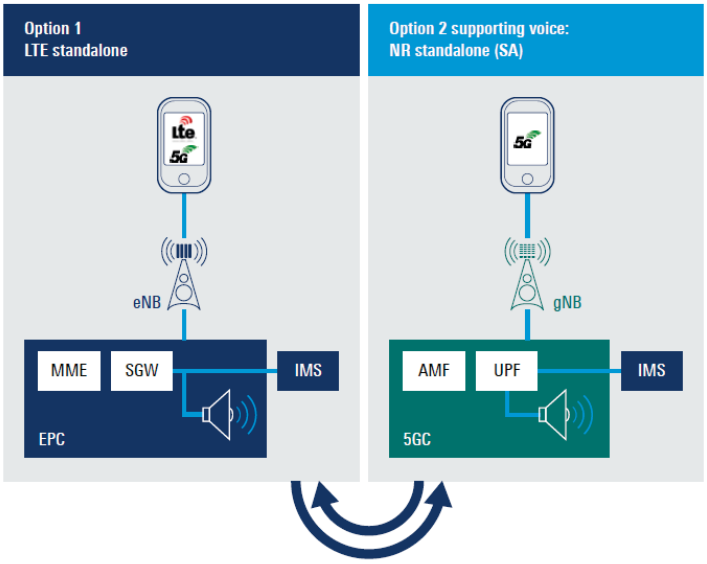


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4G_VoLTE/5G_VoNR „fallback" scenarija; Opcija_1 in Opcija_2:

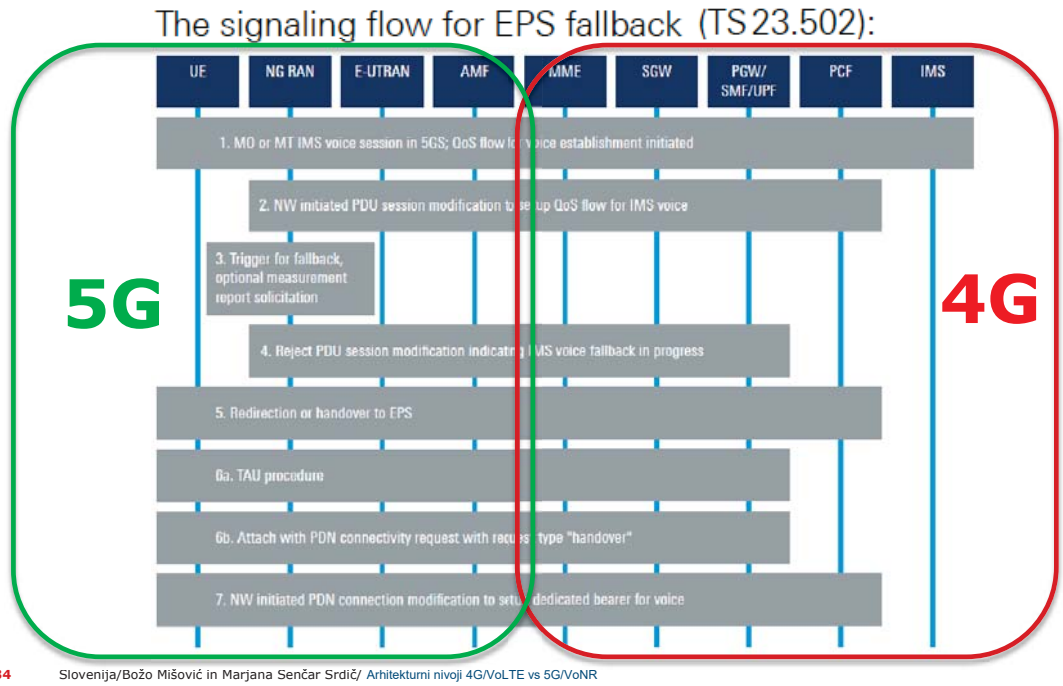


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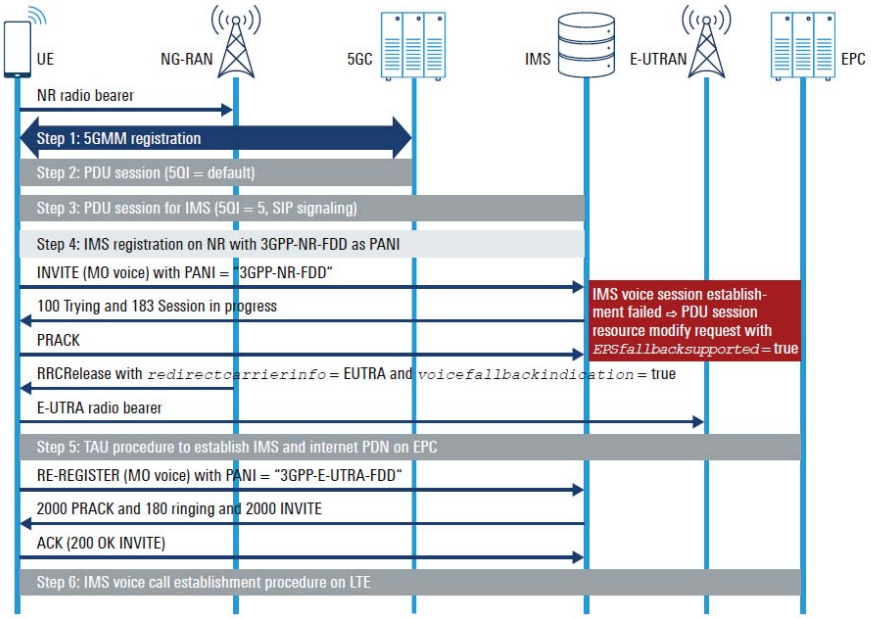
Protokolni potek med VoNR in VoLTE:



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EPS 4G/5G „fallback" govorna procedura:

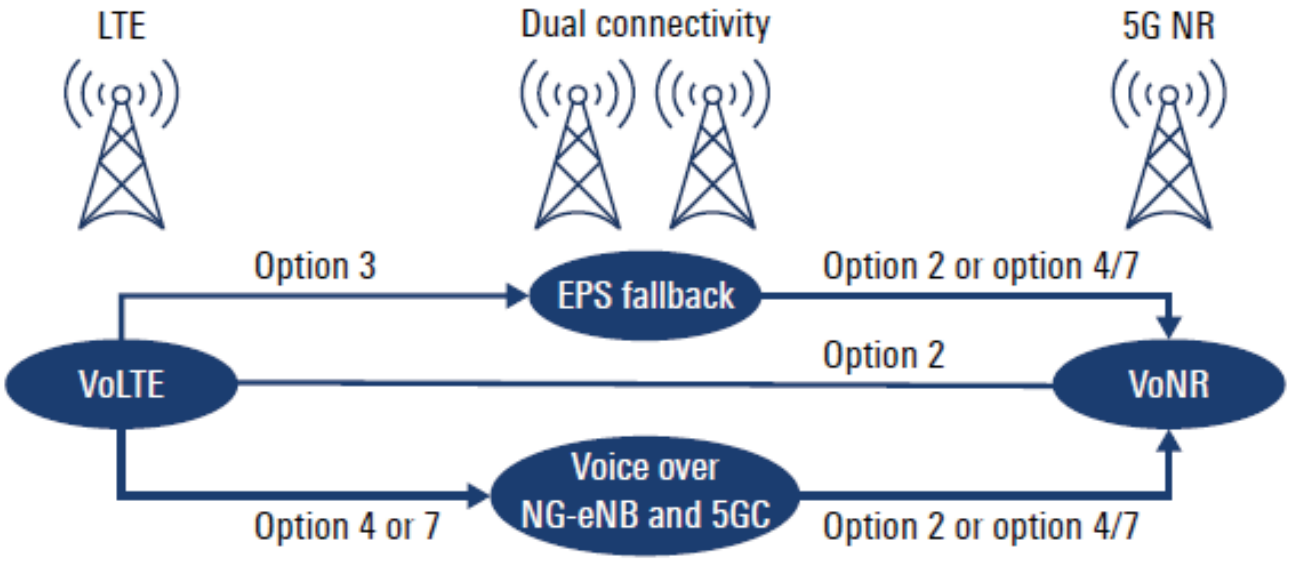


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4G_VoLTE/5G_VoNR „fallback" več opcij:

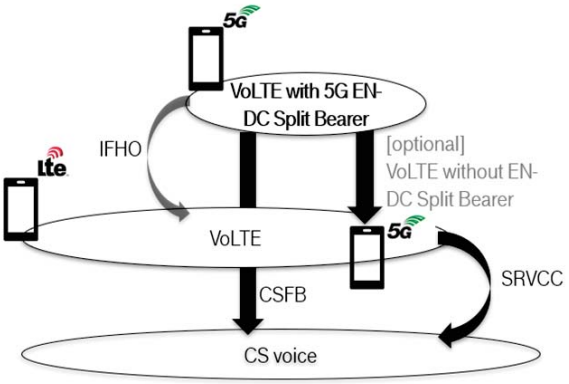


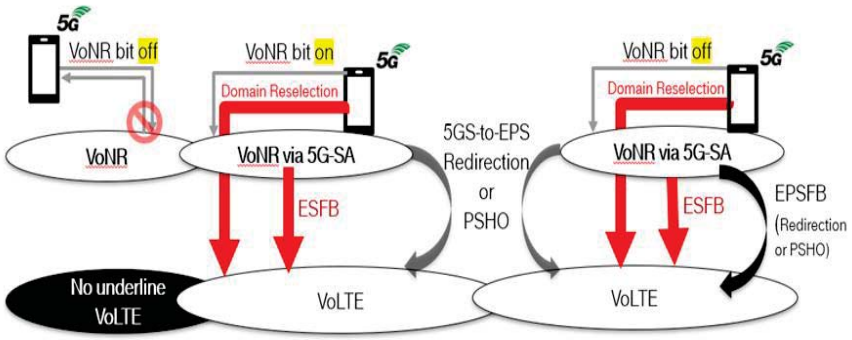
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5G/VoNR v 4G/VoLTE in CS:





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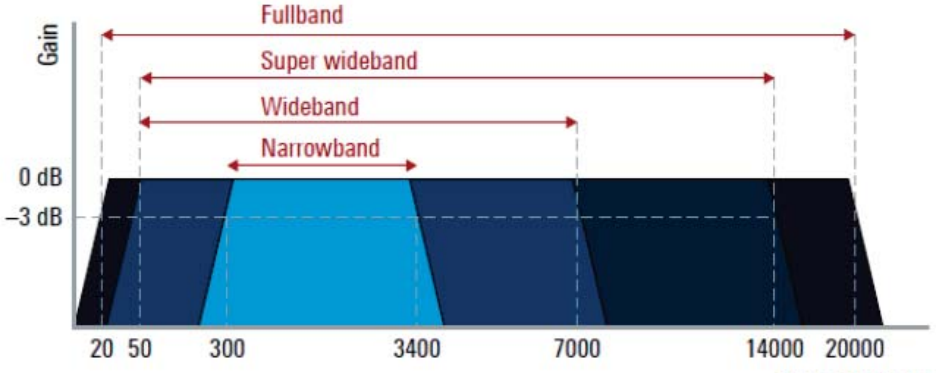
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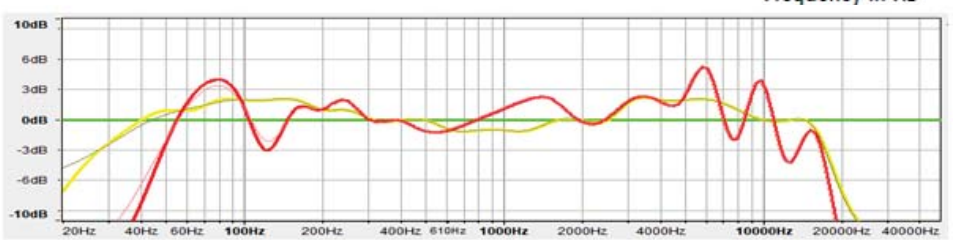
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Evolucije govornega prenosnega pasu:

- 300 Hz to 3400 Hz: narrowband (NB)
- 50 Hz to 7000 Hz: wideband (WB)
- 50 Hz to 14000 Hz: super wideband (SWB)
- 20 Hz to 20000 Hz: fullband (FB)

EVS/ Rel15





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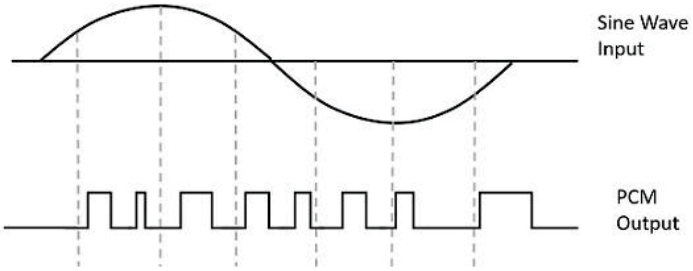
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PCM govorna modulacija:

Pulse Code Modulation



Audio compression	ISO, IEC, MPEG	MPEG-1 Layer II (Multichannel) · MPEG-1 Layer I · MPEG-1 Layer III (MP3) · AAC (HE-AAC · AAC-LD) · MPEG Surround · MPEG-4 ALS · MPEG-4 SLS · MPEG-4 DST · MPEG-4 HVXC · MPEG-4 CELP · MPEG-D USAC · MPEG-H 3D Audio
	ITU-T	G.711 (A-law · μ-law) · G.718 · G.719 · G.722 · G.722.1 · G.722.2 · G.723 · G.723.1 · G.726 · G.728 · G.729 · G.729.1
	IETF	Opus · iLBC · Speex · Vorbis
	3GPP	AMR · AMR-WB · AMR-WB+ · EVRC · EVRC-B · EVS · GSM-HR · GSM-FR · GSM-EFR
	ETSI	AC-3 · AC-4 · DTS
	Others	ACELP · ALAC · Asao · ATRAC · AVS · CELT · Codec 2 · DRA · FLAC · iSAC · MELP · Monkey's Audio · MT9 · Musepack · OptimFROG · OSQ · QCELP · RCELP · RealAudio · RTAudio · SBC · SD2 · SHN · SILK · Siren · SMV · SVOPC · TTA (True Audio) · TwinVQ · VMR-WB · VSELP · WavPack · WMA · MQA · aptX · aptX HD · aptX Low Latency · aptX Adaptive · LDAC · LHDC · LLAC

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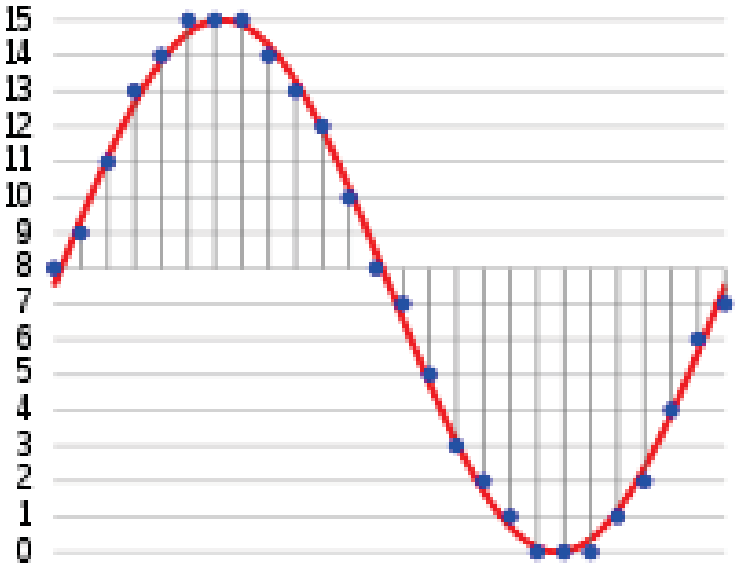
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G.711 Voice Coder/Decoder:

Pulse Code Modulation

- Sample Rate: 8 kHz
- Code bits: 8
- Bit Rate: 64 kbit/s

G.722.2/AMR-WB
6.6 – 23.85 Kbps



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GSM Audio kodeki in hitrostni razredi:

CODEC NAME	BIT RATE (KBPS)	COMPRESSION TECHNOLOGY
Full rate	13	RTE-LPC
EFR	12.2	ACELP
Half rate	5.6	VSELP
AMR	12.2 - 4.75	ACELP
AMR-WB	23.85 - 6.60	ACELP

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VoLTE AMR-WB kodne hitrosti:

Parameter	AMR-WB bit rates (kbps)								
	23.85	**23.05**	**19.85**	**18.25**	**15.85**	**14.25**	**12.65**	**8.85**	**6.6**
Payload size (bits)	477	461	397	365	317	285	253	177	132
Frame size (bits)	488	472	408	376	328	296	264	192	144
RTP header (bits)	96	96	96	96	96	96	96	96	96
Packet size (bits)	**584**	**568**	**504**	**472**	**424**	**392**	**360**	**288**	**240**

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Razpoložljivi audio kodeki in hitrostni razredi:

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Codec Name	Year of Launch	Audio Bandwidth	Technology	Bitrates
Enhanced Full-Rate (EFR)	1996	Narrow Band	2G	12.2 Kbps
AMR Narrowband (AMR-NB)	1999	Narrow Band	3G/4G	4.72- 12.2 Kbps
AMR Wideband (AMR-WB)	2001	Wide Band	HD Voice in 3G/4G	6.6 – 23.85 Kbps
Extended AMR-WB (AMR-WB+)	2004	Full Band	Full HD Voice in 3G/4G	6-48 Kbps
Enhanced Voice Service (EVS)	2014	Super Wide Band and including all Above	Super HD Voice in 4G	5.9-128 Kbps

V VoLTE 4G so najbolj pogosto uporabljena dva (2) tipa govornih kodekov;

NB-AMR/Narrow Band- Adaptive Multi-Rate in WA-AMR/Wide Band-AMR

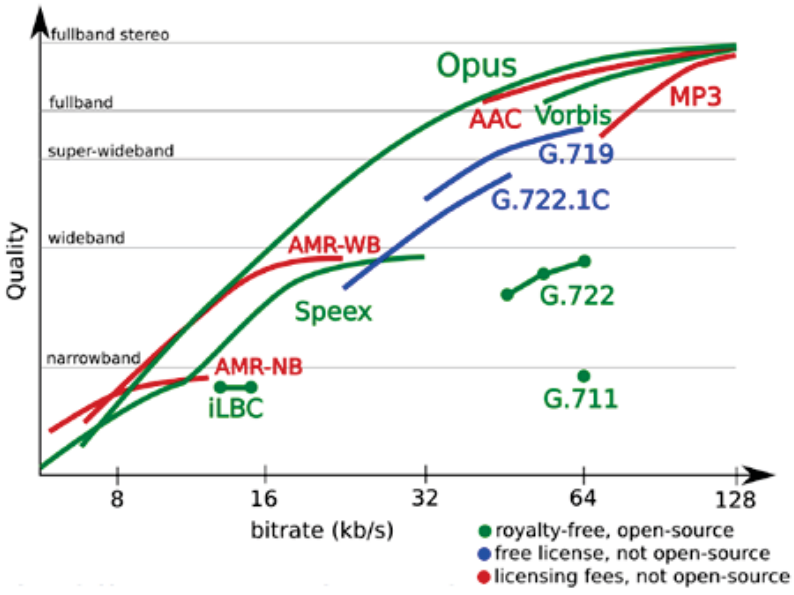
Enhanced Voice Services (EVS) is a **superwideband speech audio coding standard** that was developed for VoLTE. It offers up to 20 kHz audio bandwidth

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Kodne govorne značilnosti:

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- Built for different types of networks
- Resiliency
- Variable bit rate

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Standard VoNR:

Voice indication in RRC Connection Request	Video indication in RRC Connection Request	Emergency indication in RRC Connection Request	RTT (Real-time Text) Call Accessibility
SPS	SSAC	Multiple DRBs per PDU	Flow based QoS
5QI-1 DRB	5QI-5 DRB	VoNR Capability Bit	C-DRX
IFHO (Inter-Frequency HO)	Service-based IFHO	PSHO (IRAT HO)	RoHC
RRC Re-establishment	Short RLC SN	PDCP SN	TTI Bundling (slot aggregation)
TDD FDD HO	Xn-based HO	3GPP non-3GPP HO	5G E911 Location
Limited Service	Emergency RRC	Always-On PDU	

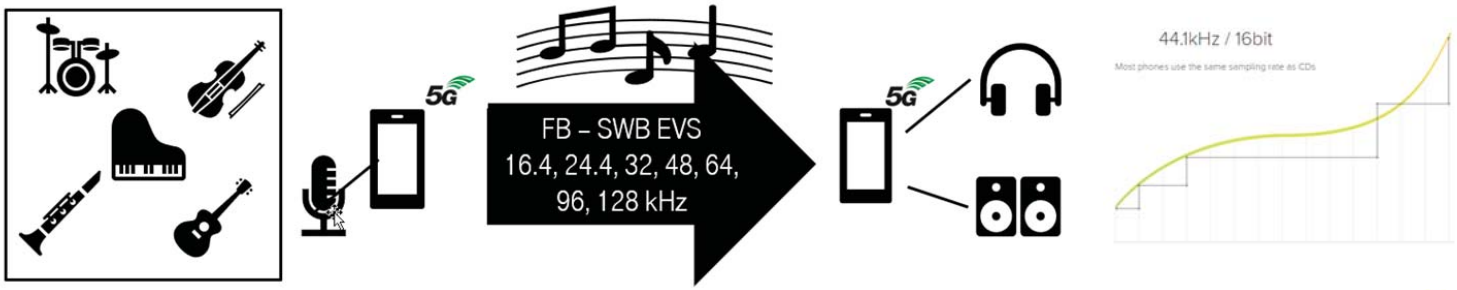
Draft for internal discussion

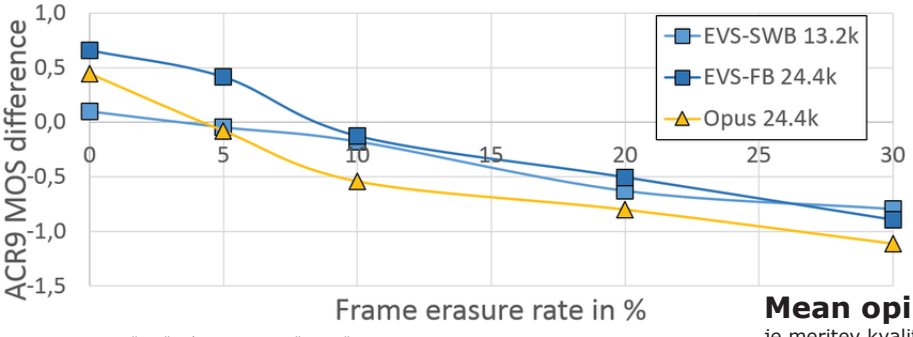
SRK 2022, Ljubljana

A1 Telekom Austria Group

5G/HiFi -VoNR:

EVS is the **first 3GPP conversational codec offering up to 20 kHz audio bandwidth**







Mean opinion score (MOS)
je meritev kvalitete v praksi od (1-5) , običajno se koristi za profiliranje kvalitete audio video vsebin

Draft for internal discussion

SRK 2022, Ljubljana

A1 Telekom Austria Group

Skupne značilnosti VoLTE in VoNR:

- Obe tehnologiji sta zasnovani na IMS profilu in uporabi VoIP
- Obe tehnologiji uporabljata enak »frame intensity«
  - Aktivni zvok se prenaša vsakih 20ms
  - Pavze na vsakih 160ms (aka »Silent Voice«)
- Obe tehnologiji uporabljata skupne dejavnike kvalitete:
  - Packet loss <1%
  - Packet delay < 80ms
  - Frame Error Rate <1%

Draft for internal discussion

SRK 2022, Ljubljana

A1 Telekom Austria Group

Skupne značilnosti VoLTE in VoNR (1):

- Obe tehnologiji uporabljata RLC Unacknowledged Mode (UM) in RLC segmentation pri kontroli BLER-a
- Obe tehnologiji uporabljata Enhanced Voice Services (EVS). Codec sheme so enake. Še bolj natančno, enake codec sheme so na voljo pri VoLTE in VoNR.

Glavne razlike:

- VoNR ima na voljo »Priority Controlled Scheduling«
- Opcijo »Slot Aggregation«

Draft for internal discussion

SRK 2022, Ljubljana

A1 Telekom Austria Group

Skupne značilnosti VoLTE in VoNR (2):

- Obe razliki sta zelo pomembni, ker omogočajo nove storitve v zvezi Ultra-Reliable/Low-Latency Communications (URLLC).
- Torej, govorimo o zanesljivosti, katero LTE ne omogoča.
- Pri codec-u dejnasko ni revolucije. VoLTE (Rel-12) že uporablja EVS. Glavna razlika bo zanesljivost.
- Torej, z večjo zanesljivostjo ima več smisla ponujati storitve, ki uporabljajo višjo kvaliteto zvoka. To pa nas pripelje do Stand Alone (SA) 5G zgodbe.
- Glavno vprašanje katero bodo postavljali je »Kdaj bo VoNR in kaj so predpogoji za uporabo?«

Draft for internal discussion

SRK 2022, Ljubljana

A1 Telekom Austria Group

VoNR časovnica glede dejavnikov:

- Pripravljenost omrežja:
  - Predvsem je mišljeno kateri KPI-ji so pomembni in kako jih lahko dosežemo s pogojem, da ostale storitve (predvsem MBB) niso na izgubi
- Strategija uvedbe VoNR -> Kje je denar in kdo bo pripravljen spremeniti obnašanje omrežje le zaradi VoNR-a (če že imamo CS in VoLTE)?
- Tudi če imamo vse zgoraj navedeno pod kontrolo, kako narediti Roaming (»interworking with other Core Networks«)? Priče smo, da VoLTE, tudi po 10-tih letih še vedno ni dosegel to zrelost.

Draft for internal discussion

SRK 2022, Ljubljana

A1 Telekom Austria Group

Draft for internal discussion

VoNR časovnica glede dejavnikov (2):

- Ne nazadnje, če hočemo uporabljati VoNR state-of-the-art functionalnosti (aka features) tudi te funkcionalnosti morajo delovati brezhibno z ostalimi (aka »feature interworking«). Torej, ekonomija obsega.

KPI- Key Performance Indicator; Revenue growth, Revenue per client, Profit margin, Client retention rate, Customer satisfaction

https://www.ericsson.com/en/blog/2019/5/evolve-volte-to-enable-real-time-interaction-over-5g-with-ims-data-channel



Standardizacija na področju tehnologije DECT

Standardization in the field of DECT technology

Drago Majcen

Slovenski inštitut za standardizacijo, TC MOC

drago.majcen@gmail.com

Povzetek

ETSI DECT-2020 je prva necelična tehnologija 5G na svetu, ki je prejela odobritev ITU-R in s tem postala zgled za možnost povezljivosti različnih tehnologij in omrežij. DECT - Digital Enhanced Cordless Telecommunication je tehnologija, ki je nastala kot evropska pobuda, zdaj ponovno hitro osvaja svet telekomunikacij. Prednosti, ki jih ponuja ta visokokakovostna tehnologija dostopa, priznava vse več uporabnikov, regulatorjev, standardizacijskih organov, operaterjev omrežij in proizvajalcev opreme. DECT se je izkazal z večkratno uporabnostjo kot dostop do omrežja v stanovanjskih, poslovnih in javnih okoljih, saj kaže enostavno mobilnost, kakovost govora, primerljivo s klasično žično telefonijo, visoko raven varnosti z napredno digitalno tehnologijo in šifriranjem, kar omogoča visoko gostoto naročnikov, prilagodljivo dodeljevanje pasovne širine, podporo za več storitev, cenovno konkurenčnost, prilagodljivo uvajanje in enostavno namestitev. V predstavitvi bom prikazal začetke razvoja te brezvrvične tehnologije in njen nadaljnji razvoj skozi desetletja uporabe.

Predstavil bom priprave in realizacijo procesov standardizacije posameznih faz in generacij DECTa. Na kratko bom razložil standardizacijsko delo v ETSI in sodelovanje ostalih mednarodnih organizacij(CEPT, ESPA, DECT FORUM, ITU) pri opredelitvi profilov, specifičnih za aplikacije in prihodnji razvoj ter uporabo DECT tehnologije.

Osnovni standard DECT tehnologije so pripravili člani Evropskega inštituta za telekomunikacijske standarde ETSI. V tehničnem pododboru STC RES-03, ETSI Radijska oprema in sistemi 03 evropski proizvajalci telekomunikacijske opreme, sistemski operaterji in regulatorji sodelujejo pri opredelitvi in razvoju standardov DECT. Poleg ETSI je v proces standardizacije DECT vključenih več drugih organov. Komisija Evropske skupnosti zagotavlja znatno podporo z zagotavljanjem zakonodaje, potrebne za vzpostavitev (v povezavi s CEPT ERC) skupne dodelitve frekvenc in (v sodelovanju z odborom ACTE) z omogočanjem vseevropske uskladitve regulativnega okolja za izdelke DECT.

Abstract

Digital Enhanced Cordless Telecommunication (DECT), the technology originated as a European initiative is now rapidly conquering the telecommunications world. The benefits offered by this high quality access technology are recognised by more and more users, regulators, standardisation bodies, network operators, and equipment manufacturers. DECT has proven multiple applicability as a network access in residential, business and public environments showing easy mobility, speech quality comparable

to wireline telephony, a high level of security through advanced digital technology and encryption, allowing for high subscriber densities, flexible bandwidth allocation, multiple service support, cost competitiveness, flexible deployment and simple installation. Presentation introduces the DECT standard and explains its main operating principles. The standardisation work in ETSI on the definition of application specific profiles and future evolutions in DECT is shortly explained. The members of the European Telecommunications Standards Institute (ETSI) have developed the DECT standard. In ETSI Sub Technical Committee Radio Equipment and Systems 03 (STC RES-03), European telecommunications equipment manufacturers, system operators and regulators work together on the definition and evolution of the DECT standards. In addition to ETSI, several other bodies are involved in the DECT standardisation process. The Commission of the European Community provides considerable support by providing the legislation needed to establish (in conjunction with CEPT ERC) a common frequency allocation and (in conjunction with the ACTE committee) by enabling European wide harmonisation of the regulatory environment for DECT products. After the first edition of the DECT standard was available in 1992, the DECT standardisation work concentrated on the definition of the Generic Access Profile (GAP) and other interworking profiles (DECT/GSM, DECT/ISDN, DECT/Radio Local Loop, CTM and several data profiles). This work and additional demands from the DECT market initiated several extensions and enhancements to the base standard enabling even more effective application of DECT products which led to the 2nd edition of the base standard being finalised by the end of 1995. The DECT common interface standard has a layered structure and is contained in ETS 300 175, Parts 1 to 8. It is a comprehensive set of requirements, protocols and messages providing implementers with the ability to create network a ccess profiles (protocol subsets) to be able to access virtually any type of telecommunications network. To stimulate interoperability between DECT equipment from different manufacturers ETSI members started to work on the definition of standard interworking profiles by the end of 1993. The Generic Access Profile GAP was the first profile, completed in 1994. It contains the protocol subset required for the basic telephony service in residential cordless telephones, business wireless PABX, and public access applications; it provides the basis for all other DECT speecifiments.

Biografija avtorja



Drago Majcen je diplomiral na Fakulteti za elektrotehniko Univerze v Ljubljani. Po končanem študiju se je zaposlil v podjetju PTT Ljubljana, ki je bilo kasneje preoblikovano v Telekom Slovenije (TS). Leta 1977 ustanovi in postane prvi vodja Centra za gradnjo in vzdrževanje magistralnih RR sistemov. Leta 1990 vodi gradnjo in montažo infrastrukture prvega analognega slovenskega mobilnega omrežja NMT. Leta 1995 prevzame mesto direktorja Sektorja Telekomunikacij v upravi Telekoma Slovenije. Leta 2001 je imenovan za člana Uprave TS, zadolženega za področje delovanja TK omrežja, omrežnih storitev, področja nabave in logistike, področja testiranj nove TK opreme in

delovanja poslovne enote GVO. Opravljal je tudi funkcije predsednika nadzornega sveta hčerinskih družb Komcard in Impulz ter bil član nadzornega sveta Mobitela. Leta 2002 postane direktor Sektorja za nadzor, upravljanje in vzdrževanje TK omrežja TS. Leta 2004 se je zaposlil v podjetju Mobitel, kot svetovalec direktorja Tehničnega področja, kasneje pa deluje v skupini za standardizacijo in Tehnološki pisarni Področja za tehnologijo ter Službi za razvoj in raziskave Sektorja za radijska omrežja. Upokojen je od leta 2015. Kot predstavnik Telekoma Slovenije je od leta 1996 predsedoval zrcalnemu tehničnemu odboru TC RES (Radijske naprave in sistemi v telekomunikacijah). Po preoblikovanju ETSI TC RES v TC DECT in ustanovitvi SIST, pride leta 2006 do preoblikovanja TC RES v TC MOC (Tehnični odbor za področje mobilnih komunikacij). Od takrat je bil večkrat izvoljen za predsednika tega odbora.

Author's biography

Drago Majcen *graduated at Faculty of Electrical Engineering in Ljubljana. After completing his studies, he got a job in PTT, a company that was later transformed into Telekom Slovenije (TS). In 1977 establishes and becomes the first head of the Construction and Maintenance Center trunk RR systems. In 1990 he leads the construction and installation infrastructure of the first analogue Slovenian mobile network NMT. In 1995 he took over the position of Director of the Telecommunications Sector in the Management Board of Telekom Slovenije. In 2001, he was appointed as a member of the TS Management Board in charge of the area of operation of the TC network, network services, procurement and logistics, testing of new TC equipment and operation of the GVO business unit. He also served as Chairman of the Supervisory Board of the subsidiaries Komcard and Impulz and was a member of the Supervisory Board of Mobitel. In 2002, he became Director of the Control, Management and Maintenance Division of the TS TC network. Since June 2004, he has been employed by Mobitel as an Advisor to the Director of the Technical Sector and later worked in the standardization team and Technology Office of the Technology Sector and the Radio Networks Research and Development Department. Drago retired in March 1, 2015. He is SIST's long-time associate. As Telekom Slovenije's representative, chairs TC RES (Radio Devices and Systems in Telecommunications), which in 2006 transformed him into TC MOC, the Technical Committee for Mobile Communications, and he has been re-elected chairman. Since then he has been re-elected president of the TC MOC several times since then.*

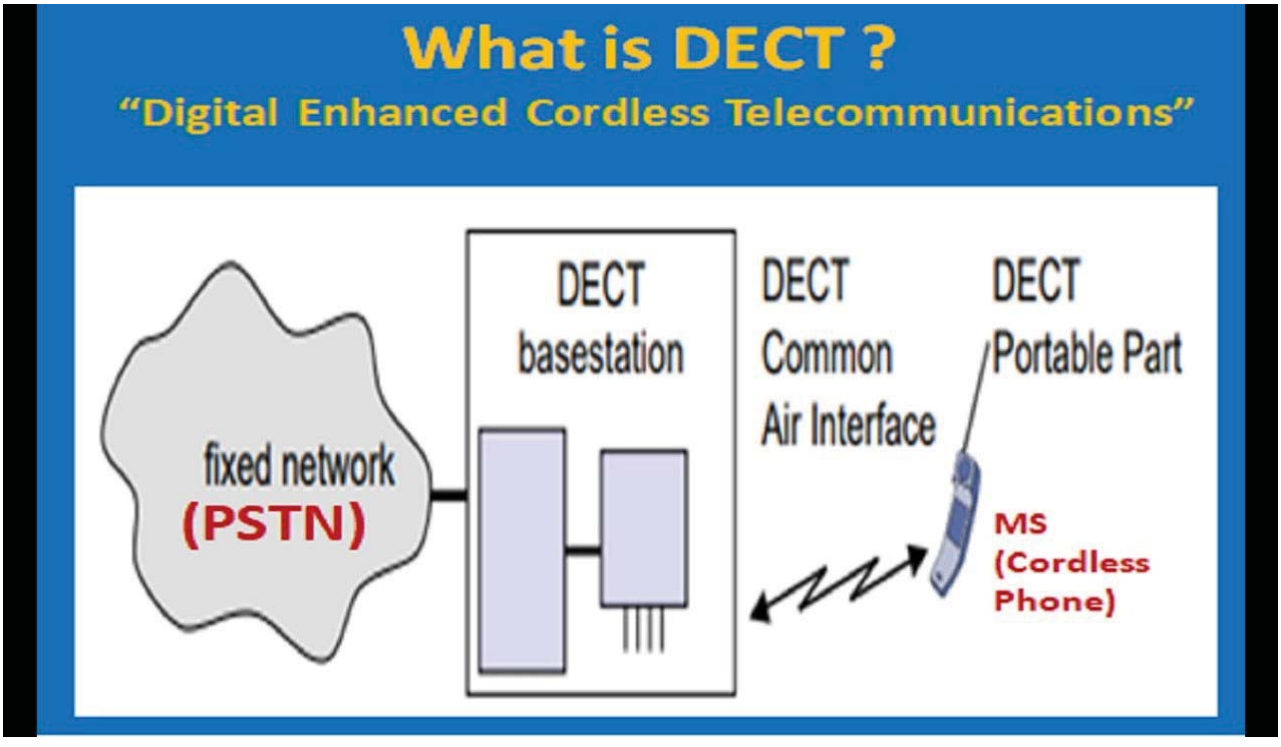
Standardizacija na področju DECT tehnologije



Drago Majcen, predsednik **SIST TC MOC**

Ljubljana, december 2021

Standardizacija na področju DECT tehnologije



Standardizacija na področju DECT tehnologije

Vsebina:

- ✓ Uvod,
- ✓ Predhodnice DECT tehnologije (CT0, CT1, CT1+, CT2, CT3,...),
- ✓ Uvod v DECT tehnologijo,
- ✓ CEPT, Evropska konferenca poštnih in telekomunikacijskih uprav,
- ✓ ERC, Evropski odbor za radiokomunikacije,
- ✓ ECC, Odbor za elektronske komunikacije,
- ✓ ERO, Evropski urad za radiokomunikacije,
- ✓ Direktiva 1999/5/ES,
- ✓ Nosilci evropske standardizacije: CEN, CENELEC in ETSI,
- ✓ ETSI, Evropski inštitut za telekomunikacijske standarde,
- ✓ ETSI TC RES, tehnični odbor za radijsko opremo in sisteme,
- ✓ ETSI tehnični pododbor RES 3 Cordless Communications,
- ✓ Kaj je standard? Definicije,
- ✓ Vrste standardov,
- ✓ Harmoniziran standard in njegov pomen,
- ✓ Prva faza standadizacije DECT tehnologije (1989 – 1992),
- ✓ Osnovni DECT standard ETS 300 175 (1-9), 1992,

3

Standardizacija na področju DECT tehnologije

- ✓ Dopolnitev osnovnih DECT standardov ETS do leta 1995,
- ✓ Leta 1995 je pripravljen tudi standard EN 300 444, GAP, generični profil dostopa,
- ✓ Med leti 1995 in 2000 je pripravljeno veliko standardov s poudarkom na podatkovnih storitvah,
- ✓ DECT forum,
- ✓ ETSI TC DECT,
- ✓ Leta 2000 potrjen standard EN 300 649, DECT Packet Radio Service,
- ✓ Leta 2002 potrjen DECT harmoniziran standard za IMT 2000,
- ✓ V obdobju 2007-2014 pripravljena družina standardov NG-DECT, New Generation DECT,
- ✓ V obdobju 2011-2012 je bila ponovno posodobljena družina standardov EN 300 175 (1-8),
- ✓ V obdobju 2013-2015 pripravljen standard DECT Ultra Low Energy, TS 102 93981,2),
- ✓ Direktiva 2014/53/EU,
- ✓ ULE Alliance,
- ✓ Do leta 2019 razvoj standardov DECT Evolution (EN 300 175, 1-8),
- ✓ ITU, ITU-R, SG- študijske skupine, Working Party 5D,
- ✓ ITU IMT- 2020, časovnica, priporočila, procesi standardizacije,
- ✓ Standard DECT 2020-NR in IMT-2020,
- ✓ DECT Forum 2021,
- ✓ Plani za naprej: DECT-5G, New LC3, posodobitev 23 DECT standardov v letu 2022,
- ✓ SIST,
- ✓ TC MOC,
- ✓ Zaključki,

Standardizacija na področju DECT tehnologije

Pojmi, prevodi:

Mobile communications:

Cordless telecommunications - brezvrvične telekomunikacije,
Wireless telecomunications - brezžične telekomunikacije,
Satelite telecommunications – satelitske komunikacije,

CAS – Cordless Access Services,
CTM – Cordless Terminal Mobility,
CT – Cordless Telephone, Telecommunications,

DECT – Digital European Cordless Telephone, CEPT, November **1987,**
Digital European Cordless Telecommunications, ETSI, **1988,**
Digitalne evropske brezvrvične telekomunikacije,

DECT – Digital Enhanced Cordless Telecommunications, ITU, **1992,**
Digitalne izboljšane brezvrvične telekomunikacije,

WDCT – Worldwide Digital Cordless Telecommunications,
Digitalna svetovna brezvrvična telefonija,
WDCT - Worldwide Digital Communications Technology,

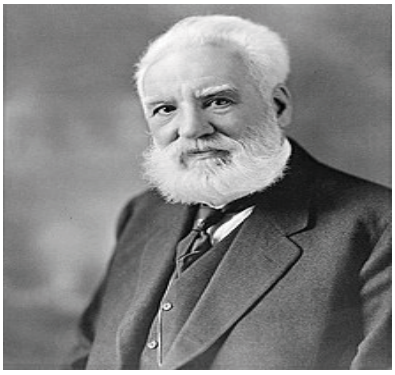
Standardizacija na področju DECT tehnologije

Kdo je izumil telefon?

Izumiteljstvo telefona ni povsem jasno.

Prve naprave uporabne za prenos signala so bile razvite že leta **1849**, vendar je šele 2. junija **1875** Bellu, kot prvemu, uspel prenos glasu. Bell je 14. februarja **1876** vložil (prvi) patent za telefonijo, le dve uri zatem pa še Elisha Gray, ki je tudi deloval na tem področju. Izumiteljstvo telefona ni povsem jasno, bistveno pa so k izumu prispevali Antonio Meucci, Philip Reis in **Alexander Graham Bell**, slednji je pogosto naveden kot edini izumitelj.





Standardizacija na področju DECT tehnologije

Kdo je izumil brezvrvični telefon?

Prvi model brezvrvičnega telefona je razvil **jazz glasbenik po imenu Teri Pall. Leta 1965** je izumil različico brezvrvičnega telefona z dosegom dveh kilometrov. Deloval je z uporabo nizkih radijskih frekvenc. Žal svojega izuma ni mogel prodati, ker so radijski signali motili letala. Svojo idejo in pravice za brezvrvični telefon je prodal proizvajalcu, ki bi ga lahko spremenil za praktično uporabo.

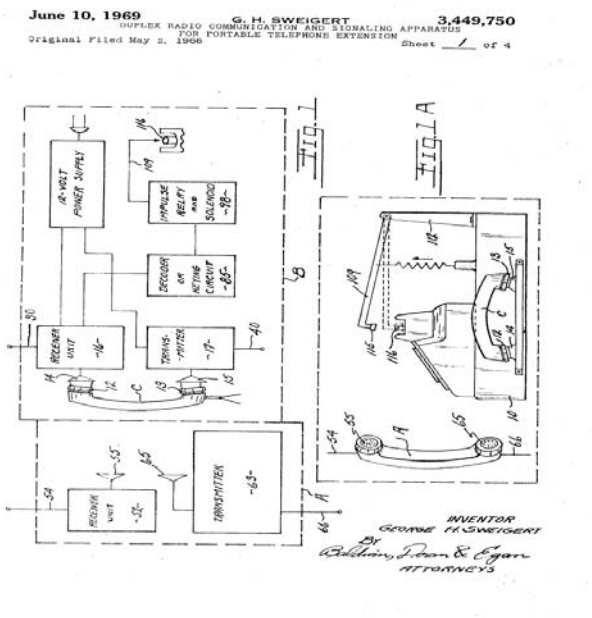
Brezvrvični telefon je nadalje razvil **George Sweigert, radijski amater in izumitelj iz Clevelanda v Ohiu. Leta 1966** je pri ameriškem uradu za patente in blagovne znamke predložil patent za brezvrvični telefon (»polni dupleksni brezvrvični komunikacijski aparat«) in **prejel patent leta 1969**. Nadalje sta ga razvila **Douglas G. Talley in L Duane Gregory med zgodnjimi 1970**. tako, da je slušalko povezal z bazo in vključeval tone za povezavo in izklop. V osemdesetih letih prejšnjega stoletja so številni proizvajalci elektronskih telefonov začeli prodajati brezvrvični telefon širši javnosti

Leta 1965 je bil predstavljen prvi brezvrvični telefon, imenovan Trimline. Zasnovan je bil kot kombiniran telefonski komplet z majhno številčnico. Glavna pomanjkljivost te naprave je bila, da je motila radijske signale bližnjih letal; vendar leta **1968** izboljšani brezvrvični telefoni niso imeli te negativne podrobnosti. Trimline je izum, ki je družbi predstavil koncept telefonske prenosljivosti. Brez tega najverjetneje ne bi bilo mobilnih telefonov.



Standardizacija na področju DECT tehnologije

Del patentne dokumentacije:


June 10, 1969 G. H. SWEIGERT 3,449,750
DUPLEX RADIO COMMUNICATION AND SIGNALING APPARATUS FOR PORTABLE TELEPHONE EXTENSION
Original Filed May 2, 1966
Sheet 1 of 4
FIG 1A
INVENTOR GEORGE H. SWEIGERT
By Baldwin, Dunn & Egan ATTORNEYS

Prosilci: SHAFER JOHN H [ZDA]

Izumitelji: SWEIGERT GEORGE H [ZDA]

SIST Standardizacija na področju DECT tehnologije

Kdo je izumil mobilne telefone ?

Mobilni telefon je leta **1973 izumil Martin Cooper**, ki je takrat delal za **Motorolo.**
Njegov prvi dizajn, ki je bil praktičen in je bil resnično "mobilen" (avtotelefoni so bili že izumljeni - vendar jih je bilo mogoče uporabljati samo v avtomobilu).

Prvi **komercialno** dostopni mobilni telefon je bil prodan šele šest let pozneje (leta **1979**).
Najprej so jih prodali na Japonskem.

Mobilni telefoni v Združenih državah niso bili komercialno na voljo do leta **1983.**

Motorola DynaTAC je bil prvi telefon, ki ga je odobrila FCC (Federal Communications Commission).

SIST Standardizacija na področju DECT tehnologije

Sovjetski mobilnik iz petdesetih

Ruski oziroma sovjetski radijski inženir **Leonid Kuprijanovič** (1929-1994) je namreč prišel na idejo o napravi, podobni mobilnemu telefonu, že v petdesetih letih 20. stoletja. Leta **1957** je uradno pridobil patent št. 115494 za »Napravo za klic in komutacijo kanalov radiotelefonske zveze«, avtomatski radiotelefon za neposredno klicanje in dvosmerno komunikacijo. Patentna dokumentacija je vključevala tudi temeljne principe mobilne telefonije, kompresijo in dekompresijo signalov in osnovno shemo naprave. Izumitelj je svoj prvi delujoči primerek poimenoval **LK-1** (Leonid Kuprijanovič, prvi vzorec)



Standardizacija na področju DECT tehnologije

Zgodovina brezvrvične telefonije (cordless telephony):

Leto 1980,
analogni **CT0,** 12 do 15 kanalov , približno 30 MHz; pod 40 MHz (odvisno od države),

Leto 1983, 1984,
analogni CT1, 40 kanalov, 900 MHz (914-915 MHz, 959 - 960 MHz), standard potrdi CEPT,

Leto 1987,
CT1 +, analogni, 80 kanalov, 900 MHz (885-887 / 930 - 932 MHz),

Leto 1989,
Digitalni CT2, 40 kanalov 0,1 MHz , ADPCM G.721, 860 MHz , (864 - 868 MHz),leta 1985ga potrdi CEPT,

Leto 1991,
CT2 / CAI (standard ETSI : ETS 300-131),

Leto 1991,
CT3, brezvrvična telefonska generacija 3 , razvoj standarda digitalne brezvrvične telefonije CT2. Ta standard je znan tudi kot Ericssonov DCT900, interni švedski standard,

Leto 1991,
digitalni **DECT**, 10 kanalov 1,7 MHz , ADPCM G.721, 1,9 GHz , (standard ETSI : ETS 300-175),

Leto 1995,
V Franciji se še vedno tržijo CT telefoni Bi-Bop ; omrežja Pointel (France Telecom)

Standardizacija na področju DECT tehnologije

CT 0

Cordless Telephone Generation 0 je standard za brezvrvično radiotelefonijo, ki se je uporabljal v Veliki Britaniji , Franciji in Španiji s tehničnimi razlikami, zlasti glede na uporabljene frekvence.
Telefoni CT0, ki so bili prvotno predstavljeni v Severni Ameriki in pacifiški regiji , so bili nato postopoma odobreni v Evropi.CT0 brezvrvični 0 generacije, je splošno ime za vse zgodnje analogne sisteme za brezžično oziroma brezvrvično telefonijo. Običajno so ti sistemi delovali v frekvenčnem področju 46–49 MHz za navzgornjo povezavo in na 1,6 MHz za povezavo navzdol. Izdelki so na splošno sledili začasnim in internim standardom in bili v skladu z nacionalnimi zahtevami posameznih držav.







Standardizacija na področju DECT tehnologije

CT1

Brezvrvični telefon generacije 1 , je rezultat razvoja standarda brezvrvične telefonije CT0, uporabljal se je v Nemčiji in skandinavskih državah. Ta standard so pripravili v CEPT .

CT1 je standard za analogne brezvrvične telefone. **Leta 1984 je CEPT sprejel standard CT1 kot prvi evropski standard te vrste in priznalo ga je enajst evropskih držav.**

CT1 deluje na 914 - 915 MHz (pri prenosu - mobilni na postajo -) in pri 959 - 960 MHz (v sprejemu). Določenih je 40 kanalov, na razdalji 25 kHz.



Standardizacija na področju DECT tehnologije

CT1+

V Belgiji , Nemčiji, Luksemburgu in Švici je bilo sproščenih 80 drugih frekvenčnih kanalov pri 885 - 887 MHz (prenos) in 930 - 932 MHz (sprejem). To povečanje je označeno z izrazom CT1 +.

Operativna licenca za naprave CT1 + je v Nemčiji potekla dne 31. december 2008.

Analogne naprave CT1 in CT1+ v Evropi po letu 2000, vse bolj nadomeščajo naprave DECT .



Standardizacija na področju DECT tehnologije

CT2, CT2 Cordless Telephone 2

Brezvrvični telefon 2. generacije, razvoj in nadgradnja **iz standarda analogne CT1, v standard brezvrvične digitalne telefonije CT2,** ki so ga na evropski ravni kasneje, pripravili v ETSI.

CT2 je splošno ime za britanski standard MPT1375, **prvi digitalni standard za brezvrvične telefone.** Sistem je razvilo nekaj britanskih podjetij, standard je bil veljaven samo v Veliki Britaniji. Kasneje je postal začasen (interim)standard ETSI.
Značilnosti:

Bazna in mobilna postaja pošiljata signale na isti frekvenci ob različnih časih (dupleks časovne razdelitve , TDD)



frekvenčno območje 864 - 868 MHz,
Trajanje okvirja 2 ms,
dve časovni reži, vsaka po 1 ms , na okvir,
ADPCM kodiranje , v skladu z G.721 , pri 32 kbit/s,

Interna standardizacija leta 1985 v Veliki Britaniji ,
nato dopolnitev v ETSI in razširitev na številne druge države.

CT2 je služil kot osnova za sistem Bi-Bop v Francij

Standardizacija na področju DECT tehnologije

CT2 je standard brezvrvične digitalne telefonije, ki je bil v zgodnjih devetdesetih letih prejšnjega stoletja (1991 – 1999) uporabljen za zagotavljanje storitev delno mobilnega telefona kratkega dosega v nekaterih evropskih državah. Navajajo ga kot predhodnika uspešnejšega sistema DECT. CT2 je bil omenjen tudi s svojim tržnim imenom Telepoint. CT2 je bil uporabljen v številnih državah, vključno z Veliko Britanijo in Francijo. V Veliki Britaniji je bil sistem Ferranti Zonephone prvo javno omrežje, ki je začelo delovati leta 1989, veliko večje omrežje Rabbit pa je delovalo v obdobju od 1992 do 1993. V Franciji je omrežje Bi-Bop delovalo od 1991 do 1997. Na Nizozemskem je takratni nizozemski PTT od leta 1992 do 1999 razvil omrežje, ki temelji na CT2, imenovano Greenpoint. Prvo leto je uporabljalo ime in maskoto Kermit, vendar so se licenčnine izkazale za pretirano velike in je bila maskota v naslednjih letih opuščena. Storitev se je nadaljevala pod blagovno znamko Greenhopper. V uspešnih letih je bilo več kot 60.000 naročnikov Greenpointa. Na Finskem je bila storitev Pointer na voljo kratek čas v 80. letih prejšnjega stoletja, preden jo je nadomestil nordijski analogni sistem mobilne telefonije (NMT).



SIST Standardizacija na področju DECT tehnologije

CT3 Cordless Telephone 3, Brezvrvični telefon CT3

Zgodnji švedski digitalni brezvrvični telefonski sistem, ki temelji na tehnologiji proizvajalca Ericsson. Sistem je bil razvit kot reakcija na razvoj CT2 in podobno kot pri CT2 je bil sprejet kot začasni ETSI standard.

DCT 900 Digitalni brezvrvični telefon

Zgodnji digitalni brezvrvični telefonski izdelek iz Ericssona, ki je bil kasneje razvit v CT3 in DECT



SIST Standardizacija na področju DECT tehnologije

Pregled uporabljenih frekvenčnih področij za brezvrvične terminale v različnih državah

Type of Cordless Telephone	Hong Kong	UK	Europe	US	Japan
CT0 (1.7 and 47 MHz bands)	✓	✓ [2]			

Type of Cordless Telephone	Hong Kong	UK	Europe	US	Japan
CT1 (914 – 915 MHz and 959 – 960 MHz)			✓		
CT1+ (885 – 887 MHz and 930 – 932 MHz)			✓		
FCC Type (46 and 49 MHz bands)	✓			✓	
CT2 (864.1 – 868.1 MHz)	✓	✓ [2]	✓ [2]		
PHS (1895 – 1906.1 MHz)	✓				✓
DECT (1880 – 1900 MHz)	✓	✓	✓		
253.85 – 255MHz and 380.2 – 381.325 MHz					✓
902 – 928 MHz				✓	
2.400 – 2.4835 GHz				✓	
5.725 – 5.850 GHz				✓ [3]	

SIST Standardizacija na področju DECT tehnologije



SIST Standardizacija na področju DECT tehnologije

MEDNARODNI STANDARDI IN VLOGA DECT

Brezžične telekomunikacije: **od 2G do 5G**

Po deregulaciji telekomunikacij v osemdesetih letih prejšnjega stoletja so bile spremembe pogoste, hitre in globoke. Zgodnji trgi žičnih omrežij z analogni telefoni so hitro prešli na brezvrvične domače telefone, kmalu pa so jim pridružili prvi in dragi analogni avtomobilski telefoni. V devetdesetih letih prejšnjega stoletja smo v Evropi dobili 2. generacijo digitalnih tehnologij:

DECT in GSM.

Od leta 2000 naprej se zmogljivosti brezvrvičnih, brezžičnih in mobilnih telefonov nenehno izboljšuje, napreduje povezljivost in storitve, ki poganjajo informacijsko dobo

SIST Standardizacija na področju DECT tehnologije

UVOD

Digitalne izboljšane brezvrvične telekomunikacije (DECTTM) je standard ETSI za brezvrvične komunikacije kratkega dosega, ki ga je mogoče prilagoditi za številne aplikacije in se lahko uporablja za dodelitev frekvenc, ki so oproščene licenc, po vsem svetu.

Akumulirano število proizvedenih DECT naprav dosega več kot **milijardo z rastočim razmerjem več kot 100 milijonov naprav na leto.**

DECT je primeren za glasovno (vključno s PSTN in VoIP telefonijo), podatkovne in mrežne aplikacije z dosegom do 500 metrov.



Ericsson BS330



Siemens Gigaset 3010 Classic



Ericsson HT50

SIST Standardizacija na področju DECT tehnologije

DECT prevladuje na brezvrvičnem stanovanjskem trgu in trgu manjših ter srednjih podjetij, ki uporabljajo lastne manjše centale PABX (Private Automatic Branch eXchange).

Sposobnost standarda za neprestano dodajanje aplikacij za telefonijo, ga dela konkurenčnega in primerljivega z vsako drugo tehnologijo. Poleg popolnega repertoarja signalizacije in postopkov za scenarije PSTN in ISDN je TC DECT (kot del nove generacije DECT) razvil celoten sklop postopkov signaliziranja za VoIP telefonijo. To omogoča doseganje resnične interoperabilnosti z vidika končnega uporabnika.

SIST Standardizacija na področju DECT tehnologije

Dr. Dag Akerberg, Ericsson Radio Systems, Švedska,
uradno proglašen kot oče DECT tehnologije

Dag Åkerberg je bil in je še vedno pionir in razvijalec brezvrvične in brezžične tehnologije. Ericssonu se je pridružil leta 1971, potem ko je doktoriral na Kraljevem inštitutu za tehnologijo v Stockholmu ter bil do leta 1984 tehnični vodja razvoja sistemov Paging Systems. V osemdesetih letih prejšnjega stoletja so bile njegove glavne dejavnosti študije, specifikacije in mednarodna standardizacija v zvezi z brezvrvičnimi pisarniškimi komunikacijami, zlasti v zvezi z DECT. Med letoma **1989 in 1991** je bil dodeljen ETSI kot del projektne skupine 10, ki podpira specifikacijo sistema za digitalno izboljšano brezvrvično telekomunikacijo (DECT). V devetdesetih letih prejšnjega stoletja je kot odgovor na pobudo PCS v Severni Ameriki pomagal oblikovati standarde PWT, ki temeljijo na DECT, poleg tega pa je kot **predsednik ETSI RES 03** še naprej igral pomembno vlogo pri nadaljnjem razvoju standardov DECT





SIST Standardizacija na področju DECT tehnologije

DECT—Digital Enhanced Communications Technology

zagotavlja zbirko tehnologij s številnimi drugimi raznolikimi aplikacijami ter omogoča tradicionalno fiksno PSTN telefonijo kot tudi IP telefonijo.

Standard brezžičnega zvoka, ki se uporablja za omogočanje brezvrvičnih domačih telefonov že dve desetletji in pol, je razvil podporo IP klicanja prek DECT CAT-iq, ki podpira interoperabilnost med baznimi postajami IP-DECT, slušalkami, in CPE opremo. S CAT-iq, ponudniki internetnih storitev, ki že dolgo vključujejo mikročipe DECT, z njihovi modemi in prehodi lahko podpirajo večlinijske HD Voice IP klice za fiksno telefonijo.

Zgodovinske značilnosti DECTa so jasnost glasu, doseg, nizka zakasnitev, varnost in izjemno zanesljiva kakovost storitve

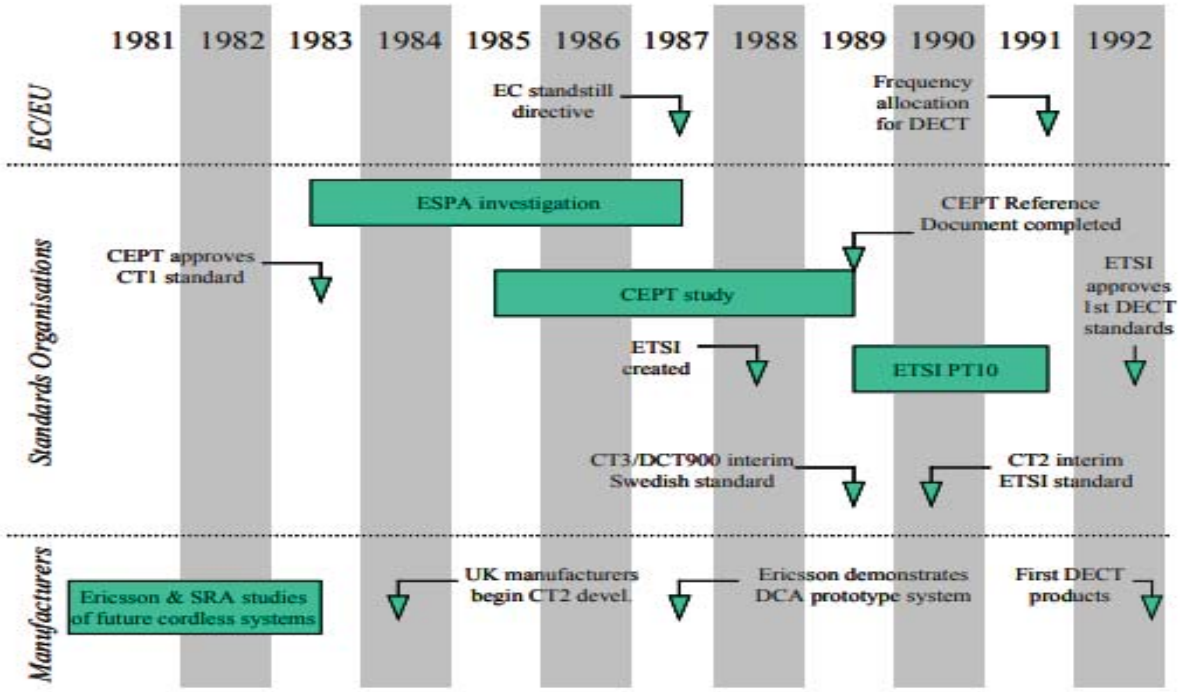
SIST Standardizacija na področju DECT tehnologije

Faze razvoja DECT tehnologije in njene standardizacije

1992	Legacy DECT
1999	IMT-2000
2007	NG-DECT (Next Gen)
2013	DECT Security
2013	ULE (Ultra Low Energy)
2017	HAN FUN (Home Area Network)
2018	DECT Evolution (Low Latency)
2019	DECT 5G – IMT 2020

SIST Standardizacija na področju DECT tehnologije

Mejniki v procesu standardizacije DECT tehnologije



Standardizacija na področju DECT tehnologije

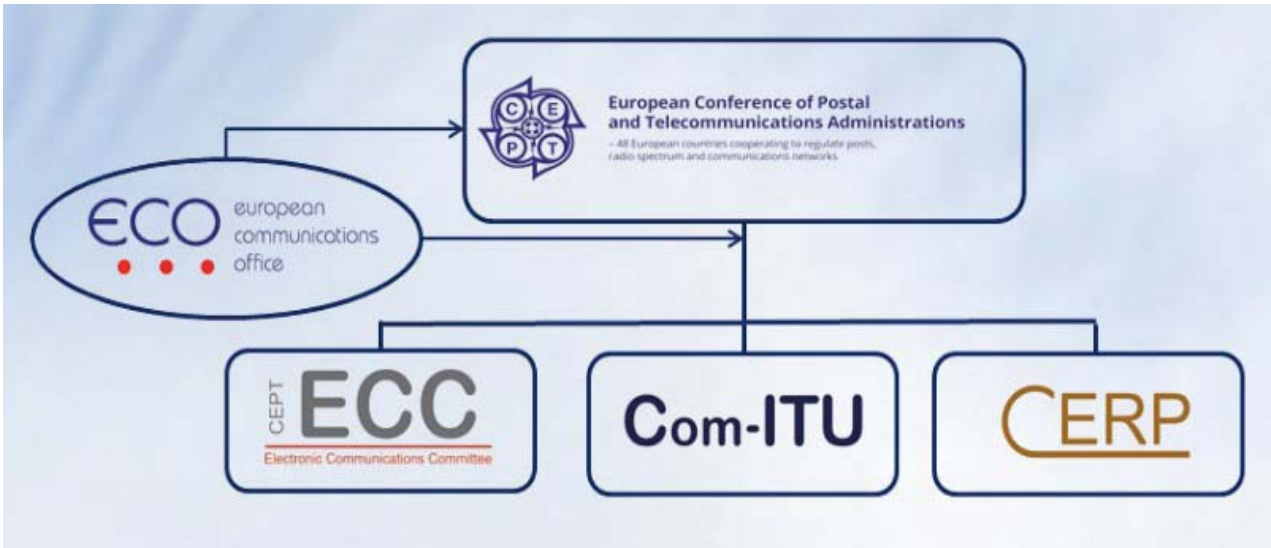
European Conference of Postal and Telecommunications Administrations

– 48 European countries cooperating to regulate posts, radio spectrum and communications networks

Evropska konferenca poštnih in telekomunikacijskih uprav

CEPT novembra 1987 potrdi novo radijsko tehnologijo, tako imenovani DECT, digitalni evropski brezvrvični telefon; ime je bil predlog italijana Enrica Tosate. Ime je bilo kmalu spremenjeno v Digitalne evropske brezvrvične telekomunikacije, kar odraža širši nabor aplikacij, vključno s podatkovnimi storitvami. Leta 1995 se je zaradi globalne uporabe ime spremenilo iz evropskega v Izboljšane. Tehnologiji DECT mednarodna organizacija ITU priznava , da izpolnjuje zahteve IMT-2000 in jo zato kvalificira kot 3G sistem. V okviru tehnološke skupine IMT-2000 se DECT imenuje IMT-2000 Frekvenčni čas (IMT-FT).

Standardizacija na področju DECT tehnologije



ODBOR ZA ELEKTRONSKE KOMUNIKACIJE

CEPT ECC Electronic Communications Committee

ECC obravnava in razvija politike o dejavnostih elektronskih komunikacij v evropskem okviru ob upoštevanju evropskih in mednarodnih zakonodaj in predpisov.

Standardizacija na področju DECT tehnologije

ERC, Evropski odbor za radiokomunikacije

ERC, Evropski odbor za radiokomunikacije, je pododbor Konference Européenne des Administration des Postes (**CEPT**), ki razvija smernice za radijske zadeve. Odbor ERC zagotavlja radijske in radiodifuzijske frekvence za radijske tehnologije in GEO satelitske komunikacije v Evropi. Zadeva enotno uporabo frekvenc in opredelitev omejitev za radijske aplikacije in sevanje motenj.

Evropski odbor za radijske komunikacije (ERC), ki ga sestavljajo predstavniki nacionalnih inšpektoratov za radijske komunikacije iz vseh držav članic CEPT, sprejema sklepe o usklajevanju na področju radijskih komunikacij. V ta namen ta odbor zagotavlja široko predhodno posvetovanje s telekomunikacijskih telesi in drugimi dobavitelji storitev, industrije in uporabnikov ter tesno sodelovanje z **ETSI, Evropskim inštitutom za telekomunikacijske standarde** in Komisijo. Ta sodeluje pri dejavnostih Odbora v svetovalni vlogi.

Standardizacija na področju DECT tehnologije

ERO, Evropski urad za radio-komunikacije

Maja 1991 je zaradi potrebe **ERC** po stalnih dodatnih kadrih, da pomaga Odboru pri njegovem delu pri določanju in usklajevanju prihodnjih razvojnih dogodkov v zvezi z upravljanjem frekvenc in regulativnimi vprašanji, ustvaril Evropski urad za radiokomunikacije **(ERO**), ki se nahaja v Københavnu na Danskem. ERO zagotavlja strokovno središče za dolgoročne dejavnosti načrtovanja in poleg tega deluje kot središče posvetovanj v zvezi z upravljanjem spektra in regulativnimi zadevami.

ERO je bila ustanovljena na podlagi Memoranduma o soglasju (MO), ki opredeljuje referenčne pogoje ERO, njegovo razmerje z ERC in ureditev financiranja. Leta 1996 je ta MOu nadomestila "Konvencija o ustanovitvi Evropskega urada za radio-komunikacije", ki jo je do danes podpisalo 30 uprav CEPT.

ERO je distribucijsko mesto za vso dokumentacijo ECC in ponuja tudi podrobne informacije o delu ECC prek spletnega mesta ERO www.ero.dk. Spletna stran ERO je pomemben element v procesu, kjer se informacije o najnovejših dogodkih v ECC zagotavljajo s poročili o nedavnih sestankih in odobrenimi besedili sklepov, priporočil in poročil ECC.

SIST

Standardizacija na področju DECT tehnologije

ACTE, Odbor za odobritve terminalske opreme (Approval Committee for Technical Equipment) je bil ustanovljen z **Direktivo 91/263/EGS** in je med drugim odgovoren za sprejetje **skupnih tehničnih predpisov (CTR)**, na katerih temeljijo postopki EU za harmonizirano homologacijo.

Direktiva Sveta 91/263/EGS z dne 29. aprila 1991 o približevanju zakonodaje držav članic o telekomunikacijski terminalski opremi, vključno z vzajemnim priznavanjem njihove skladnosti (91/263/EGS)

SVET EVROPSKIH SKUPNOSTI, ob upoštevanju Pogodbe o ustanovitvi Evropske gospodarske skupnosti in zlasti člena 100a Pogodbe, ob upoštevanju predloga Komisije, v sodelovanju z Evropskim parlamentom ob upoštevanju mnenja Ekonomske in socialne komiteje, ker je Direktiva 86/361/EGS (4) uvedla začetno fazo vzajemnega priznavanja homologacije za telekomunikacijsko terminalsko opremo, zlasti v členu 9 pa je bila predvidena nadaljnja faza za popolno vzajemno priznavanje homologacije tipa za terminalsko opremo;

ker Odločba 87/95/EGS določa ukrepe, ki jih je treba izvajati za spodbujanje standardizacije v Evropi ter priprava in izvajanje standardov na področju informacijske tehnologije in telekomunikacij.

CTR, Skupni tehnični predpis. V telekomunikacijah, se CTR nanaša na pravilo, ki ureja povezavo terminalne opreme in omrežja. CTR se sestavijo v skladu z določbami **Direktiva EU 98/13 / ES** Telekomunikacijski raziskovalni in akcijski center (**TRAC**) in Evropski inštitut za telekomunikacijske standarde (**ETSI**) na zahtevo **ACTE, ki ji predseduje Evropska komisija.** Ta pravila veljajo za vse države članice EU.

SIST

Standardizacija na področju DECT tehnologije

276 SL Uradni list Evropske unije 13/Zv. 10

31991L0287

8.6.1991 URADNI LIST EVROPSKIH SKUPNOSTI L 144/45

DIREKTIVA SVETA

z dne 3. junija 1991

o frekvenčnem pasu, ki ga je treba določiti za usklajeno uvajanje digitalnih evropskih brezžičnih telekomunikacij (DECT) v Skupnosti

(91/287/EGS)

EUR-Lex

Standardizacija na področju DECT tehnologije

EUROPEAN RADIOCOMMUNICATIONS COMMITTEE

ERC Decision
of 24th October 1994
on the frequency band to be designated for the coordinated introduction of the
Digital European Cordless Telecommunications system
(ERC/DEC/(94)03)

Standardizacija na področju DECT tehnologije

Directive 1999/5/EC of the European Parliament and of the Council

Evropski parlament

Svet Evropskega sveta Evropske unije

European Union

European Commission

Evropska komisija, Generalni direktorat za komuniciranje

Direktiva 1999/5/ES Evropskega parlamenta in Sveta z dne 9.3.1999

Direktiva R&TTE, o radijski opremi in telekomunikacijski terminalski opremi ter vzajemnem priznavanju njihove skladnosti

Direktiva **1999/5/ES** Evropskega parlamenta in Sveta o radijski opremi in telekomunikacijski terminalski opremi ter vzajemno priznavanje njihove skladnosti določa regulativni okvir za dajanje na trg radijske opreme in telekomunikacijske terminalske opreme. Oprema se lahko da v promet in/ali da v uporabo le, če je v skladu z bistvenimi zahtevami te direktive, ki se običajno imenuje direktiva o **R&TTE**

SIST Standardizacija na področju DECT tehnologije

ECC, Odbor za elektronske komunikacije

Evropska konferenca poštnih in telekomunikacijskih uprav (CEPT) ima dva odbora, ki poročata plenarnem zasedanju CEPT. To sta CERP (ki se ukvarjata s poštnimi zadevami) in ECC (Odbor za elektronske komunikacije), odgovorna za elektronske komunikacijske zadeve. **ECC je bil ustanovljen septembra 2001** kot posledica združitve med **ECTRA** (odgovoren za splošne telekomunikacijske zadeve) in **ERC** (odgovoren za radijske zadeve).

ECC je združil regulativne uprave držav članic CEPT. Svetovalci Evropske komisije in Sekretariata Evropskega združenja za prosto trgovino sodelujejo pri dejavnostih ECC in njenih delovnih skupin.

Predstavnike ustreznih medvladnih organizacij ter drugih organizacij ali uprav, ki se nanašajo na evropske elektronske komunikacije, lahko predsedniki ECC ali njenih delovnih skupin na ad hoc podlagi povabijo k sodelovanju kot opazovalci na sestankih.

SIST Standardizacija na področju DECT tehnologije

Evropske organizacije za standardizacijo:

CEN - European Committee for Standardization,
Evropski komite za standardizacijo (1961)

CENELEC – European Committee for Electrotechnical Standardization,
Evropski komite za standardizacijo v elektrotehniki (1973)

ETSI – European Telecommunications Standards Institute,
Evropski inštitut za telekomunikacijske standarde, (1988)

Standardizacija na področju DECT tehnologije

Standardizacijski procesi,

ETSI standardi,



Standardi DECT so danes sestavljeni iz več kot sto dokumentov pripravljenih v tehničnih odborih Evropskega inštituta za telekomunikacijske standarde, ETSI. Dokumenti so poimenovani Evropski telekomunikacijski standardi, skrajšano **ETS.** Dokumente ETS dopolnjujejo tehnična poročila **ETSI ETR**, ki so namenjena podrobnejši razlagi standardov in idej v njih.

V nadaljevanju bo podan pregled standardov DECT, v posameznih razvojnih fazah te tehnologije, ki jih je uradno odobril ETSI. Poudarek bom dal na standarde, sprejete leta **1992**, ki podajajo temeljno zasnovo sistema. Od takrat naprej se je proces standardizacije seveda še nadaljeval, deloma s pregledom in posodobitvijo prvotnega standarda, deloma pa z uvedbo novih delov sistema, ki so bili identificirani, vendar niso bili obdelani v zgodnjih standardih (npr. podatkovne storitve in več enot za medsebojno delovanje).

Standardizacija na področju DECT tehnologije

Standardi 2. generacije, 2G – DECT in GSM,

sta bila **prva standarda, ki jih je ustvaril evropski ETSI**
Inštitut za telekomunikacijske standarde. Naprave DECT so hitro izpodrinile telefone prve generacije (CTO, CT1, CT2), pa tudi začetne verzije DECT telefonov. Nove generacije so ponujale visoko kakovost, omogočale visoko gostoto, uporabo vedno večjih lokalnih območij, osnovno telefonijo in klicanje v druga omrežja. GSM je ponudil podobne zmogljivosti, namenjene široki uporabi na prostem/ in v vozilih.
Osnovni standard **DECT, EN 300 175**, je bil objavljen leta **1992**. Ekonomija obsega v devetdesetih letih prejšnjega stoletja je povzročila znižanje stroškov proizvodnje in s tem cen. Uporaba se je hitro širila, povečuje se obseg in uvaja po vsem svetu.
DECT se je razvil iz "Digital European Cordless **Telephon**, evropski digitalni brezvrvični telefon, a se kmalu preoblikuje v **brezvrvično telefonijo** in končno v **"Digitalno izboljšane brezvrvične telekomunikacije"**,
kar odraža izboljšave tehnologije in standardov ter globalne trge.

Podobno se je GSM iz „**Groupe Spéciale Mobile**“ razvil v „**Globalni sistem za mobilne naprave“.**

Standardizacija na področju DECT tehnologije

ETSI, Evropska organizacija za standarde v telekomunikacijah

1987: Generalni direktorji Evropske konference poštnih in telekomunikacijskih uprav (**CEPT**) načeloma sprejmejo odločitev, da ustanovijo ETSI

1998: januar : Ustanovitev ETSI

1992: ETSI uradno potrjena kot Evropska organizacija za standarde v skladu z Direktivo 83/189/**EGS**

1997: ETSI začne ustvarjati evropske standarde(**ENS**), ki bodo zamenjali evropske telekomunikacijske standarde (**ETS**)

2020, objavljen nov radijski vmesnik **DECT-2020**

ETSI je DECT standarde razvil v več fazah, od katerih se je prva zgodila med letoma **1988 in 1992,** ko je bil objavljen prvi krog standardov. To je bila serija **ETS 300-175** v devetih delih, ki opredeljujejo zračni vmesnik in **ETS 300-176,** ki določajo, kako je treba testirati in odobriti enote. Za razlago standarda je bilo objavljeno tudi tehnično poročilo **ETR-178**. ETSI je razvila in še nadalje objavlja nove standarde za pokrivanje profilov interoperabilnosti in standardov preskušanja.

Standardizacija na področju DECT tehnologije

ETSI TC RES, Radio Equipment and Systems, tehnični pododbor RES 3

Tehnični odbor za radijsko opremo in sisteme je bil oblikovan za razvoj standardov za vso radijsko komunikacijsko opremo in sisteme, razen za tiste, ki so posebej dodeljeni drugim tehničnim odborom. TC RES je bil ukinjen **21. 7. 1997**.
Aktivni delovni elementi so bili razdeljeni na naslednji način: - RES1 (Maritime) na TC ERM - RES2 (Land Mobile Radio) na TC ERM - **RES3 (Cordless Communications) ep DECT.** - RES4 (Paging Systems) do TC ERM - RES5 (Terrestrial Flight Telecommunications System) do TC ERM - RES 6 (Terrestrial Trunked Radio) do EP TETRA - RES 8 (Naprave kratkega dosega) do TC ERM. - RES 9 (elektromagnetna združljivost) s TC ERM. - POSTAVKE RES 10 (radijska lokalna omrežja), ki se nanašajo na HIPERLAN z EP BRAN; drugi predmeti TC ERM - RES 11 (Radio Site Engineering)

V tem obdobju je v Sloveniji deloval tehnični odbor USM TC RES Radijske naprave in sistemi (1995- 2006), najprej v sklopu Urada Republike Slovenije za standardizacijo in meroslovje(1990-2001), ki je bil 16. junija 2006, preobražen v SIST TC MOC, Mobilne komunikacije.

To je obdobje ko, tehnični pododbor pripravlja dokumente kot so

ETSI **ETS, Evropski telekomunikacijski standardi**.

Dokumente ETS dopolnjujejo

tehnična poročila ETSI ETR, ki so namenjena podrobnejši razlagi standardov in idej v njih.

Standardizacija na področju DECT tehnologije

ES Standard ETSI,
uporablja se, kadar dokument vsebuje tehnične zahteve. ES se predloži v odobritev celotnemu članstvu ETSI

ETS, European TelecommunicatioEvropski telekomunikacijski standardi,

pokrivajo delo vseh evropskih tehničnih komitejev na področju telekomunikacij - standardizacije telekomunikacij v ETSI

Kaj je harmoniziran standard?

Harmonizirani standard je evropski standard EN (Europäische Norm, European Norm),

ki je bil pripravljen po naročilu **Evropske komisije in Sekretariata EFTA** z namenom, da podpre bistven zahteve evropskih direktiv. Seznami harmoniziranih standardov se objavljajo v Uradnem listu ES z navedbo direktive, v podporo katere so bili pripravljeni. Od takrat dalje uporaba takih standardov ustvarja domnevo o skladnosti z ustrezno evropsko direktivo.

Standardizacija na področju DECT tehnologije

Rezultati dela ETSI tehničnih odborov in delovnih skupin, so tudi naslednji dokumenti:

ETSI Guide (EG) – Used for guidance to ETSI in general on the handling of speechnical Committee that drafted it. It is submitted to the whole ETSI membership for approval.

ETSI Technical Specification (TS) – Used when the document contains technical requirements and it is important that it is available for use quickly.

ETSI Technical Report (TR) – Used when the document contains explanatory material. A TR is approved by the Technical Committee that drafted it.

ETSI Special Report (SR) – Used for various purposes, including to make information publicly available for reference. An SR is approved by the Technical Committee which produced it.

ETSI Group Specification (GS) – Provides technical requirements or explanatory material or both. Produced and approved within our Industry Specification Groups (ISGs).

ETSI Group Report (GR) – An ETSI deliverable, containing only informative elements, approved for publication by an Industry Specification Group

SIST Standardizacija na področju DECT tehnologije

DECT – Svetovna tehnologija za glasovne in podatkovne aplikacije

Od svoje ustanovitve leta 1992 tehnologija DECT (Digital Enhanced Cordless Telecommunications) podpira tako glasovne kot podatkovne storitve na katerem koli spektru, dodeljenem DECT, in so opisane v specifikacijah radijskega vmesnika. Ključni parametri, ki določajo uporabo DECT, so del standarda ETSI Base **EN 300 175**, DECT, DECT 6.0 (DECT v NA/LATAM) in njihov naslednik CAT-iq sta sprejeta v več kot 100 državah po vsem svetu.



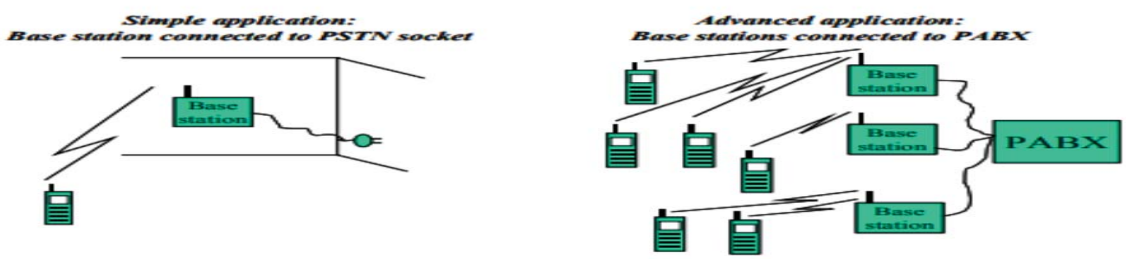
SIST Standardizacija na področju DECT tehnologije

Osnovni standardi DECT tehnologije

Osnovni standard DECT družine **ETS EN 300 175-1 do 9**:

Izdal ga je ETSI (European Telecommunications Standards Institute). Tehnični pododbor **STC RES –03** standardizira zračni vmesnik za govorni in podatkovni promet DECT. Standard DECT je bil po vsem svetu zelo razširjen v radijskem spektru, ki je blizu tistemu, ki je dodeljen v evropski regiji, v skladu z zahtevami CEPT. DECT zagotavlja osebne telekomunikacijske storitve v stanovanjskih in poslovnih okoljih.

Dve osnovni konfiguraciji uporabe DECT telefonije



SIST Standardizacija na področju DECT tehnologije

Prva, osnovna faza standardizacije DECT tehnologije (1989 - 1992)

Date	Milestone	Comments
1989 - 1992	Development of DECT base standards	• The core standard, developed originally for cordless telephony products, later extended for other applications. • Applications: – Cordless telephony. – Enterprise systems (PABX). – Public access telephony. – Wireless Local Loop (WLL). – Etc. • Main standards: – ETSI EN 300 175 parts 1 [i.1] to 8 [i.8]. • Spectrum: – 1 880 MHz - 1 900 MHz band in Europe. – Other bands possible worldwide.

SIST Standardizacija na področju DECT tehnologije

Leta 1992 objavljeni ETS Evropski telekomunikacijski DECT standardi

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-1 (Overview). Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-2 (Physical Layer) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-3 (MAC Layer) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-4 (Data Link Control Layer) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-5 (Network Layer) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-6 (Identities and Addressing) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-7 (Security Features) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-8 (Speech Coding & Transmission) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 175-9 (Public Access Profile) Oct. ETSI Secretariat, Sophia Antipolis Cedex, France.

European Telecommunications Standards Inst. 1992. RES-3 DECT Ref. Doc. ETS 300 176 (Approval Test

SIST Standardizacija na področju DECT tehnologije

Družina ETSI standardov ETS 300 175, 1 do 9 delov, dokumentov



EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-1
October 1992

Source: ETSI TC-RES
Reference: DE/RES-3001-1

ICS: 33.060
Key words: DECT

**Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 1: Overview**

ETSI ETS 300 175-1, 1992,

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 1: Pregled

SIST Standardizacija na področju DECT tehnologije



EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-2
October 1992

Source: ETSI TC-RES
Reference: DE/RES-3001-2

ICS: 33.060
Key words: DECT

**Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 2: Physical layer**

ETS 300 175-2, 1992,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
skupni vmesnik (CI);

Del 2: Fizična plast (PHL)

SIST Standardizacija na področju DECT tehnologije

ETS 300 175-3, leta 1992, napovedan dokument

Radijska oprema in sistemi (RES). Evropske digitalne brezvrvične telekomunikacije (DECT). Skupni vmesnik.
Del 3: Plast za nadzor dostopa do prenosnih medijev

ETS 300 175-3, ed.1: 2006, dosegljiv dokument,
našel dokument ETS 300 175-3, ed.2, september 1996,

Dokument ETS nadgrajen v standard EN leta 2008

Final draft ETSI EN 300 175-3 V2.2.0 (2008-06)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 3: Medium Access Control (MAC) layer

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-3
September 1996
Second Edition

Source: ETSI TC-RES

Reference: RE/RES-03027-3

ICS: 33.060, 33.060.50

Key words: DECT, MAC, radio

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 3: Medium Access Control (MAC) layer

Evropske digitalne brezvrvične telekomunikacije (DECT).
Skupni vmesnik.
Del 3: Plast za nadzor dostopa do prenosnih medijev

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-4
October 1992

Source: ETSI TC-RES Reference: DE/RES 3001-4

ICS: 33.060
Key words: DECT

**Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 4: Data link control layer**

ETS 300 175-4, 1992,

Radijska oprema in radijski sistemi (RES). Digitalne evropske brezvrvične telekomunikacije (DECT). Skupni vmesnik.
Del 4: Plast za nadzor podatkovnih povezav

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-5
October 1992

Source: ETSI TC-RES Reference: DE/RES 3001-5

ICS: 33.060
Key words: DECT

**Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common Interface
Part 5: Network layer**

ETS 300 175-5, 1992,

Radijska oprema in sistemi (RES). Digitalne evropske brezvrvične telekomunikacije (DECT). Skupni vmesnik,
Del 5: Omrežna plast

SIST Standardizacija na področju DECT tehnologije



EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-6

October 1992

Source: ETSI TC-RES

Reference: DE/RES-3001-6

ICS: 33.060

Key words: DECT

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 6: Identities and addressing

ETS 300 175-6 ed.1:1992

Digitalne izboljšane brezvrvične telekomunikacije (DECT) -- Skupni vmesnik(CI) --
6. del: Identitete in naslavljanje

SIST Standardizacija na področju DECT tehnologije

SIST ETS 300 175-7 E1:2005



EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-7

October 1992

Source: ETSI TC-RES

Reference: DE/RES-3001-7

ICS: 33.060

Key words: DECT

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 7: Security features

ETSI

European Telecommunications Standards Institute

ETSI Secretariat

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ETSI ETS 300 175-7 . ed. 1 (oktober 1992), ed.3 (1997-09) -

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 7: Varnostne funkcije

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-8

October 1992

Source: ETSI TC-RES

Reference: DE/RES-3001-8

ICS: 33.060

Key words: DECT

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Common interface
Part 8: Speech coding and transmission

ETS 300 175-8, oktober 1992,

Radijska oprema in sistemi (RES). Digitalne evropske brezvrvične telekomunikacije(DECT), Skupni vmesnik.
Del 8: Kodiranje govora in prenos govora

SIST Standardizacija na področju DECT tehnologije

ETSI

INTERIM EUROPEAN TELECOMMUNICATION STANDARD

I-ETS 300 176

October 1992

Source: ETSI TC-RES

Reference: DI/RES 3002

ICS: 33.060

Key words: DECT

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
Approval test specification

I-ETS 300 176, 1992,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);

Specifikacija homologacijskega preskusa;

Standardizacija na področju DECT tehnologije



INTERIM EUROPEAN TELECOMMUNICATION STANDARD

I-ETS 300 131
April 1992

Source: ETSI TC-RES Reference: CV/RES-0001

ICS: 33.060, 33.060.20
Key words: CT2, CAI

Radio Equipment and Systems (RES);
Common air interface specification to be used for
the interworking between cordless telephone apparatus
in the frequency band 864,1 MHz to 868,1 MHz,
including public access services

Radijska oprema in sistemi (RES) - Specifikacija skupnega radijskega vmesnika, ki se uporablja za medsebojno delovanje brezvrvičnih telefonskih aparatov v frekvenčnem pasu od **864,1 MHz do 868,1 MHz** vključno s storitvami javnega dostopa

Standardizacija na področju DECT tehnologije



ETSI TECHNICAL REPORT

ETR 056
July 1993

Source: ETSI TC-RES Reference: DTR/RES-3005

ICS: 33.060, 33.060.20
Key words: DECT, system description

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT)
System description document

ETSI ETR 056

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Dokument z opisom sistema

Standardizacija na področju DECT tehnologije

ETSI

TECHNICAL BASIS for REGULATION

TBR 6
January 1997
Second Edition

Source: ETSI TC-RES

Reference: RTBR/RES-03051

ICS: 33.050.60

Key words: DECT, test specification, TBR, radio

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
General terminal attachment requirements

Radijska oprema in sistemi (RES) – prva edicija dokumenta **objavljena v decembru 1993,**
Digitalne izboljšane brezvrvične telekomunikacije (DECT) - **Splošne zahteve za priključevanje terminalov**

Standardizacija na področju DECT tehnologije

ETSI

TECHNICAL BASIS for REGULATION

DRAFT
prTBR 10
September 1995
Second Edition

Source: ETSI TC-RES

Reference: DTBR/RES-03052

ICS: 33.060.50

Key words: DECT, test specification, speech

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT);
General terminal attachment requirements
Telephony applications

TBR 010 E1, prva edicija objavljena **18. decembra 1993**

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Splošne zahteve za vključitev terminala: Aplikacije za telefonijo

SIST Standardizacija na področju DECT tehnologije

ETSI

INTERIM EUROPEAN TELECOMMUNICATION STANDARD

I-ETS 300 235

March 1994

Source: ETSI TC-RES Reference: DI/RES-00002

ICS: 33.020

Key words: Radio, testing, CT1

Radio Equipment and Systems (RES);
Technical characteristics, test conditions and methods of measurement for radio aspects of cordless telephones CT1

Radijska oprema in sistemi (RES) -- Tehnične značilnosti, preskusni pogoji in merilne metode za radijske vidike brezvrvičnih telefonov CT1

SIST Standardizacija na področju DECT tehnologije

ETSI

ETSI TECHNICAL REPORT

ETR 159

July 1995

Source: ETSI TC-RES Reference: DTR/RES-03022

ICS: 33.060

Key words: DECT, mobility, GSM

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT);
Wide area mobility using the Global System for Mobile communications (GSM)

PSIST ETR 159:1998

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Globalni sistem za mobilne komunikacije (GSM);
Široka mobilnost območja z uporabo GSM

Standardizacija na področju DECT tehnologije

ETSI TECHNICAL REPORT

ETR 178

October 1995

First Edition

Source: ETSI TC-RES

Reference: DTR/RES-03029

ICS: 30.020, 30.060.50

Key words: DECT standardization

Radio Equipment and System (RES);
Digital European Cordless Telecommunications (DECT);
A high level guide to the DECT standardization

- Radijska oprema in sistemi (RES);
  digitalne evropske brezvrvične telekomunikacije (DECT);

  Vodnik na visoki ravni za standardizacijo DECT

Standardizacija na področju DECT tehnologije

ETR 246-1995【现行】无线电设备和系统（RES）.欧洲数字无绳通信（DECT）.DECT无线中继站（WRS）的应用

原文题名： Radio Equipment and Systems (RES) - Digital European Cordless Telecommunications (DECT) - Application of DECT Wireless Relay Station (WRS)

中文题名： 无线电设备和系统（RES）.欧洲数字无绳通信（DECT）.DECT无线中继站（WRS）的应用

ETSI

ETSI TECHNICAL REPORT

ETR 246

November 1995

Source: ETSI TC-RES

Reference: DTR/RES-03068

ICS: 33.020, 33.060.50

Key words: DECT, WRS

Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications (DECT);
Application of DECT Wireless Relay Station (WRS)

PSIST ETR 246:1998 -
Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Uporaba DECT brezvrvičnih relejnih postaj (WRS)

Standardizacija na področju DECT tehnologije

ETSI

ETSI TECHNICAL REPORT

ETR 308

August 1996

Source: ETSI TC-RES

Reference: DTR/RES-03074

ICS: 33.020, 33.060.50

Key words: Access, configuration, DECT, facility, profile, RLL, service, traffic

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Services, facilities and configurations
for DECT in the local loop

ETSI - ETR 308

Radijska oprema in sistemi (RES); Digitalne izboljšane brezvrvične telekomunikacije (DECT); Storitve, zmogljivosti in konfiguracije za DECT v lokalni zanki

Standardizacija na področju DECT tehnologije

ETSI

ETSI TECHNICAL REPORT

ETR 310

August 1996

Source: ETSI TC-RES

Reference: DTR/RES-03077

ICS: 33.020, 33.060.50

Key words: DECT, traffic

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Traffic capacity and spectrum requirements for multi-system
and multi-service DECT applications co-existing in a
common frequency band

- Radijska oprema in sistemi (RES);
  Digitalne izboljšane brezvrvične telekomunikacije (DECT);

  Zahteve glede prometne zmogljivosti in spektra za več sistemov in več storitvene DECT aplikacije, ki soobstajajo v skupnem frekvenčnem pasu

SIST Standardizacija na področju DECT tehnologije

ETSI

CORRIGENDUM **ETR 310**

October 1996

Source: ETSI TC-RES Reference: DTR/RES-03077-C1

ICS: 33.020, 33.060.50

Key words: DECT, traffic

This corrigendum modifies the ETSI Technical Report ETR 310 (August 1996)

Radio Equipment and Systems (RES); Digital Enhanced Cordless Telecommunications (DECT); Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

FINAL DRAFT
pr ETS 300 446

March 1996

Source: ETSI TC-RES Reference: DE/RES-09012

ICS: 33.100, 33.060.20, 33.060.50

Key words: CT2, EMC, radio

Radio Equipment and Systems (RES); Electro-Magnetic Compatibility (EMC) standard for second generation Cordless Telephone (CT2) apparatus operating in the frequency band 864,1 MHz to 868,1 MHz, including public access services

ETSI - ETS 300 446

Radijska oprema in sistemi (RES); Elektro-magnetna združljivost (EMC) standard za drugo generacijo brezvrvičnega telefona (CT2), aparati, ki delujejo v frekvenčnem pasu 864,1 MHz do 868,1 MHz, vključno s storitvami javnega dostopa

Standardizacija na področju DECT tehnologije

Po prvi izdaji DECT standarda leta **1992** je bilo delo DECT standardizacije osredotočeno na opredelitev profila splošnega dostopa (GAP) in drugih medsodelovalnih profilov (DECT/GSM, DECT/ISDN, DECT/Radio Local Loop, CTM in več profilov podatkov). To delo in dodatne zahteve trga DECT so sprožile več razširitev in izboljšav osnovnega standarda, kar je omogočilo še učinkovitejšo uporabo izdelkov DECT, zaradi česar se je do konca leta **1995 dokončno končala 2. izdaja osnovnega standarda.** Nekateri primeri tega so:

- vključitev postopkov klica v sili za sprejem DECT za vloge za javni dostop,

- opredelitev brezžične relejne postaje (WRS) kot nove komponente sistema, ki omogoča stroškovno učinkovitejšo infrastrukturo in

- opis izbirne neposredne prenosne do prenosne komunikacijske funkcije za DECT.

Za spodbujanje interoperabilnosti med DECT opremo različnih proizvajalcev so člani ETSI TC začeli delati na opredelitvi standardnih meddelujočih profilov do konca leta **1993**. Generični dostop Pro-file GAP je bil prvi profil, dokončan leta **1994**. Vsebuje podskupino protokola, ki je potrebna za osnovno telefonsko storitev v stanovanjskih brezvrvičnih telefonih, poslovnem brezžičnem PABX in aplikacijah za javni dostop; je podlaga za vse druge govorne profile DECT. Testiranje interoperabilnosti za GAP je uspešno končano.

Standardizacija na področju DECT tehnologije

Dopolnitev standardov ETSI tehnologije v letu 1995

1995	Release of Generic Access Profile (GAP) standard	• Generic Access Profile (GAP) standard defines a comprehensive feature set for interoperability of cordless telephony devices. • Standard: ETSI EN 300 444 [i.9].

Generični profil dostopa (GAP) je osnovni signalni protokol za brezvrvično telefonijo z uporabo digitalnih izboljšanih brezvrvičnih telekomunikacij (DECT).

V specifikaciji Evropskega inštituta za telekomunikacijske standarde (ETSI) so opisane metode za interoperabilnost naprav različnih proizvajalcev. Malo je obveznih v SKP. Običajna predstavitev identifikacije klicne vrstice (CLIP) na primer ostaja neobvezna. [1]

Obstajajo še nekateri drugi profili za DECT, pripravljeni v ETSI.

SIST Standardizacija na področju DECT tehnologije

Draft EN 300 444 V1.3.2 (1998-03)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Generic Access Profile (GAP)

Standard EN 300 444, planiran v letu 1995, na razpolago osnutek v 1998 in dokončan dokument v maja 1999,

Digitalne izboljšane brezvrvične telekomunikacije (DECT).
Profil splošnega dostopa (GAP)

SIST Standardizacija na področju DECT tehnologije

SIST EN 300 444 V1.3.3:2003

EN 300 444 V1.3.3 (1999-05)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Generic Access Profile (GAP)



ETSI ETS 300 444, V.1 1995

Digital Enhanced Cordless Telecommunications (DECT); **Profil splošnega dostopa (GAP)**

standard Evropskega inštituta za telekomunikacijske standarde, **12/01/1995**

SIST Standardizacija na področju DECT tehnologije

Standardizacijski dokumenti iz obdobja 1995 do leta 2000

1995 - 2000 (approx.)	Data Services Profile (DSP)	• A range of DECT Data Service Profiles for different services and applications. • Main standards: – ETSI TR 102 185 [i.21]. – ETSI EN 301 240 [i.22]. – ETSI EN 301 239 [i.23]. – ETSI EN 301 238 [i.24]. – Etc.

ETSI TR 102 185: Digital Enhanced Cordless Telecommunications (DECT), Data Services Profile (DSP); Profile overview, (v arhivu nisem našel dokumenta !)

ETSI EN 301 240: Digital Enhanced Cordless Telecommunications (DECT); Data Services Profile (DSP); Point-to- Point Protocol (PPP) interworking for internet access and general multi-protokol datagram transport;

ETSI EN 301 239: Digital Enhanced Cordless Telekommunications (DECT); Data Services Profile (DSP); Isochronous data bearer services with roaming mobility (service type D, mobility class 2;

ETSI EN 301 238: Digital Enhanced Cordless Telekommunications (DECT); Data Services Profile (DSP), Isochronous data bearer service with roaming mobility (service type D, mobility class 2;

SIST Standardizacija na področju DECT tehnologije

ETSI TR 102 185 V1.2.1 (2001-05)

Technical Report

Digital Enhanced Cordless Telecommunications (DECT);
Data services overview

ETSI TR 102 185

Digitalne izboljšane brezvrvične telekomunikacije (DECT); **Profil podatkovnih storitev (DSP)**; Pregled profila

SIST Standardizacija na področju DECT tehnologije

Final draft ETSI EN 301 238 V1.3.0 (2001-06)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Isochronous data bearer services with roaming mobility
(service type D, mobility class 2)**

SIST EN 301 238:2001

Digitalne izboljšane brezvrvične telekomunikacije (DECT); Profil podatkovnih storitev (DSP); Storitve nosilca izohronih podatkov z mobilnostjo gostovanja (tip storitve D, razred mobilnosti 2)

SIST Standardizacija na področju DECT tehnologije

Final draft EN 301 239 V1.1.2 (1998-03)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Isochronous data bearer services for closed user groups
(service type D, mobility class 1)**

ETSI EN 301 239,

Digitalne izboljšane brezvrvične telekomunikacije (DECT). Profil podatkovnih storitev (DSP). Storitve nosilca izohronih podatkov za skupine zaprtih uporabnikov (tip storitve D, razred mobilnosti 1)

SIST Standardizacija na področju DECT tehnologije

Final draft EN 301 240 V1.1.2 (1998-04)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Point-to-Point Protocol (PPP) interworking for internet access
and general multi-protocol datagram transport**

EN 301 240,

Digitalne brezvrvične telekomunikacije (DECT) - Profil podatkovnih storitev (DSP)
Protokol za sodelovanje med točkami in točkami (PPP) za internetni dostop in splošni multi protokol datagramski prenos

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 494-3

August 1996

Source: ETSI TC-RES

Reference: DE/RES-03040-3

ICS: 33.020, 33.060.50

Key words: DECT, GAP, testing

**Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Generic Access Profile (GAP);
Profile Test Specification (PTS);
Part 3: Profile Specific Test Specification (PSTS)
- Fixed radio Termination (FT)**

ETS 300 494-3

Radijska oprema in sistemi (RES). Digitalne telekomunikacije (DECT). Profil glavnega dostopa (GAP). Specifikacija preskusa profila (PTS).
Del 3: Specifikacija preskusa posebnega profila(PSTS) - fiksni radijski konec (FT)

Standardizacija na področju DECT tehnologije

ETSI

AMENDMENT

TBR 22
pr A1
November 1997

Source: ETSI EP-DECT Reference: RTBR/DECT-000092

ICS: 33.020

Key words: Access, DECT, generic, radio, testing, type approval

This draft amendment A1, if approved, will modify the Technical Basis for Regulation TBR 22 (1997)

**Radio Equipment and Systems (RES);
Attachment requirements for terminal equipment for
Digital Enhanced Cordless Telecommunications (DECT)
Generic Access Profile (GAP) applications**

SIST TBR 022, 2000

Radijska oprema in sistemi (RES); Zahteve za odobritev terminalske opreme za aplikacije za digitalne izboljšane brezvrvične telekomunikacije (DECT), (GAP) profil Generičnega dostopa,

Standardizacija na področju DECT tehnologije

ETSI EN 300 444 V2.1.1 (2008-10)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Generic Access Profile (GAP)**

Standarda iz leta 1995, nisem našel, to je kasnejša posodobljena verzija iz leta 2008. Na SIST našel, dokument s slovenskim naslovom. Leta 1995 smo imeli ETS, leta 2008 pa že EN standard!!

ETSI
ETSI ETS 300 444 ed.1 (1995-12)
SIST ETS 300 444 E1:2003
Digitalne izboljšane brezžične telekomunikacije (DECT); Profil splošnega dostopa (GAP)

Standardizacija na področju DECT tehnologije

Profili aplikacij DECT, **DECT Applications Profiles,**

Profili aplikacij vsebujejo dodatne specifikacije, ki določajo, kako naj se zračni vmesnik DECT uporablja v posebnih aplikacijah. Standardna sporočila in pod nabori protokolov so izpeljani iz osnovnega standarda, prilagojeni za posebne aplikacije z namenom doseči največjo interoperabilnost med opremo DECT različnih proizvajalcev.

Profil splošnega dostopa GAP - Generic Access Profiles,

Generični dostopni profil (GAP) je osnovni profil DECT in velja za vse DECT prenosne in fiksne dele, ki podpirajo 3.1 kHz telefonske storitve ne glede v katero vrsto omrežja dostopate. Opredeljuje minimalni obvezni niz tehničnih zahtev za zagotovitev interoperabilnosti med katerim koli DECT GAP fiksnim delom in prenosnim delom.

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Standardizacija na področju DECT tehnologije

DECT/GSM profil za medsebojno delovanje (GIP), Interworking Profile

DECT je tehnologija dostopa in omogoča mobilnost po celotnem omrežju zunaj obsega. Standard DECT GIP je zmogljiv dodatek, ki zagotavlja mobilnost v DECT v strukturah, razporejenih na več mestih prek funkcij GSM mobilnosti.
Profil za medsebojno delovanje DECT/GSM za osnovno govorno storitev 3,1 kHz je obravnavan v evropskem telekomunikacijskem standardu **ETS 300 370.** Skupaj z **ETS 300 499** in **ETS 300 703** opredeljuje zahteve protokola za medsebojno delovanje obeh tehnologij.

Profili za medsebojno delovanje ISDN (IAP in IIP), ISDN interworking Profiles(IAP and IIP)

Za medsebojno delo med omrežjem ISDN in sistemom DECT sta bila definirana dva profila
Profil DECT/ISDN za konec sistemske konfiguracije je opredeljen v ETS 300 434 (IAP)
Profil DECT/ISDN za vmesne sistemske konfiguracije pa v DE/RES 03039 (IIP). IAP se uporablja, ko DECT FP in PP skupaj tvorita terminal ISDN (ISDN storitve in dopolnilne storitve opravlja DECT PP). IIP se uporablja, kadar DECT FP in DECT PP skupaj tvorita pregleden prehod med omrežjem ISDN in enim ali več terminalov ISDN, povezanih na S0-vmesnik na DECT Intermediate Portable Sistem (DIPS). IIP podpira ISDN basic dostop in vse omrežno določene storitve, tj. 3,1 kHz govor, 64 kbit/s neomejen prenos ISDN paketnih podatkov in dopolnilnih storitev.

Standardizacija na področju DECT tehnologije

Profil dostopa do radijske lokalne zanke (RAP), Radio local loop Access Profile

Radijska lokalna zanka DECT zagotavlja stroškovno učinkovit način za vzpostavitev javnega telekomunikacijskega omrežja, ki je zaščiteno pred izpadi prometa.
S tehnologijo DECT RLL lahko telekomunikacijski operaterji koristno zaščitijo promet svojih strank z relativno nizkimi naložbami v primerjavi s tehnologijami žične krajevne zanke. Na razvitih trgih in lokacijah, kjer ni ekonomično ali praktično namestiti žično javno telefonijo, tehnologija RLL lahko zagotovi stroškovno učinkovito rešitev in omogoča konkurenco novim operaterjem.
Profil dostopa do lokalne zanke je opredeljen v dokumentu **ETS 300 765.** RAP definira DECT podnabor protokolov, ki je potreben za zagotavljanje javnih omrežnih storitev končnim uporabnikom.

CTM dostopni profil (CAP), CTM Access Profile(CAP),

Mobilnost brezžičnega terminala (CTM) omogoča storitve uporabnikom brezvrvičnih terminalov, da gostujejo znotraj in med omrežji. Kjer je zagotovljena radijska pokritost in ima brezvrvični terminal ustrezne pravice dostopa, uporabnik lahko kliče in sprejema klice kadar koli ne glede na lokacijo znotraj fiksnega javnega in/ali zasebnega omrežja in se lahko premika brez prekinitve potekajočega klica. CAP je podoben profil kot DECT-GSM. Razlika v tem, da CAP ni omejen na funkcije mobilnosti obstoječega GSM omrežja lahko pa medsebojno delujejo – na standardiziran način, s katerim koli omrežjem, ki zagotavlja funkcije mobilnosti.

Standardizacija na področju DECT tehnologije

Data Service Profiles, profili podatkovnih storitev - (A, B, C, D, E, F, internetno medsebojno delovanje)

ETSI je razvil družino profilov za prenos podatkov, da bi zagotovil interoperabilnost za opremo za podatkovno komunikacijo, ki je povezana prek zračnega vmesnika DECT. Vsak član družine profilov je optimiziran za določeno storitev. Spodnja tabela prikazuje seznam podatkovnih profilov, kot je trenutno načrtovano.

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SIST Standardizacija na področju DECT tehnologije

DECT podatkovni profili (1997)

Profile	Reference	Application
A/B.1	ETS 300 435	Generic frame relay for interworking with Ethernet and Token ring LANs at up to 552 kbit/s. Forms the basis for the C and F profiles.
A/B.2	ETS 300 701	Supports similar services as ETS 300 435 for mobile applications and provides direct interworking with the Internet Protocol (IP).
C.1	ETS 300 699	Generic data link service built upon the generic frame relay service of the A/B profile for applications that need a high degree of data integrity. It includes interworking with V.24 interfaces.
C.2	ETS 300 651	The C.2 profile extends the Data Stream service into environments where mobility is required. It contains interworking with V.24 and connection oriented bearer services.
D.1	not yet finalised	Provides transparent and isochronous transfer of synchronous data services for Closed User Groups.
D.2	not yet finalised	Similar to D.1 for mobile applications.
E.2	ETS 300 757	Low Rate Messaging service for roaming applications. Providing both point-to-point and point-to-multipoint messaging (e.g. alphanumeric paging) using the signalling channels.
F.2	ETS 300 755	Multimedia Messaging Service for mobile applications (Fax, E-mail, WWW access, SMS).

SIST Standardizacija na področju DECT tehnologije

SIST ETS 300 435 :1999

Oznaka standarda: SIST ETS 300 435:1999

Naslov (angleški): Digital Enhanced Cordless Telecommunications (DECT); Data Services Profile (DSP); Base standard including interworking to connectionless networks (service types A and B, class 1)

Naslov (slovenski): Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Profil podatkovnih storitev (DSP) - Temeljni standard, ki vsebuje vzajemno delovanje do nepovezavnih omrežij (storitve tipov A in B, razred 1)

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

DRAFT
pr ETS 300 701
January 1996

Source: ETSI TC-RES Reference: DE/RES-03032

ICS: 33.020, 33.060.50
Key words: DECT, profile, data, LAN

**Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Generic frame relay service with mobility
(service types A and B, class 2)**

ETSI ETS 300 701

Digitalne izboljšane brezvrvične telekomunikacije (DECT); Profil podatkovnih storitev (DSP); Generična relejna storitev okvirja z mobilnostjo (vrste storitev A in B, razred 2)

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

DRAFT
pr ETS 300 699
January 1996

Source: ETSI TC-RES Reference: DE/RES-03035

ICS: 33.020, 33.060.50
Key words: DECT, profile, data, LAN

**Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Generic data link service for closed user groups
(service type C, mobility class 1)**

SIST ETS 300 699: 1998

Digitalne izboljšane brezvrvične telekomunikacije (DECT); Profil podatkovnih storitev (DSP); Storitev generične podatkovne povezave za zaprte skupine uporabnikov (vrsta storitve C, mobilnost razred 1),

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

FINAL DRAFT
pr ETS 300 651
June 1996

Source: ETSI TC-RES Reference: DE/RES-03036

ICS: 30.020, 30.060.50

Key words: DECT, data, layer 2, mobility, profile, radio

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Generic data link service;
Service type C, class 2

ETSI - ETS 300 651

Radijska oprema in sistemi (RES); Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Profil podatkovnih storitev (DSP);
Storitev generičnih podatkovnih povezav; Vrsta storitve C, razred 2

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

FINAL DRAFT
pr ETS 300 757
December 1996

Source: ETSI TC-RES Reference: DE/RES-03078

ICS: 33.020

Key words: DECT, profile, data, messaging

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Low rate messaging service;
(Service type E, class 2)

ETSI - ETS 300 757

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Profil podatkovnih storitev (DSP);
Storitev za nizko stopnjo sporočanja; (Vrsta storitve E, razred 2)

Standardizacija na področju DECT tehnologije

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 755

May 1997

Source: ETSI EP-DECT

Reference: DE/DECT-020038

ICS: 33.020

Key words: Data, DECT, facsimile, mobility, profile, radio

**Digital Enhanced Cordless Telecommunications (DECT);
Data Services Profile (DSP);
Multimedia Messaging Service (MMS) with specific
provision for facsimile services;
(Service type F, class 2)**

ETSI - ETS 300 755

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Profil podatkovnih storitev (DSP);
Multimedijska storitev sporočanja (MMS) s posebnimi storitvami za storitve facsimile;
(Vrsta storitve F, razred 2)

Standardizacija na področju DECT tehnologije

TR 101 030 V1.1.1 (1997-07)

Technical Report

**Radio Equipment and Systems (RES);
Radio Local Loop (RLL) Co-ordination Group;
Survey of ETSI activities and recommendations for
the ETSI work programme**

Radijska oprema in sistemi (RES);

Koordinacijska skupina za radijsko lokalno zanko (**RLL**);

Pregled dejavnosti ETSI in priporočila za delovni program ETSI

SIST Standardizacija na področju DECT tehnologije

Tehnično poročilo **ETSI ETR 178** je pripravil tehnični odbor RES(radijska oprema in sistemi).
ETR so informativni dokumenti, ki izhajajo iz študij ETSI, ter niso primerni za objavo kot evropski standard za telekomunikacije **(ETS)** ali začasni (Interim) evropski telekomunikacijski standard **(I-ETS)**.
ETR se lahko uporablja za objavo gradiva, ki je bodisi informativne narave ter se nanaša na uporabo ETS ali I-ETS, ali, ki še ni primerno za uradno sprejetje kot ETS.

ETSI

ETSI TECHNICAL REPORT

ETR 178
October 1995
First Edition

Source: ETSI TC-RES
Reference: DTR/RES-03029

ICS: 30.020, 30.060.50
Key words: DECT standardization

**Radio Equipment and System (RES);
Digital European Cordless Telecommunications (DECT);
A high level guide to the DECT standardization**

ETSI ETR 178-ed.1, 1995,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Vodnik na visoki ravni za standardizacijo DECT

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 370
July 1995

Source: ETSI TC-RES
Reference: DE/RES-03017

ICS: 33.060, 33.060.20
Key words: DECT, GSM

**Radio Equipment and Systems (RES);
Digital European Cordless Telecommunications/
Global System for Mobile communications
(DECT/GSM) inter-working profile
Access and mapping
(Protocol/procedure description for 3,1 kHz speech service)**

ETSI - ETS 300 370, 1995,

TC radijska oprema in sistemi (RES); Digitalni evropski brezvrvični telekomunikacijski/ globalni sistem za mobilne komunikacije (DECT/GSM) medobvezni dostop in preslikava profilov (Protokol/ Opis postopka za govorno storitev 3,1 kHz), 1. januar 1995. **Dokument je bil posodobljen še v letih 1996, 1997, 1998 in 2001.**

SIST Standardizacija na področju DECT tehnologije

Draft EN 300 175-1 V1.4.1 (1998-02)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 1: Overview**

EN 300 175-1

Digitalne izboljšane brezvrvični telekomunikacije (DECT) -- Skupni vmesnik (CI) --
1. del: Pregled

SIST Standardizacija na področju DECT tehnologije

Final draft EN 300 175-1 V1.4.2 (1999-03)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 1: Overview**

EN 300 175-1

Digitalne izboljšane brezvrvični telekomunikacije (DECT) -- Skupni vmesnik (CI) --
1. del: Pregled

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-2
September 1996
Second Edition

Source: ETSI TC-RES

Reference: RE/RES-03027-2

ICS: 33.060, 33.060.50
Key words: DECT, radio

**Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 2: Physical layer (PHL)**

SIST ETS 300 175-2:1999 -
Digitalne izboljšane brezvrvične telekomunikacije (DECT);
skupni vmesnik (CI);

Del 2: Fizična plast (PHL)

SIST Standardizacija na področju DECT tehnologije

SIST

SLOVENSKI STANDARD
SIST ETS 300 175-2:1999
01-julij-1999

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Skupni vmesnik (CI) - 2. del: Fizična plast (PHL)

Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)

iTeh STANDARD PREVIEW
(standards.iteh.ai)

Ta slovenski standard je istoveten z: **ETS 300 175-2 Edition 2**

SIST ETS 300 175-2:1999
https://standards.iteh.ai/catalog/standards/sist/0c3c1230-d377-4e38-9dc0-

SIST Standardizacija na področju DECT tehnologije

EN 300 175-3 V1.4.2 (1999-06)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 3: Medium Access Control (MAC) layer**

ETSI EN 300 175-3

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
skupni vmesnik (CI);
Del 3: sloj srednje dostopne kontrole (MAC)

SIST Standardizacija na področju DECT tehnologije

ETSI ETS 300 175-4 V1.4.2 (1999-09)

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-4
September 1996
Second Edition

Source: ETSI TC-RES

Reference: RE/RES-03027-4

ICS: 33.060, 33.060.50
Key words: DECT, radio

**Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 4: Data Link Control (DLC) layer**

ETSI ETS 300 175-4,

Digitalne brezvrvične telekomunikacije (DECT),
Skupni vmesnik (CI),
Del 4: Plast za nadzor podatkovnih povezav (DLC)

SIST Standardizacija na področju DECT tehnologije

SIST ETS 300 175-5:1999

Oznaka standarda:	SIST ETS 300 175-5:1999
Koda projekta:	5487
Organizacija:	SIST
Naslov (angleški):	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 5: Network (NWK) layer
Naslov (slovenski):	Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Skupni vmesnik (CI) - 5. del: Omrežna plast (NWK)

SIST Standardizacija na področju DECT tehnologije

ETS 300 175-6, September 1996

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 6: Identities and addressing

ETS 300 175 -7, September 1997,

Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 7: Security features

SIST Standardizacija na področju DECT tehnologije

SIST

SLOVENSKI STANDARD
PSIST ETS 300 175-8:1998
01-december-1998

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Skupni vmesnik (CI) - 8. del: Kodiranje in prenos govora

ETSI – ETS 300 175-9, januar 1992, v SIST leta 1996,

Radijska oprema in sistemi (RES); Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);

Del 9: Profil javnega dostopa (PAP)

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 175-9
September 1996
Second Edition

Source: ETSI TC-RES

Reference: RE/RES-03027-9

ICS: 33.060, 33.060.50
Key words: DECT, PAP, radio

Radio Equipment and Systems (RES);
Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 9 : Public Access Profile (PAP)

ETSI - ETS 300 175-9, september 1996

Radijska oprema in sistemi (RES); Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 9: Profil javnega dostopa (PAP)

SIST Standardizacija na področju DECT tehnologije

ETSI ETR 043 ED.1 (1992–1997)

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI); Specifikacija zahtev za storitve in objekte

ETSI ETR 043-ed.1

Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Services and facilities requirements specification

SIST

SLOVENSKI STANDARD
PSIST ETR 043:1998
01-november-1998

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Skupni vmesnik (CI) - Specifikacija zahtev za storitve in lastnosti

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 765-1
August 1997

Source: ETSI EP-DECT

Reference: DE/DECT-050075-1

ICS: 33.020

Key words: DECT, GSM, RLL

Digital Enhanced Cordless Telecommunications (DECT);
Radio in the Local Loop (RLL) Access Profile (RAP);
Part 1: Basic telephony services

ETSI ETS 300 765-1,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Radio v profilu dostopa lokalne zanke (RLL) (RAP);
Del 1: **Storitve osnovne telefonije**

SIST Standardizacija na področju DECT tehnologije

ETSI

EUROPEAN TELECOMMUNICATION STANDARD

ETS 300 765-2

April 1998

Source: DECT

Reference: DE/DECT-050075-2

ICS: 33.020

Key words: DECT, GSM, RLL

Digital Enhanced Cordless Telecommunications (DECT);
Radio in the Local Loop (RLL) Access Profile (RAP);
Part 2: Advanced telephony services

ETS 300 765-2, 1998,

Digitalne brezvrvične telekomunikacije (DECT) - Profil dostopa lokalnega radijskega vezja (RLL)
2. del: Izboljšane storitve telefonije

SIST Standardizacija na področju DECT tehnologije

Draft EN 301 242 V1.2.1 (1998-07)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Global System for Mobile communications (GSM);
DECT/GSM integration based on dual-mode terminals

EN 301 242 1998

Digitalne izboljšane brezvrvične telekomunikacije (DECT)
Globalni sistem za mobilne komunikacije (GSM)
Integracija DECT/GSM na podlagi terminalov z dvojnim načinom delovanja

Standardizacija na področju DECT tehnologije

1999/497/ES: Odločba Komisije z dne 7.

Velja od 08.7.1999 .

Prom. L UL. 192*/24 Jul 1999*

Текст на йта на EUR-Lex

ODLOČBA KOMISIJE
julija 1999
o skupnem tehničnem pravilniku za digitalno izboljšano brezžično telekomunikacijsko opremo DECT/GSM v dvojnem načinu
(priglašeno pod številko dokumenta C(1999) 2026)
(Besedilo s pomembnostjo EGP)
(1999/497/ES)

KOMISIJA EVROPSKIH SKUPNOSTI,
ob upoštevanju Pogodbe o ustanovitvi Evropske skupnosti,
ob upoštevanju Direktive 98/13/ES Evropskega parlamenta in Sveta z dne 12.
(1) ker je Komisija sprejela ukrepe za opredelitev vrste terminalske opreme, za katero je potreben skupni tehnični predpis, in s tem povezano izjavo o obsegu v skladu s prvo alineo člena 7(2);
(2) ker je treba sprejeti ustrezne usklajene standarde ali dele teh standardov, ki izvajajo bistvene zahteve, ki naj se spremenijo v skupne tehnične predpise;
(3) ker je za zagotovitev neprekinjenega dostopa do trgov za proizvajalce treba omogočiti prehodne ureditve glede opreme, homologacijske v skladu z nacionalnimi predpisi o homologaciji;
(4) ker je bil predlog predložen Odboru (ACTE) v skladu s členom 29(2);
(5) ker je skupni tehnični predpis, ki ga je treba sprejeti v tem sklepu, v skladu z mnenjem acte–
SPREJELA TA SKLEP:

Standardizacija na področju DECT tehnologije

3G in 4G

Leta **1992** je Mednarodna telekomunikacijska zveza **ITU** dodelila spekter za naslednjo generacijo brezžičnih telekomunikacij 3G in iskala globalno uskladitev njenega

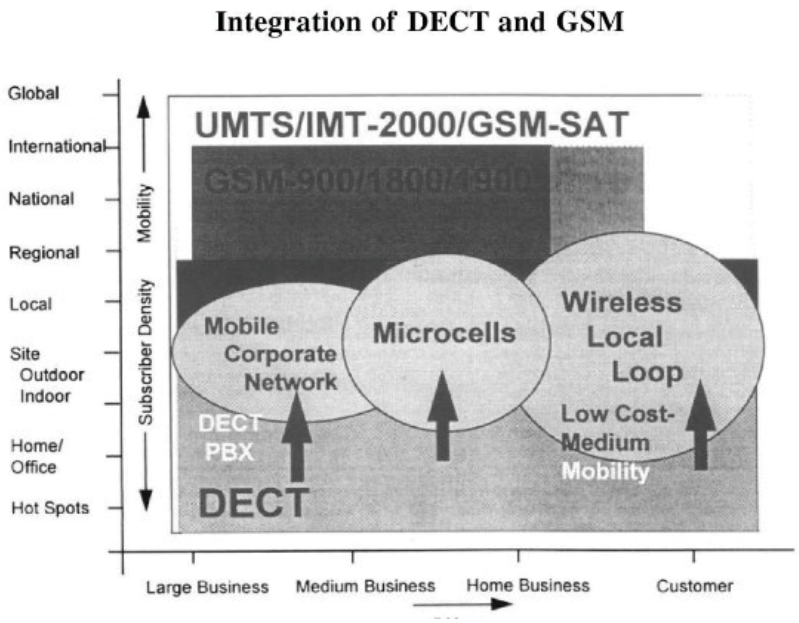
Radio Interface Technologies (RIT) pod imenom
IMT-2000, International Telecommunications-2000;

to je vključevalo tudi široko paleto večpredstavnosti in aplikacije, storitve ter terminale.

ETSI je izboljšal standard DECT z visoko stopnjo modulacijskih načinov in višjih hitrostih prenosa podatkov in s tem izpolnil zahteve IMT-2000.

ITU oceni izboljšani standard DECT in ga vključili v nabor radijskih vmesnikov Radio Interface Technologies, SRIT, **za IMT-2000**.

Standardizacija na področju DECT tehnologije



SIST ETS 300 370:1999

Digitalne izboljšane brezvrvične telekomunikacije (DECT); **Globalni sistem za mobilne komunikacije (GSM); DECT/GSM profil dela (IWP)**; Dostop in preslikava (opis protokola/postopka za govorno storitev 3,1 kHz)

Standardizacija na področju DECT tehnologije

Tehnologija 3G je bila rezultat raziskovalnega in razvojnega dela **Mednarodne telekomunikacijske unije (ITU) v začetku 80. le**t. Specifikacije in standardi 3G so bili razviti v petnajstih letih.
Tehnične specifikacije so bile na voljo javnosti pod imenom IMT-2000. Komunikacijski spekter med 400 MHz in 3 GHz je bil dodeljen za 3G. Tako vlada kot komunikacijska podjetja so potrdili standard 3G. Prvo predkomercialno 3G omrežje je začel NTT DoCoMo na Japonskem leta 1998 z blagovno znamko FOMA. Prvič je bila na voljo maja 2001 kot pred-izdaja (test) W-CDMA tehnologije. Prvo komercialno uvedbo 3G je 1. širša razpoložljivost sistema je bila odložena zaradi očitnih pomislekov glede njegove zanesljivosti.

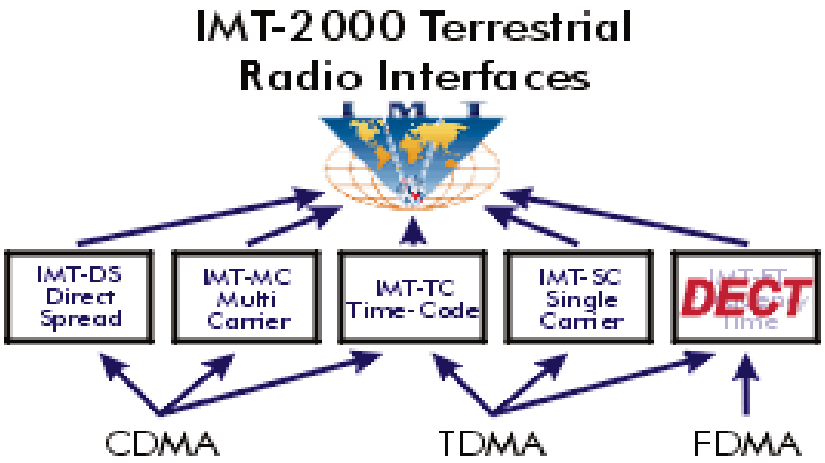
Prvo evropsko predkomercialno omrežje je bilo omrežje UMTS na otoku Man by Manx Telecom, operater, ki je bil nato v lasti British Telecoma, in prvo komercialno omrežje (tudi W-CDMA, UMTS) v Evropi je norveški telekom Telenor decembra 2001 odprl za podjetja brez komercialnih telefonov in s tem brez strank, ki bi plačale storitve.

Raziskovalni in razvojni projekti **3G (UMTS in CDMA2000)** so se začeli leta **1992. Leta 1999 je ITU** odobril **pet radijskih vmesnikov za IMT-2000** kot del priporočila **ITU-R M.1457;** WiMAX je bil dodan leta 2007.

Obstajajo evolucionarni standardi (EDGE in CDMA), ki so za nazaj združljivi z že obstoječimi 2G omrežji, pa tudi revolucionarni standardi, ki zahtevajo vse nove omrežne strojne in frekvenčne dodelitve. Mobilni telefoni uporabljajo UMTS v kombinaciji s 2G GSM standardi in pasovno širino, vendar ne podpirajo EDGE. Ta skupina je družina UMTS, ki je sestavljena iz standardov, razvitih za IMT-2000, pa tudi **neodvisno razvitih standardov DECT in WiMAX, ki sta bila vključena, ker ustrezata opredelitvi IMT-2000**.

SIST

Standardizacija na področju DECT tehnologije



DECT frekvenčni pas je del spektra IMT-2000,
ITU je junija 1999 potrdila, da DECT izpolnjuje zahteve IMT-2000,
ITU je sprejel DECT (imenovan IMT-FT v IMT-2000) kot člana družine IMT-200,

Soobstoj z drugimi zajamčenih načini radijskega prenosa IMT-2000,
Edina tehnologija IMT-2000 s komercialno razpoložljivimi operativnimi izdelki zdaj!

SIST

Standardizacija na področju DECT tehnologije

ITU-R M.1457, 1. januar 1999
Podrobne specifikacije prizemnih radijskih vmesnikov
Mednarodne mobilne telekomunikacije-2000 (IMT-2000)

Priporočilo določa specifikacije prizemnega radijskega vmesnika IMT-2000 na podlagi proizvodnje dejavnosti zunaj ITU.

Ti radijski vmesniki podpirajo funkcije in parametre oblikovanja IMT-2000, vključno z zmožnostjo zagotavljanja združljivosti po vsem svetu, mednarodnega gostovanja in dostopa do hitrih podatkovnih storitev.

To priporočilo dopolnjujejo druga priporočila ITU-R in poročila o IMT-2000, ki vsebujejo dodatne podrobnosti o številnih vidikih, vključno s frekvenčnimi ureditvami in neželenimi lastnostmi emisij.

RECOMMENDATION ITU-R M.1457-1

Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)*

(2000-2001)

Standardizacija na področju DECT tehnologije

EN 300 176-1, 2000,
Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Specifikacija preskusa;
1. del: Radio

Draft ETSI EN 300 176-1 V1.3.3 (2000-10)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Approval test specification;
Part 1: Radio

Standardizacija na področju DECT tehnologije

ETSI TC DECT, Tehnični odbor Digitalne izboljšane brezvrvične telekomunikacije (DECT™)

Ustanovljen na sestanku TC RES, **maja 2005** [ETSI/B52(05)16]. Tehnični odbor je v okviru ETSI odgovoren za razvoj in vzdrževanje standardov za digitalne izboljšane brezvrvične telekomunikacije (DECT ™) in nadaljnji razvoj DECT™.

Cilj: Razviti, podpreti in vzdrževati standarde za DECT ™, ki uporabljajo celoten potencial DECT ™ kot tehnologije za dostop do omrežja in ki razširijo njegove aplikacije in njeno medsebojno delovanje z drugimi sistemi/omrežji. Zagotovitev skladnosti in skladnosti družine standardov DECT™ ter visoke kakovosti.

14. junija 2006 je bil ustanovljen **USM**(Urad Republike Slovenije za standardizacijo in meroslovje (1990-2001)) **tehnični odbor TC RES**, Radijske naprave in sistemi, po 10 letih delovanja, preoblikovan v **SIST TC MOC,** Mobilne komunikacije, ki tudi že deluje 15 let.

Standardizacija na področju DECT tehnologije

Standardizacija na področju DECT tehnologije

DECT Forum je neprofitna panožna organizacija, ustanovljena leta **1997** in ima sedež v Bernu v Švici.

Misija foruma DECT je podpreti sodelovalno okolje industrije DECT in spodbujati programe za razvoj in izboljšanje brezvrvične tehnologije DECT, da bi prehiteli brezžična komunikacijska pričakovanja in izpolnili potrebe sveta, ki spreminja tehnologijo.

Da bi to dosegli, bo DECT forum:

skrbel za DECT tehnologijo na najboljši možni način s sredstvi, ki so na voljo,
zaščitil in razširil dodelitev FREKVENC DECT po vsem svetu,
spodbujal svoje člane, da sodelujejo pri izboljšanju standardov in aplikacij DECT z aktivnim sodelovanjem v organih za standardizacijo ter programih interoperabilnosti in certificiranja
spodbujal in navdihoval DECT industrijo, da uporabi celoten frekvenčni spekter z aplikacijami in izdelki, v podporo DECT poslovanja in prihodkov članov foruma DECT

Standardizacija na področju DECT tehnologije

DECT standardizacijski dokumenti (ETS, ETR) izdani do februarja 1997

[1] ETS 300 175-1: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 1: Overview".
[2] ETS 300 175-2: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 2: Physical layer".
[3] ETS 300 175-3: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 3: Medium access control layer".
[4] ETS 300 175-4: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 4: Data link control layer".
[5] ETS 300 175-5: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 5: Network layer".
[6] ETS 300 175-6: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 6: Identities and addressing".
[7] ETS 300 175-7: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 7: Security features".
[8] ETS 300 175-8: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 8: Speech coding and transmission".
[9] ETS 300 444: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Generic Access Profile (GAP)".
[10] ETS 300 370: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); DECT/GSM Interworking Profile".
[11] ETS 300 499: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); DECT/GSM Interworking Profile; FP to MSC interconnection".
[12] ETS 300 703: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); DECT/GSM Interworking Profile; phase 2 supplementary services".
[13] ETS 300 434: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) and Integrated Services Digital Network (ISDN) inter-working for end system configuration; Part 1: Inter-working specification and Part 2: Access profile".
[14] DE/RES-03039: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); DECT/ISDN Interworking for Intermediate System Configuration, Part 1: Interworking Specification and Part 2: Access profile".
[15] ETS 300 765-1/2: "Radio Equipment and Systems (RES); Digital Enhanced Cordless Telecommunications (DECT); Radio in the local loop (RLL) Access Profile (RAP); Part 1: Basic telephony services and part 2 : Advanced Telephony Services".
[16] ETR 178: "Radio Equipment and Systems (RES); Digital Enhanced Cordless Telecommunications (DECT); A high level guide to the DECT standardisation".
[17] ETS 300 700: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Wireless Relay Station (WRS)".
[18] ETR 246 "Radio Equipment and Systems (RES); Digital Enhanced Cordless Telecommunications (DECT); Application of DECT Wireless Relay Station (WRS)".
[19] ETR 310: "Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band."

Standardizacija na področju DECT tehnologije

2000	DECT Packet Radio Service (DPRS) standard	• The DPRS standard defines a features and services at MAC, DLC and NWK layer for data services. • Standard: ETSI EN 301 649 [i.25].

Predlog osnovnega standarda, december 1999 in dopolnjena verzija iz decembra 2004

Draft ETSI EN 301 469-1 V0.0.2 (1999-11)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
DECT Packet Radio Service (DPRS) Test Case Library (TCL);
Part 1: Test Suite Structure (TSS) and
Test Purposes (TP) - Medium Access Control (MAC) layer**

ETSI EN 301 649 V1.4.1 (2004-12)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
DECT Packet Radio Service (DPRS)**

SIST Standardizacija na področju DECT tehnologije

Leto 2002:

2002	DECT Harmonised Standard for IMT-2000	• Harmonised EN for IMT-2000, FDMA/TDMA (DECT) covering essential requirements of article 3.2 of the "R&TTE Directive [i.29]". • Standard: – ETSI EN 301 908-10 [i.26].

ETSI EN 301 908-10:2016

IMT cellular networks;
Harmonised Standard for access to radio spectrum;
Part 10: Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks

Elektromagnetna združljivost in radiofrekvenčni spekter (ERM), IMT – 2000 bazne postaje (BS) celičnih omrežij, repetitorji in uporabniška oprema (UE) **za mobilna omrežja tretje generacije, 10 del**: **Usklajeni standard za IMT-2000, FDMA/TDMA (DECT)**, ki zajema bistvene zahteve iz člena 3.2 Direktive 2014/53/EU o IMT-2000. **Dokument dopolnjen leta 2016 in 2021**.

SIST Standardizacija na področju DECT tehnologije

Leto 2005

2005	Launch of "DECT 6.0" for North American markets	• Marketing term for DECT devices intended for operation in North America (USA and Canada). • Standard: – ETSI TS 102 497 [i.10]. • Spectrum: – 1 920 MHz - 1 930 MHz UPCS band in North America

ETSI TS 102 497 V1.1.1 (2005-10)

Technical Specification

Digital Enhanced Cordless Telecommunications (DECT); DECT in the 1 920 MHz to 1 930 MHz Unlicensed Personal Communications Services (UPCS) frequency band; Specific requirements

Digitalne izboljšane brezvrvične telekomunikacije (DECT); DECT v frekvenčnem pasu 1 920 MHz do 1 930 MHz. Nelicenčne storitve osebnih komunikacijskih storitev (UPCS); Posebne zahteve

SIST Standardizacija na področju DECT tehnologije

ETSI TR 101 178 V1.5.1 (2005-02)

Technical Report

Digital Enhanced Cordless Telecommunications (DECT);
A High Level Guide to the DECT Standardization

ETSI TR 101 178 2005

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Vodnik na visoki ravni za standardizacijo DECT

SIST Standardizacija na področju DECT tehnologije

ETS 300 370 ed.2, 2006

Digital Enhanced Cordless Telecommunications (DECT);

System for Mobile communications (GSM);
DECT/GSM Interworking Profile (IWP);

Access and mapping (protocol/procedure description for 3,1 kHz speech service)

SIST ETS 300 370, 2006

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Globalni sistem za mobilne komunikacije (GSM);
DECT/GSM profil dela (IWP);
Dostop in preslikava (opis protokola/postopka za govorno storitev 3,1 kHz)

SIST Standardizacija na področju DECT tehnologije

Procesi standardizacije v obdobju od leta 2007 do 2014

2007 - 2014	Development of "New Generation DECT" (NG-DECT) standards	• Extends the basic DECT standards to cover wideband and super-wideband audio, and mandatory interoperability features. Also includes security enhancements and Software Upgrade Over The Air (SUOTA). • Applications: – Wideband cordless telephony. – Wideband cordless headsets. – Etc. • Standards: – ETSI TS 102 527 parts 1 [i.11] to 5 [i.15].

SIST Standardizacija na področju DECT tehnologije

Nova generacija DECT

Nova generacija **DECT (NG-DECT)** je ime, ki je dano razvoju DECT standarda s primarnim ciljem na VoIP aplikacijah. NG-DECT se izvaja z dodajanjem novih funkcij osnovnemu standardu DECT (ohraniti skladnost nazaj z vsemi prejšnjimi razvoji) in oblikovanjem namenskega sklopa profilov aplikacij, ki opredeljujejo nove vrste izdelkov. Specifikacije nove generacije DECT se osredotočajo na :

- širokopasovni govor (**TS 102 527-1**),
- podatke IP paketa **(TS 102 527-2)**,
- razširjene širokopasovne govorne storitve **(TS 102 527-3)**,
- Light Data Services **(TS 102 527-4)** in dodatni set funkcij
- za razširjeni široko pasovni govor **(TS 102 527-5).**

Standardizacija na področju DECT tehnologije

DECT nove generacije vključuje naslednje funkcije:

Vrhunska kakovost glasu je boljša od vseh obstoječih tehnologij.
Širokopasovni in super širokopasovni govor.
Celoten sklop signaliziranja in postopkov za scenarije VoIP (SIP in H.323) in mešanih (baznih postaj z dvojno povezljivostjo PSTN in VoIP).

Nove naprave za slušalke DECT (dect radio i/f).
Podpora širokopasovnih podatkov in pretakanje zvoka.
Zmogljivost video telefonije.
Home Monitoring, Vrata & telefon, Baby monitor, Nabiralnik.
Plug & Play funkcionalnost vseh komponent
Samodejno zaznavanje in konfiguracija naprave (enostavno združevanje).
Posodobitev programske opreme (SUOTA) in druge brezžične naprave.

Standardizacija na področju DECT tehnologije

Dodatne informacije

Številka	PN-ETSI EN 300 175-8 V2.1.1:2008 - angleška različica
Naslov	Digitalne izboljšane brezžične telekomunikacije (DECT) -- Skupni vmesnik (CI) -- 8. del: Kodiranje govora in prenos govora
Datum objave	28-05-2008
Datum odstopa od pogodbe	14-02-2017
Število strani	44

Profil Specifikacija preskusa za prostovoljno testiranje terminalov, ki so skladni z **DE/RES-03039 (DECT/ISDN ISC)**.

Standardizacija na področju DECT tehnologije

Tudi to serijo oziroma družino evropskih standardov (**ETSI EN 300 176**) je izdelal ETSI tehnični odbor TC DECT- Digital Enhanced Cordless Telecommunications in je zdaj predložen v postopek odobritve kot ETSI EN standard.
Prvi dokument vsebuje besedilo, ki se nanaša na homologacijsko testiranje skupnega vmesnika izboljšane brezvrvične naprave DECT. Takšno besedilo je treba obravnavati kot napotke organom za odobritev ali licenciranje DECT opreme.

ETSI EN 300 176-1, (2009),

Digital Enhanced Cordless Telecommunications,
Test specifications, Part 1: Radio,

ETSI EN 300 176-2, (2009),

DECT,
Test specificatios, Part 2: Audio and Speech,

Standardizacija na področju DECT tehnologije

Final draft ETSI EN 300 176-1 V2.1.0 (2009-03)

European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Test specification;
Part 1: Radio**

ETSI EN 300 176-1, 2009,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Specifikacija preskusa;
1. del: Radio

SIST Standardizacija na področju DECT tehnologije

Final draft ETSI EN 300 176-2 V2.1.0 (2008-12)

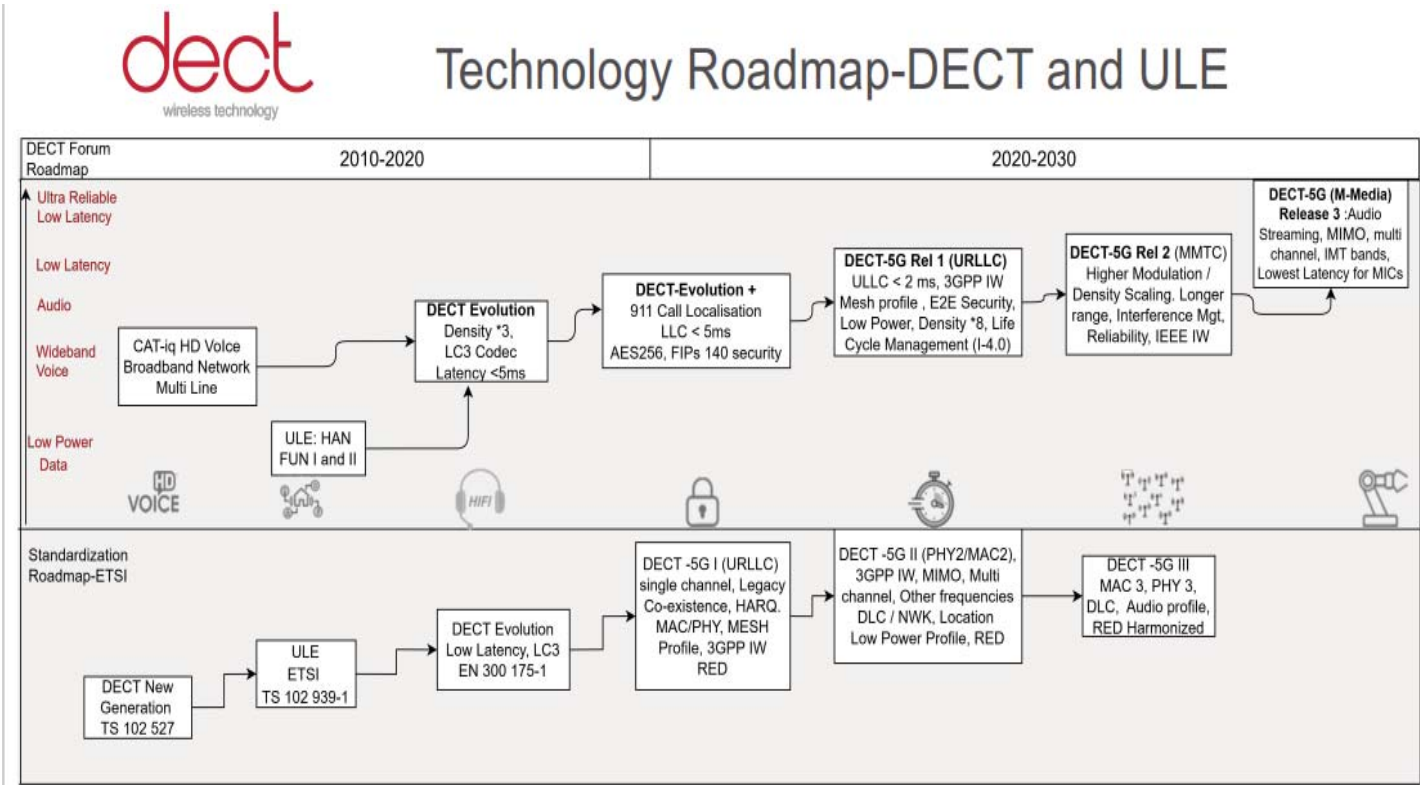
European Standard (Telecommunications series)

**Digital Enhanced Cordless Telecommunications (DECT);
Test specification;
Part 2: Audio and speech**

EN 300 176-2 V2.1.1:2009

**Digitalne izboljšane brezvrvične telekomunikacije (DECT); Specifikacija preskusa;
Del 2: Zvok in govor**

SIST Standardizacija na področju DECT tehnologije



SIST Standardizacija na področju DECT tehnologije

DECT Nove generacije, DECT New Generation

Osnovna tehnična specifikacija se imenuje **TS 102 527** in je standardizirala integracijo DECT v širokopasovni domači prehod(Broadband Home Gateway). Ta tehnološki korak se imenuje CAT-iq (brezvrvična napredna tehnologija: internet in kakovost). Ta nadgradnja osnovnega standarda je omogočila številne nove dodatne funkcije SIP in HD Voice, ki so združljiva z zvokom (HD Voice) v mobilnih omrežjih.
Člani foruma DECT lahko svoje izdelke certificirajo v certifikacijskem programu CAT-iq.

Standard nove generacije DECT(NG-DECT)

je bil prvič objavljen leta **2007**; razvili so jih v ETSI, v skladu s smernicami in pobudo Home Gateway, ki so jo pripravili v **DECT Forumu** za podporo ip-DECT funkcijam v domači opremi gateway/IP-PBX.

Serija standadov **ETSI TS 102 527** obsega **pet delov** in zajema širokopasovne audio in obvezne funkcije interoperabilnosti med terminalno opremo in osnovnimi postajami. S tehničnim obrazložitvenim poročilom **ETSI TR 102 570** DECT Forum vzdržuje cat-iq blagovno znamko in certifikacijski program; CAT-iq širokopasovni glasovni profil 1.0 in profili interoperabilnosti 2.0/2.1 temeljijo na ustreznih delih ETSI TS 102 527.

SIST Standardizacija na področju DECT tehnologije

DECT Forum je naročil ETSI tehničnemu odboru **TC DECT,** da razvije specifikacije za izdelke "nove generacije DECT", ki bodo temeljili na zahtevah tržišča. DECT Forum zahteva, da se v celoti opredelijo in implementirajo novi standardi, v katerih bo obvezna interoperabilnost med baznimi postajami, prehodi in ter terminalno opremo različnih proizvajalcev.
Za zagotovitev interoperabilnosti namerava DECT Forum vzpostaviti certifikacijski program. Zato DECT Forum zahteva od ETSI, da poleg **sistemskih specifikacij razvije tudi testne specifikacije.**

ETSI TR 102 570 V1.1.1 (2007-03)
Technical Report

**Digital Enhanced Cordless Telecommunications (DECT);
New Generation DECT;
Overview and Requirements**

Digitalne izboljšane brezvrvične telekomunikacije (DECT);

Nova generacija DECT;
Pregled in zahteve

SIST Standardizacija na področju DECT tehnologije

ETSI TS 102 527-1 V1.1.1, 2007-04-03,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Nova generacija DECT;
1. del: Širokopasovni govor

ETSI TS 102 527-2 V1.1.1 (2007-06)
Technical Specification

**Digital Enhanced Cordless Telecommunications (DECT);
New Generation DECT;
Part 2: Support of transparent IP packet data**

SIST Standardizacija na področju DECT tehnologije

ETSI TS 102 527-3 V1.3.1 (2011-02)
Technical Specification

**Digital Enhanced Cordless Telecommunications (DECT);
New Generation DECT;
Part 3: Extended wideband speech services**

ETSI TS 102 527-3 V1.1.1, 19.6. 2008

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Nova generacija DECT;
Del 3: Razširjene širokopasovne govorne storitve

Standardizacija na področju DECT tehnologije

ETSI TS 102 527-4 V1.1.1 (2009-10)

Technical Specification

**Digital Enhanced Cordless Telecommunications (DECT);
New Generation DECT;
Part 4: Light Data Services;
Software Update Over The Air (SUOTA),
content downloading and HTTP based applications**

ETSI - TS 102 527-4

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Nova generacija DECT;
Del 4: Lahke podatkovne storitve; Posodobitev programske opreme nad zrakom (SUOTA), prenos vsebine in aplikacije, ki temeljijo na HTTP

Standardizacija na področju DECT tehnologije

Tri verzije dokumenta TS 102 527 -5:

ETSI TS 102 527-5 V1.1.1 (2013-04)



PREVIEW

**Digital Enhanced Cordless Telecommunications (DECT);
New Generation DECT;
Part 5: Additional feature set nr. 1
for extended wideband speech services**

SIST Standardizacija na področju DECT tehnologije



TS 102 527-5, V1.3.1:2015

brezvrvične razširjene digitalne telekomunikacije (DECT); **Nova generacija DECT; Del 5:** Skupina dodatnih funkcij Št. 1 za razširjene široko pasovne govorne storitve

SIST Standardizacija na področju DECT tehnologije

Večkratna nadgradnja osnovnega standarda DECT

Osnovni standard DECT družine **ETS 300 175-1 do 9**:

Izdal ga je ETSI (European Telecommunications Standards Institute). Tehnični pododbor **STC RES –03** standardizira zračni vmesnik za govorni in podatkovni promet DECT.

Standard DECT je bil po vsem svetu zelo razširjen v radijskem spektru, ki je blizu tistemu, ki je dodeljen v evropski regiji, V skladu z zahtevami CEPT, DECT zagotavlja osebne telekomunikacijske storitve v stanovanjskih in poslovnih okoljih.

Naslednje nadgradnje DECT standardov so pripravili v tehničnem odboru ETSI **TC DECT.**

Standardizacija na področju DECT tehnologije

Rezultat teh zahtev in nadgradnja predhodnih ETSI DECT tehničnih specifikacij in poročil so naslednji evropski standardi:

[1] **ETSI EN 300 175-1**: Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 1**: Overview

[2] **ETSI EN 300 175-2:** "Digital Enhanced Cordless Telecommunications (DECT); Common Interface(CI), **Part 2:** Physical Layer (PHL)"

[3] **ETSI EN 300 175-3**: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 3:** Medium Access Control (MAC) layer".

[4] **ETSI EN 300 175-4**: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 4**: Data Link Control (DLC) layer".

[5] **ETSI EN 300 175-5**: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 5:** Network (NWK) layer".

[6] **ETSI EN 300 175-6:** "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 6**: Identities and addressing".

[7] **ETSI EN 300 175-7**: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 7**: Security features".

[8] **ETSI EN 300 175-8**: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); **Part 8**: Speech and audio coding and transmission".

Standardizacija na področju DECT tehnologije



EN 300 175-1

Digital Enhanced Cordless Telecommunications (DECT) - Skupni vmesnik (CI),
1. del: Pregled

Standardizacija na področju DECT tehnologije



EN 300 175-2

Digitalne izboljšane brezvrvične telekomunikacije (DECT) – Skupni vmesnik (CI) –
2. del: Fizična plast (PHL)

Standardizacija na področju DECT tehnologije



EN 300 175-3

Digitalne izboljšane brezvrvične telekomunikacije (DECT). skupni vmesnik (CI).
Del 3: sloj srednje dostopne kontrole (MAC)

SIST Standardizacija na področju DECT tehnologije

ETSI EN 300 175-4 V2.6.1 (2015-07)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 4: Data Link Control (DLC) layer**

EN 300 175-4

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 4: Plast za nadzor podatkovnih povezav (DLC)

SIST Standardizacija na področju DECT tehnologije

Final draft ETSI EN 300 175-5 V2.4.0 (2011-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 5: Network (NWK) layer**

EN 300 175-5

Digitalne izboljšane brezvrvične telekomunikacije (DECT) – Skupni vmesnik (CI) –
5. del: Omrežna plast (NWK)

SIST Standardizacija na področju DECT tehnologije



EN 300 175-6

Digitalne izboljšane brezvrvične telekomunikacije (DECT). Skupni vmesnik (CI).
Del 6: Identitete in obravnavanje (označevanje)

SIST Standardizacija na področju DECT tehnologije



EN 300 175-7, 2012,

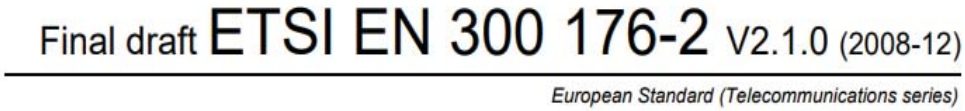
Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 7: Varnostne funkcije

SIST Standardizacija na področju DECT tehnologije



EN 300 175-8
Digitalne izboljšane brezvrvične telekomunikacije DECT; skupni vmesnik (CI);
Del 8: Kodiranje in prenos govora in zvoka

SIST Standardizacija na področju DECT tehnologije



Digital Enhanced Cordless Telecommunications (DECT);
Test specification;
Part 2: Audio and speech

Digitalne izboljšane brezvrvične telekomunikacije (DECT);

Specifikacija preskusa;
Del 2: Zvok in govor

SIST Standardizacija na področju DECT tehnologije

In posodobitev v naslednjem letu:

ETSI EN 300 176-2 V2.1.1 (2009-05)

European Standard (Telecommunications series)

Digital Enhanced Cordless Telecommunications (DECT);
Test specification;
Part 2: Audio and speech

SIST Standardizacija na področju DECT tehnologije

ETSI EN 300 444 V2.3.1 (2012-04)



Digital Enhanced Cordless Telecommunications (DECT);
Generic Access Profile (GAP)

EN 300 444 V2.4.1:2013

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Profil splošnega dostopa (GAP)
Splošne informacije

Standardizacija na področju DECT tehnologije

In posodobitev v naslednjem letu:



Standardizacija na področju DECT tehnologije

Nova direktiva o radijski opremi **2014/53/ES,** Direktiva **1999/5/ES** razveljavljena

Za razliko od prejšnje direktive se direktiva o radijski opremi ne uporablja več za telekomunikacijsko terminalsko opremo (TTE). **TTE** bo od zdaj regulirana z Direktivo 2008/63/ES "o konkurenci na trgih telekomunikacijske terminalske opreme".

Standardizacija na področju DECT tehnologije

Iz arhiva tehničnega odbora **ETSI TC DECT**:

DECT NewGen	463	Specifikacija preskusa Light Data Services	ZAPRTO
DECT NewGen	432	Standardi za testiranje skladnosti DECT 2011	ZAPRTO
DECT NewGen	418 V	DECT stds 2011 prostovoljno	ZAPRTO
DECT NewGen	418	Vzdrževanje DECT in razvoj NG-DECT 2011	ZAPRTO
DECT NewGen	389	DECT-nova generacija izdaja 2010	ZAPRTO
DECT NewGen	339	Posodobitev testnih standardov za novo generacijo DECT,	ZAPRTO
DECT NewGen	338	Posodobitev osnovnih standardov za novo generacijo DECT,	ZAPRTO

Standardizacija na področju DECT tehnologije

Standardizacija v obdobju med 2013 in 2015

Date	Milestone	Comments
2013 - 2015	Development of "DECT Ultra Low Energy" (ULE) standards	• Enhances DECT to allow ultra-low energy operation suitable for Internet Of Things (IoT), Home Automation and Home Security. • Applications: – Wireless security sensors. – Wireless smoke/fire detectors. – Wireless room temperature sensors. – Wireless actuators. – Wireless "smart plugs". – Etc. • Standards: – ETSI TS 102 939 parts 1 [i.16] to 2 [i.17].

SIST Standardizacija na področju DECT tehnologije

Directive 2014/53/EU of the European Parliament and of the Council of 16. april 2014

Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1995/5/EC.

The Radio Equipment Directive (RED, EU directive 2014/53/EU) established a regulatory framework for placing radio equipment on the market in the EU. All radio equipment within the scope of this directive that are placed on the EU market must have been compliant with the directive from 13 June 2017.

Direktiva 2014/53/EU Evropskega parlamenta in Sveta z dne 16. aprila 2014 o uskladitvi zakonodaje držav članic v zvezi z dajanjem na trg radijske opreme in razveljavitvijo **Direktive 1999/5/ES.**

SIST Standardizacija na področju DECT tehnologije

ULE ALLIANCE

ULE obravnava zahteve za aplikacijo **Ultra-Low Energy** z uvedbo optimiziranih komunikacijskih metod. Z zelo majhno porabo energije, majhno latenco, dolgim dometom, zmerno hitrostjo podatkov in komplementarnimi glasovnimi zmogljivostmi z dodano vrednostjo, je ULE najboljša tehnologija razreda, ki predstavlja naslednjo evolucijo v domačem omrežju.

Standardizacija na področju DECT tehnologije

ULE Alliance

je neprofitna organizacija s sedežem v Švici. Združenje ULE je leta **2012** formiral **forum DECT**, da bi se osredotočili na različne tržne segmente in tehnološke izboljšave za ULE.

ULE obravnava zahteve za aplikacijo **Ultra-Low Energy** z uvedbo optimiziranih komunikacijskih metod. Z majhno porabo energije, majhno latenco, dolgim dometom, zmerno hitrostjo podatkov in komplementarnimi glasovnimi zmogljivostmi z dodano vrednostjo, je ULE najboljša tehnologija razreda, ki predstavlja naslednjo evolucijo v domači mreži.

ULE temelji na DECT (Digital Enhanced Cordless Telecommunications), ki je de-facto standard za stanovanjske in poslovne brezvrvične telefonske komunikacije po vsem svetu.

Standard in certificiranje

Specifikacija ULE je bila ustvarjena kot začetno sodelovanje med forumom DECT in ETSI.
Fizična plast ULE uporablja obstoječo specifikacijo ETSI DECT. Tehnične specifikacije za zgornji del transportne plasti ULE so bile izvedene v ETSI **TC DECT,** pri tem pa so bile posodobljene naslednje lastnosti:

Nadzor podatkovne povezave, Omrežna plast, Meddelavna enota, protokol aplikacijskih plasti
Protokol aplikacijske plasti **HAN FUN (Home Area Network FUNctional protocol)** je izdala zveza ULE novembra 2013 in zajema naslednje funkcije:

Opredelitev protokola, definicija naprave, upravljanje naprav, itd,...

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Standardizacija na področju DECT tehnologije

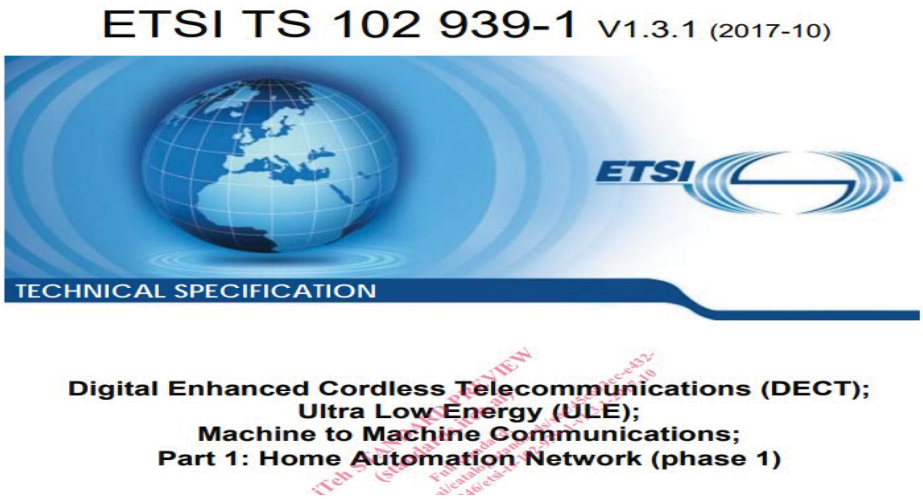
Standard DECT Ultra Low Energy (DECT ULE)

je bil objavljen januarja **2011**, prve komercialne izdelke pa je kasneje tega leta lansiral Dialog Semiconductor . Standard je bil ustvarjen tako, da omogoča avtomatizacijo doma, programe varnosti, zdravja in nadzora na baterijski pogon. Tako kot DECT, DECT ULE standard uporablja obseg 1,9 GHz in je manj občutljiv na motnje kot Zigbee, Bluetooth ali Wi-Fi, ki vsi delujejo v nelicenciranem 2,4 GHz ISM območju. DECT ULE uporablja preprosto zvezdno topologijo omrežja, zato je lahko več naprav v hiši priključenih na eno samo kontrolno enoto.

Kot možnost za revizijo DECT standarda **v 2019** je bil dodan **nov zvočni kodek majhne zahtevnosti, LC3plus**. Ta kodek je namenjen visokokakovostnim glasovnim in glasbenim aplikacijam ter podpira razširljive ozkopasovne, širokopasovne, super širokopasovne aplikacije in polno kodiranje s hitrostjo vzorčenja 8, 16, 24, 32 in 48 kHz ter pasovno širino zvoka do 20 kHz.

Standardizacija na področju DECT tehnologije

ETSI - TS 102 939-1 V1.3.1 -Digitalne izboljšane brezvrvične telekomunikacije (DECT); **Ultra nizka energija (ULE); M2M** komunikacije; **1. del: Omrežje avtomatizacije doma (1. faza)**



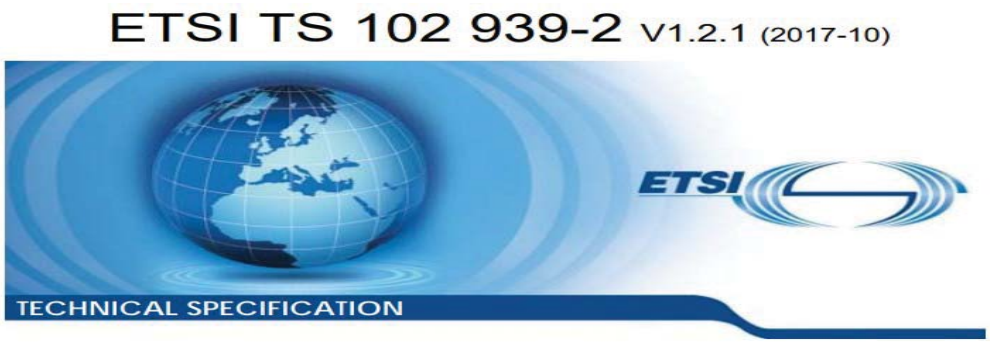
Standardizacija na področju DECT tehnologije



ETSI TS 102 939-2 V1.1.1 (2015-03)

Digitalne izboljšane brezvrvične komunikacije (DECT); Ultra nizka energija (ULE); M2M komunikacije; **Del 2:** Omrežje avtomatizacije doma (faza 2)

SIST Standardizacija na področju DECT tehnologije



ETSI TS 102 939-2 V1.3.1 (2019-01)

Digitalne izboljšane brezvrvične telekomunikacije (DECT); Ultra nizka energija (ULE); M2M komunikacije;
Del 2: Omrežje avtomatizacije doma (faza 2)

SIST Standardizacija na področju DECT tehnologije

ETSI TR 103 422

Digital Enhanced Cordless Telecommunications (DECT); Tehnična študija razvoja DECT; Zahteve in tehnična analiza za nadaljnji razvoj DECT in DECT ULE



Standardizacija na področju DECT tehnologije

Iz arhiva tehničnega odbora **ETSI TC DECT**

Zaključeno delo na naslednjih dokumentih:

DECT ULE	506	DECT ULE repetitorji	ZAPRTO
DECT ULE	465	Ultra Low Energy (ULE) Tehnična specifikacija za fazo 2 (domača in industrijska avtomatizacija)	ZAPRTO
DECT ULE	464	Specifikacija testa ULE	ZAPRTO
DECT ULE	444	DECT baza za razvoj ULE in DECT-NG 2012	ZAPRTO
DECT ULE	444V	DECT ULE 2012 prostovoljno	ZAPRTO
DECT ULE	441	Tehnična študija z ultra nizko porabo energije (ULE).	ZAPRTO
DECT ULE	419 V	DECT ULE 2011 prostovoljno	ZAPRTO
DECT ULE	419	Tehnična študija z ultra nizko porabo energije (ULE).	ZAPRTO

Standardizacija na področju DECT tehnologije

Procesi standardizacije v obdobju 2016 do 2018

SLOVENSKI STANDARD
SIST EN 301 406 V2.2.1:2016
01-junij-2016

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Harmonizirani standard, ki zajema bistvene zahteve člena 3.2 direktive 2014/53/EU

Digital Enhanced Cordless Telecommunications (DECT) - Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU

iTeh STANDARD PREVIEW
(standards.iteh.ai)

Ta slovenski standard je istoveten z: ETSI EN 301 406 V2.2.1 (2016-04)

Standardizacija na področju DECT tehnologije

Draft ETSI EN 300 444 V2.4.8 (2017-07)



Digital Enhanced Cordless Telecommunications (DECT); Generic Access Profile (GAP)

ETSI EN 300 444 V2.2.1,
Digitalne brezvrvične telekomunikacije (DECT) - **Generični profil dostopa (GAP**)

Standardizacija na področju DECT tehnologije

Ta dokument določa nabor tehničnih zahtev za fiksni del (FP) in prenosni del DECT (PP) za digitalne izboljšane brezvrvične telekomunikacije (DECT), ki so potrebni za podporo generičnega profila dostopa (GAP).
GAP se uporablja za vse prenosne radijske terminalne enote DECT (PT) in fiksne radijske postaje (FT), ki so podrobneje obdelani v standardu **ETSI EN 300 176-2** (tj. 3,1 kHz telefonska telekomunikacijska storitev) in določa minimalno funkcionalnost, ki jo podpirajo vsi drugi glasovni profili 3,1 kHz

SLOVENSKI STANDARD
SIST EN 300 444 V2.5.1:2017
01-december-2017

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - Profil generičnega dostopa (GAP)

Digital Enhanced Cordless Telecommunications (DECT) - Generic Access Profile (GAP)

SIST Standardizacija na področju DECT tehnologije

DECT-2020 Standardisation Roadmap

ETSI

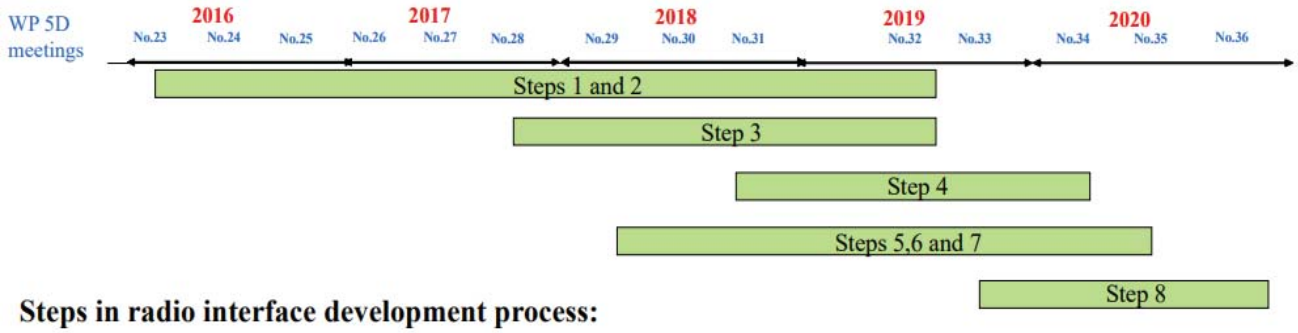
- **Technical Report 'DECT evolution'**
  - published June 2017
- **Technical Report 'DECT-2020 radio'**
  - Spring 2018
- **IMT-2020 submission proposal**
  - mid 2018
- **Technical Specifications**
  - end 2019

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SIST Standardizacija na področju DECT tehnologije

IMT-2020 Radio Interface Development Process

ETSI



Steps in radio interface development process:

Step 1: Issuance of the circular letter

Step 2: Development of candidate RITs and SRITs

Step 3: Submission/Reception of the RIT and SRIT proposals and acknowledgement of receipt

Step 4: Evaluation of candidate RITs and SRITs by Independent Evaluation Groups

Step 5: Review and coordination of outside evaluation activities

Step 6: Review to assess compliance with minimum requirements

Step 7: Consideration of evaluation results, consensus building and decision

Step 8: Development of radio interface Recommendation(s)

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SIST Standardizacija na področju DECT tehnologije

Standardizacijski procesi med 2018 in 2019

Date	Milestone	Comments
2018-2019	Development of "DECT Evolution" standard	• Evolves DECT standard by the implementation of a number of technical enhancements, whilst still using the DECT "classic" radio interface (Gaussian Frequency Shift Keying (GFSK)): – Audio enhancements (new codecs, e.g. LC3plus). – Low latency audio (< 10 ms). – Enhanced support of advanced chipset features such as higher modulation rates and channel coding. • Applications: – Professional audio microphones and in-ear headsets, etc., for Programme-Making and Special Events (PMSE). – Wireless Hi-Fi/audio equipment (e.g. wireless speakers, etc.). • Standards: – ETSI EN 300 175 parts 1 [i.1] to 8 [i.8] (due Q3 2019).

SIST Standardizacija na področju DECT tehnologije

Evropa **(ETSI) – Novi standardi, 19. marec 2020**

ETSI je v obdobju od 25. novembra do 25. decembra 2019 objavil naslednje nove standarde:

ETSI **EN 300 176-2** V2.3.1 (2019-2012) za digitalne izboljšane brezžične telekomunikacije (DECT); Specifikacija preskusa; Del 2: Zvok in govor,
ETSI **EN 300 175-8** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 8: Kodiranje in prenos govora in zvoka,
ETSI **EN 300 175-7** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 7: Varnostne funkcije,
ETSI **EN 300 175-6** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 6: Identitete in obravnavanje,
ETSI **EN 300 175-5** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 5: Omrežna (NWK) plast,
ETSI **EN 300 175-4** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 4: Plast za nadzor podatkovnih povezav (DLC),
ETSI **EN 300 175-3** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 3: sloj srednje dostopne kontrole (MAC),
ETSI **EN 300 175-2** V2.8.1 (2019–2012) za digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 2: Fizična plast (PHL),
ETSI **EN 300 175-1** V2.8.1 (2019–2012) Digitalne izboljšane brezžične telekomunikacije (DECT); skupni vmesnik (CI); Del 1: Pregled

SIST Standardizacija na področju DECT tehnologije



ETSI EN 300 175-1 V2.8.1 (2019-12)

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 1: Pregled

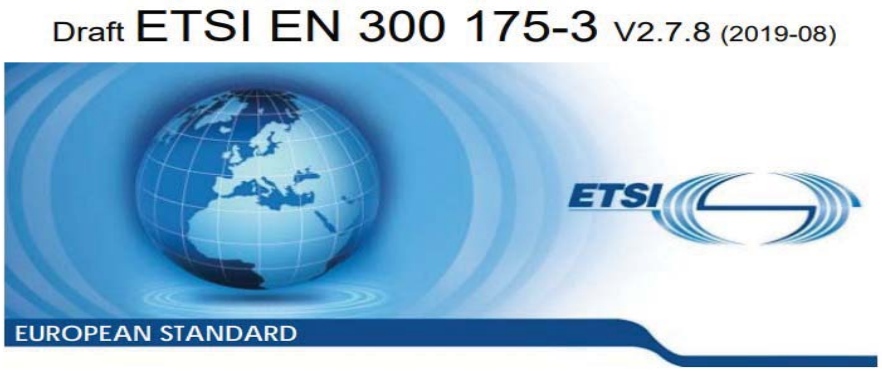
SIST Standardizacija na področju DECT tehnologije



ETSI ETS 300 175-2

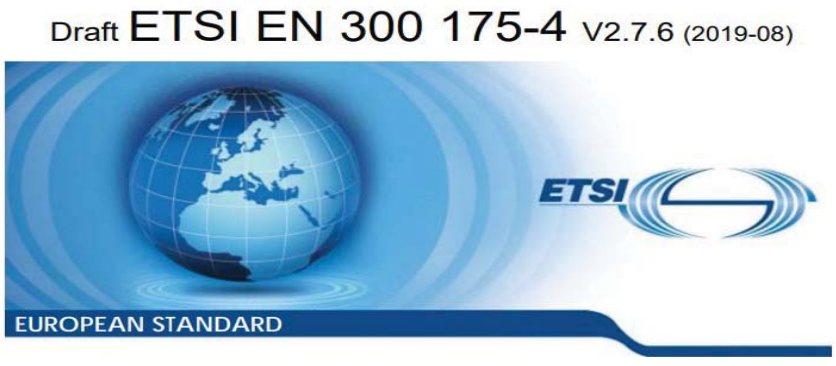
Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 2: Fizična plast (PHL)

SIST Standardizacija na področju DECT tehnologije



ETSI EN 300 175-3, 2019
Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 3: sloj srednje dostopne kontrole (MAC)

SIST Standardizacija na področju DECT tehnologije



EN 300 175-4,
Digital Enhanced Cordless Telecommunications (DECT) -- Skupni vmesnik (CI) --
4. del: Plast za upravljanje podatkovnih povezav (DLC)

SIST Standardizacija na področju DECT tehnologije

ETSI EN 300 175-5 V2.8.1 (2019-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 5: Network (NWK) layer**

ETSI SL 300 175-5

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 5: Omrežna (NWK) plast

SIST Standardizacija na področju DECT tehnologije

ETSI - EN 300 175-6

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 6: Identitete in obravnavanje

ETSI EN 300 175-6 V2.8.1 (2019-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 6: Identities and addressing**

SIST Standardizacija na področju DECT tehnologije

Draft ETSI EN 300 175-7 V2.7.5 (2019-08)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 7: Security features**

ETSI SL 300 175-7

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 7: Varnostne funkcije

SIST Standardizacija na področju DECT tehnologije

ETSI EN 300 175-8 V2.8.1 (2019-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 8: Speech and audio coding and transmission**

ETSI EN 300-175-8

Digitalne izboljšane brezvrvične telekomunikacije (DECT); skupni vmesnik (CI);
Del 8: Kodiranje in prenos govora in zvoka

SIST Standardizacija na področju DECT tehnologije



ETSI EN 300 176-1, januar 2018,

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Specifikacija preskusa;
1. del: Radio,

SIST Standardizacija na področju DECT tehnologije

Tehnični odbor:	MOC - Mobilne komunikacije
ICS:	33.060.99 33.070.99
Status:	Objavljen
Objavljen:	01-jan-2020
Refer. št. objave:	Sporocila 2020-01
Referenčna oznaka:	ETSI EN 301 908-1 V13.1.1 (2019-11)

SIST Standardizacija na področju DECT tehnologije



TS 102 527-1, V1.5.1: 2019

DECT brezvrvične razširjene digitalne telekomunikacije; Nova generacija DECT;
1. del: široko pasovni govor

SIST Standardizacija na področju DECT tehnologije



ETSI TR 103 513 V1.1.1, (2019–2011),

Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Načrt tehnologije DECT,

Standardizacija na področju DECT tehnologije

Dogajanje na področju standardizacije po letu 2019

2019-2020	Enhancements for DECT Evolution	• Additional work to further standardize high-rate asymmetric audio links. For example asymmetric audio: high bandwidth downlink/low bandwidth uplink; or low bandwidth downlink/high bandwidth uplink. Also, high fidelity, massive audio broadcast capability. • Optimizations, e.g. allowing double simplex bearers without the need for dedicated duplex bearer (i.e. shared duplex bearer for control). • Applications: – Smart speakers/voice-assistants. – Audio broadcast to multiple headsets (e.g. tour guide applications. • Standards: – TBD (due Q4 2020).

Standardizacija na področju DECT tehnologije

DECT Evolution, DECT Evolucija

DECT Evolution je srednjeročni program evolucije, namenjen izboljšavi DECT z izvajanjem številnih tehničnih izboljšav, medtem ko še vedno uporablja DECT "klasični" radijski vmesnik:

Zvočne izboljšave (novi kodeki, npr. LC3plus)
Zvok z nizko latenco (< 10 ms)
Izboljšana podpora naprednim funkcijam čipov, kot so višje stopnje modulacije in kodiranje kanalov.

Eno od glavnih aplikacijskih področij so visoki in profesionalni avdio sistemi, kot so tisti, ki jih uporablja industrija PMSE, kjer je bistven pretok zvoka z višjimi stopnjami podatkov in zelo nizko zamudo.

SIST Standardizacija na področju DECT tehnologije

SIST EN 301 908-1 V13.1.1:2020

Oznaka standarda:	SIST EN 301 908-1 V13.1.1:2020
Koda projekta:	53611
Organizacija:	SIST
Naslov (angleški):	IMT cellular networks - Harmonised Standard for access to radio spectrum - Part 1: Introduction and common requirements
Naslov (slovenski):	Celična omrežja IMT - Harmonizirani standard za dostop do radijskega spektra - 1. del: Uvod in splošne zahteve

Tehnični odbor:	MOC - Mobilne komunikacije
ICS:	33.060.99 33.070.99
Status:	Objavljen
Objavljen:	01-jan-2020
Refer. št. objave:	Sporocila 2020-01
Referenčna oznaka:	ETSI EN 301 908-1 V13.1.1 (2019-11)

SIST Standardizacija na področju DECT tehnologije

Ta dokument se uporablja za uporabniško opremo, ponavljalnike in bazne postaje za sisteme IMT, ki spadajo na področje uporabe enega od drugih delov standarda ETSI EN 301 908 [i.8], razen za IMT-2000 FDMA/TDMA (digitalna izboljšana brezvrvična komunikacija (DECT)). Ta dokument zajema tudi ustrezno pomožno opremo. OPOMBA 1: ETSI EN 301 908-10 [i.7] vsebuje predvsem zahteve za izsevane lažne emisije ter funkcije upravljanja in nadzorovanja opreme IMT-2000 FDMA/TDMA (digitalna izboljšana brezvrvična komunikacija). Ta dokument zajema tehnične zahteve, skupne za opremo, ki spada na področje uporabe nekaterih drugih delov. Uporabljati ga je treba skupaj z vsaj še enim delom standarda ETSI EN 301 908 [i.8]. OPOMBA 2: Drugi deli standarda ETSI EN 301 908 [i.8], navedeni v predgovoru tega dokumenta, določajo tehnične zahteve v zvezi z določenim tipom opreme IMT. OPOMBA 3: Priporočili ITU-R M.1457-12 [i.4] in M.2012-1 [i.5] določata karakteristike članov družine IMT-2000 in IMT-Advanced s tehničnimi specifikacijami, ki so jih razvile organizacije za pripravo standardov. Ta dokument se uporablja za opremo, ki ustreza vsem različicam prizemnih specifikacij, navedenih v priporočilih ITU-R M.1457-12 [i.4] in M.2012-1 [i.5]. Ta dokument vsebuje zahteve, s katerimi se dokazuje, da je radijska oprema izdelana tako, da učinkovito uporablja in podpira učinkovito rabo radijskega spektra z namenom preprečevanja škodljivih motenj. OPOMBA 4: Razmerje med tem dokumentom in bistvenimi zahtevami člena 3.2 Direktive 2014/53/EU [i.1] je podano v dodatku A.

Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

ITU-R M.1457-12 , verzija1*

RECOMMENDATION ITU-R M.1457-12

Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

* dokument dopolnjen v letih:
(2000-2001-2004-2005-2006-2007-2009-2010-2011-2013-2015)

SIST Standardizacija na področju DECT tehnologije

Družina priporočil M.2012:

Podrobne specifikacije prizemnih radijskih vmesnikov mednarodne mobilne telekomunikacije Advanced **(IMT-Advanced)**

Radiocommunication Study Groups

INTERNATIONAL TELECOMMUNICATION UNION

Source: Document 5/198

Document 5/BL/23-E
21 July 2015
English only

Working Party 5D

DRAFT REVISION OF RECOMMENDATION ITU-R M.2012-1

Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-Advanced (IMT-Advanced)

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SIST Standardizacija na področju DECT tehnologije

SIST

SLOVENSKI STANDARD
SIST EN 301 908-2 V13.1.1:2020
01-september-2020

Celična omrežja IMT - Harmonizirani standard za dostop do radijskega spektra - 2. del: CDMA z neposrednim razprševanjem ("Direct Spread") (UTRA FDD) (UE)

IMT cellular networks - Harmonised Standard for access to radio spectrum - Part 2: CDMA Direct Spread (UTRA FDD) User Equipment (UE)

iTeh STANDARD PREVIEW
(standards.iteh.ai)

Ta slovenski standard je istoveten z: ETSI EN 301 908-2 V13.1.1 (2020-06)

SIST EN 301 908-2 V13.1.1:2020
https://standards.iteh.ai/catalog/standards/sist/56d9a73f-fe3c-4953-a7fa-1e9741798aff/sist-en-301-908-2-v13.1.1-2020

Standardizacija na področju DECT tehnologije

Tehnični odbor SIST TC MOC, 16. februarja 2020, potrdi slovenski naslov, originalnega ETSI standarda, sprejetega 16. decembra 2019:

SIST EN 300 175-1 V2.8.1:2020

Digital Enhanced Cordless Telecommunications (DECT) - Common Interface (CI) - Part 1: Overview

Digitalne izboljšane brezvrvične telekomunikacije (DECT) - **Skupni vmesnik (CI) - 1. del: Pregled**

V tem dokumentu sta predstavitev in pregled celotnega skupnega vmesnika (CI) za digitalne izboljšane brezvrvične telekomunikacije (DECT). V tem dokumentu je povzetek drugih delov standarda za DECT in splošen opis:

• ciljev tega dokumenta,
• skupnega vmesnika za digitalne izboljšane brezvrvične telekomunikacije,
• arhitekture protokola digitalnih izboljšanih brezvrvičnih telekomunikacij.

V tem dokumentu je tudi obsežen slovar, ki vključuje zlasti skupne definicije vseh tehničnih izrazov, uporabljenih v različnih delih tega dokumenta. Ta dokument vključuje novo generacijo digitalnih izboljšanih brezvrvičnih telekomunikacij, nadaljnji razvoj standarda za digitalne izboljšane brezvrvične telekomunikacije, ki uvaja širokopasovni govor, izpopolnjene podatkovne storitve, nove tipe rež in druge tehnične izpopolnitve. Dokument vključuje razvoj digitalne izboljšane brezvrvične telekomunikacije.

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Standardizacija na področju DECT tehnologije

Date	Milestone	Comments
2019-2020	Development of DECT-2020 standards	• Standardization of new PHL and MAC layers and architecture with the intention of meeting some of the requirements of ITU-R IMT-2020, specifically Ultra-Reliable Low Latency Communications (URLLC) and Massive Machine-Type Communications (mMTC). The PHL and MAC architecture provides massively higher data rates (compared to legacy DECT), as well as higher reliability, and lower latency. • Utilizing OFDM, FEC, HARQ, MIMO, etc. • Targeting low latency and high reliability. • Applications: – Traditional cordless telephony, PABX, etc. – Home Automation/Security, IoT, etc. – Industrial Automation – Mesh-based networks, asset tracking, etc. – Etc. • Standards: – TBD (due 2020-2021). • Spectrum: – 1 880 MHz - 1 900 MHz band in Europe. – Other IMT bands may be possible.

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SIST Standardizacija na področju DECT tehnologije

ETSI TR 103 513 V1.1.1 (2019-11)



**Digital Enhanced Cordless Telecommunications (DECT);
DECT Technology Roadmap**

ETSI TR 103 513, 11. 1. 2019

Digitalne izboljšane brezvrvične telekomunikacije (DECT); Načrt tehnologije DECT standarda evropskega inštituta za telekomunikacijske standarde,

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SIST Standardizacija na področju DECT tehnologije

DECT FORUM

DECT2020 Summary

DECT and ULE as a 5G technology is a unique proposition

- Opportunity for industries to help shape DECT2020
  - Support for idustries of national significance
  - Create the specification according to requirements
  - The Voice of IoT
  - Local Area 5G Network
- Dynamic community driving down time to market
  - Partake with vibrant community of chip, manufacturing and SW engineereing driving the standard
- Mission critical applications that require reliability, low latency
  - Smart Home
  - Industrie 4.0
  - eHealth
  - Audio
- 5G Technology:
  - worldwide acceptance
  - Dedicated spectrum

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Standardizacija na področju DECT tehnologije

ETSI LAUNCHES DECT-2020 NEW RADIO INTERFACE FOR IOT

New standard addresses ultra-reliable, low-latency and massive machine-type communication use

Sophia Antipolis, 20 October 2020

ETSI DECT-2020 NR kot tehnološka fundacija je usmerjena v lokalne brevrvične aplikacije, ki se jih lahko vsak v trenutku razporedi kjerkoli. Tehnologija omogoča avtonomno in avtomatsko delovanje z minimalnim naporom vzdrževanja. DECT-2020 NR podpira komunikacijo z omrežjem z nizko zakasnitvijo komunikacijskih povezav, kar omogoča masivne komunikacije strojnega tipa (mMTC) za avtomatizacijo industrije brez potrebe po infrastrukturnih naložbah. Podpira tudi ultra-zanesljive komunikacije z nizko latenco (URLLC) za profesionalne brezvrvične zvočne aplikacije s točkami na točko ali multicast komunikacije. Zaradi svoje dinamične funkcije izbire kanalov, DECT-2020 NR ne zahteva načrtovanja frekvenc in kompleksnost te tehnologije je razmeroma nizka. Standard je predviden za naprave, ki delujejo v globalnem frekvenčnem pasu okoli 1900 MHz.

Standard NR DECT-2020 zagotavlja visoko prilagodljivost uporabe:

Izjemno zanesljive brezvrvične povezave od točke do točke in od točke do več točk,
Lokalna brezvrvična dostopna omrežja,
Samoorganiziranje lokalnega omrežja za brezvrvični dostop po topologiji omrežja mreže,

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Standardizacija na področju DECT tehnologije

Novi radijski protokol DECT-2020,

je bil objavljen **julija 2020**; določa nov fizični vmesnik, ki temelji na ciklični predponi Orthogonal Frequency-Splitting Multiplexing (CP-OFDM), ki omogoča hitrosti prenosa do 1,2 Gbit/s z [QAM]] - 1024 modulacijo. Posodobljeni standard podpira multi-antic MIMO in oblikovanje snopov , FEC kodiranje kanalov in hibridno samodejno ponavljanje zahteve . Določa 17 frekvenc radijskih kanalov, ki segajo od 450 MHz do 5 875 MHz in pasovne širine kanalov 1728, 3456 ali 6912 kHz. Neposredna komunikacija med končnimi napravami je možna s topologijo omrežja . ETSI je predlagal posodobljen PROTOKOL DECT kot kandidata za prihajajoče standarde IMT-2020 za industrijo avtomatizacije množičnih komunikacijskih vrst (MMTC), presek izjemno zanesljivih profesionalnih brezžičnih avdio aplikacij z nizko latenco (URLLC) s točkami na točko ali multicast komunikacijo. Odbor ESTI DECT je prav tako preučil uporabo modulacije OFDMA in SC-FDMA.

OpenD je odprtokodni okvir, ki je zasnovan tako, da zagotavlja celovito izvajanje protokolov DECT ULE o referenčni strojni opremi iz Dialog Semiconductor in DSP Group.

Standardizacija na področju DECT tehnologije

IMT-2020 (5G)

Leta 2015 je ITU-R objavil ocene prometa IMT za leta 2020–2030 in **IMT Vision za leto 2020 in naprej**.
Primerjava tehničnih zahtev za 5G z IMT-Advanced, pokaže v mnogih primerih povečavo za 10x ali več.

Predhodniki 5. Generacije:
1G/analogni, **2G**/digitalni, **3G**/IMT-2000, **4G**/IMT-Advanced,

5G cilji:
pomemben razvoj osnovne tehnologije, omrežne infrastrukture, uporabe spektra in porabe energije, učinkovitosti, vendar scenariji njegove uporabe presegajo 2G-4G.

Oba **3GPP in ETSI TC DECT** sta objavila načrte za ponudbo konkurenčnih **RIT za IMT-2020.**

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Standardizacija na področju DECT tehnologije

Mednarodne organizacije za standardizacijo:

ISO - International Organization for Standardization
(Mednarodna organizacija za standardizacijo), 1947

IEC - International Electrotechnical Commission
(Mednarodna elektrotehniška komisija),1906

ITU - International Telecommunication Union
(Mednarodna zveza za telekomunikacije),1865

ITU – R Sektor za standardizacijo telekomunikacij,

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Standardizacija na področju DECT tehnologije

ITU, Mednarodna telekomunikacijska unija,

je specializirana agencija **Združenih narodov za informacijske in komunikacijske tehnologije – IKT.**

Ustanovljena leta **1865** za lažjo mednarodno povezljivost v komunikacijskih omrežjih, dodeljujejo globalni radijski spekter in satelitske tirnice, razvijajo tehnične standarde, ki zagotavljajo brezhibno medsebojno povezovanje omrežij in tehnologij ter si prizadevajo izboljšati dostop do IKT za skupnosti po vsem svetu.

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Standardizacija na področju DECT tehnologije

ITU-R, sektor za radiokomunikacije

Strateški cilji sektorja za radiokomunikacije ITU (ITU-R) so:

zagotoviti delovanje radijskih sistemov brez vmešavanja z izvajanjem radijskih predpisov in regionalnih sporazumov ter učinkovito in pravočasno posodabljanje teh instrumentov s postopki svetovnih in regionalnih konferenc o radiokomunikacijah;

določitev priporočil, namenjenih zagotavljanju potrebne učinkovitosti in kakovosti v operacijskih sistemih radiokomunikacij;

poiskati načine in sredstva za zagotovitev racionalne, pravične, učinkovite in gospodarne uporabe radiofrekvenčnega spektra in virov satelitske orbite ter spodbujati prožnost za prihodnje širjenje in nova tehnološka gibanja.

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SIST Standardizacija na področju DECT tehnologije

Delovna skupina ITU-R 5D (WP 5D) - IMT Sistemi

WP 5D je odgovoren za splošne vidike radijskih sistemov **Mednarodne mobilne telekomunikacije (IMT), ki jih sestavljajo:**

IMT-2000,

IMT-Advanced,

IMT-2020 in

IMT za leto 2030 in naprej .

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SIST Standardizacija na področju DECT tehnologije

Radiocommunication Study Groups ITU

Received: XX August 2021 **Source:** Wireless World Research Forum	**Document 5D/XXXX** **XX August 2021** **English only** **TECHNOLOGY ASPECTS**

Wireless World Research Forum

UPDATED FINAL EVALUATION REPORT ON THE CANDIDATE TECHNOLOGY SUBMISSION FOR IMT-2020 "ETSI (TC DECT) AND DECT FORUM PROPONENT" AS PART OF THE RE-ENGAGEMENT IN STEP 4 EVALUATION

This contribution to the to the 23-27 August 2021 Technology Aspects Working Group (Option 2) virtual "interim meeting" contains the updated final evaluation report from the Independent Evaluation Group Wireless World Research Forum (WWRF) for ETSI (TC DECT), DECT FORUM, IMT-2020/17 Submission, and in particular the DECT-2020 NR RIT component.

Following the finalization of Step 7 in the IMT-2020 Process, ETSI (TC DECT) and DECT Forum technology submission evaluation was granted an extension in the IMT-2020 Process, for re-engagement and re-evaluation. The evaluation is based on the characteristics defined in ITU-R Reports M.2410-0, M.2411-0 and M.2412-0 using a methodology described in Report ITU-R M.2412-0. The report consists of 3 Parts and a series of Annexes according to the proposed

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Standardizacija na področju DECT tehnologije

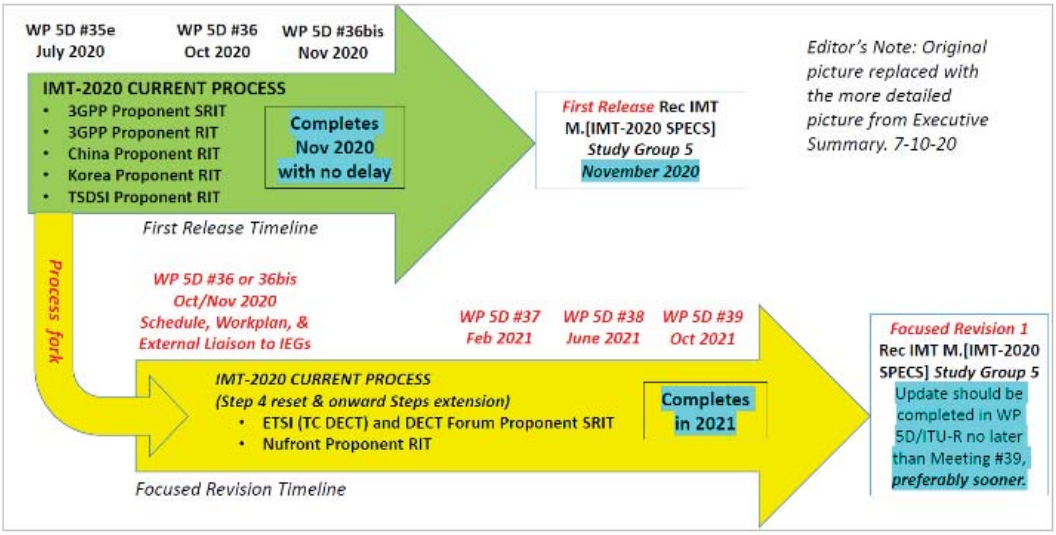
Step 4 Synopsis for "Proponent ETSI (TC DECT) & DECT FORUM"

IMT-2020 submissions	Final evaluation reports
ETSI (TC DECT), DECT FORUM IMT-2020/17 Rev.1	**Total 6 relevant IEG evaluation reports**, among them: 3 IEGs evaluation reports on **3GPP NR RIT component** confirmed that the **"3GPP 5G NR" RIT** as one component RIT of the IMT-2020/17(Rev 1) candidate technology proposal fulfils the minimum requirements for the five test environments comprising the three usage scenarios (**AND** consequently also fulfilling the minimum requirements of at least **two test environments is necessary for a component RIT**) 4 IEGs evaluated the "**DECT 2020 NR RIT**" component • 3 received evaluation reports indicated that the evaluation groups were of the opinion that this candidate "**DECT 2020 NR RIT**" component **does not meet** the minimum requirements of **Urban Macro-URLLC** test environments • 1 received evaluation report indicated that the evaluation groups were of the opinion this candidate "**DECT 2020 NR RIT**" component **meets** the minimum requirements of **Urban Macro -URLLC** test environments, but it was **inconclusive** whether it meets the minimum requirements of the **Urban Macro-mMTC** test environment. • There was NO evaluation report provided to WP 5D (*besides the proponent's own self-evaluation provided with the submission*) to indicate that the "DECT 2020 NR RIT" component fulfils *all* the necessary minimum requirements for an RIT component of an SRIT (at least two test environments)

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Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

ITU-R Res. 65 Based
Conclusion on
"ETSI (TC DECT & DECT Forum Proponents" Submission

DECT 2020 NR RIT Component

Controversial on whether the candidate technologies from these proponents meet the minimum requirements in all test environments of IMT-2020.

Consequently, the meeting [cannot] agree[s] *that they meet the requirements and criteria defined in 6 a) of Res.65*

It is evident, if we are to abide by Res ITU-R 65

- based on the process and technical information provided by the required deadlines for each process stage,
- the deliberations through Step 3 and Step 4 of the process by ITU-R members and the IEGs, and
- recognizing the difference of view between the formally received IEG evaluation reports (see Doc IMT-2020/38, etc),

That

- **in alignment with the mandate in Res 65 resolves *6d)***
  - *ITU-R at this time in this IMT-2020 process cycle cannot for the* candidate *DECT 2020 NR RIT component proposal based on the facts of the process* ***"ensure that they meet the requirements and criteria defined in 6 a)"*** in order to fulfil the minimum requirements for the two test environments – thereby the entire SRIT cannot fulfil the criteria.
  - It is noted, that in a dedicated time of discussion at Mtg #35e under the Step 6 context, of Docs 5D/ 156, 157, 158 submitted by a member, *that the differences of view on the ability of the technology to fulfil the minimum requirement remains unresolved.*

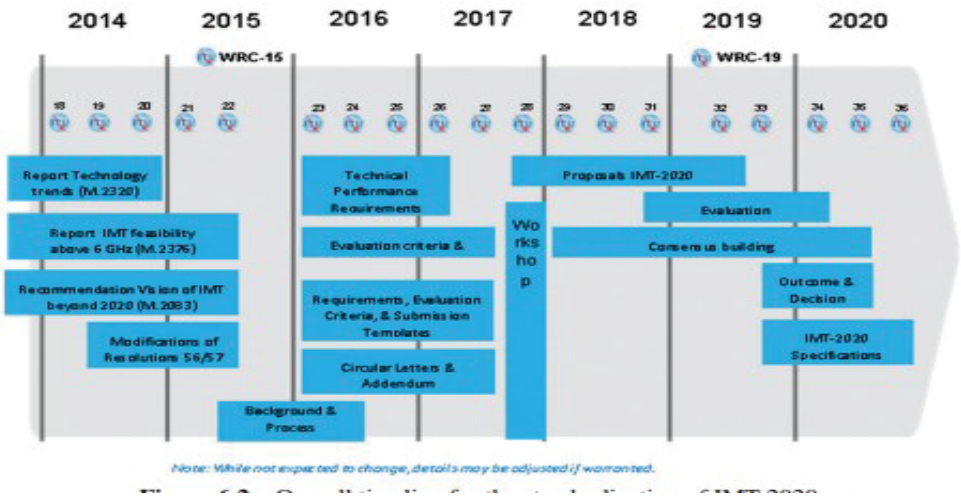
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Standardizacija na področju DECT tehnologije

IMT for 2020 and Beyond



Časovnica standardizacijskih postopkov pri IMT- 2020

SIST Standardizacija na področju DECT tehnologije



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SIST Standardizacija na področju DECT tehnologije

ITU-R M.2410-0, Minimalne zahteve v zvezi s tehnično učinkovitostjo radijskih vmesnikov IMT-2020

To poročilo vsebuje smernice za postopek, metodologijo in merila (tehnična, spekter in storitev) za uporabo pri ocenjevanju konkurenčnih tehnologij radijskih vmesnikov IMT-2020 (RIT) ali nabor RIT (SRIT) za številna testna okolja. Ta testna okolja so izbrana za natančno simulacijo strožjih radijskih operacijskih okolij. Postopek ocenjevanja je oblikovana tako, da je lahko celotna uspešnost konkurenčnih RIT/SRIT poštena in enakovredno ocenjena na tehnični podlagi. Zagotavlja, da so izpolnjeni splošni cilji IMT-2020.

To poročilo za predlagatelje zagotavlja razvijanje konkurenčnih RIT/SRIT in neodvisne ocenjevalne skupine, skupno metodologijo vrednotenja in konfiguracije ocenjevanja za ocenjevanje različnih RIT/SRIT in sistemskih vidikov, ki vplivajo na delovanje radia.

To poročilo omogoča določeno stopnjo svobode pri vključevanju novih tehnologij. Dejanski izbor RIT/SRIT za IMT-2020 je zunaj področja uporabe tega poročila

RIT - Radio Interface Technology.
SRIT - Set of Radio Interface Technologies.

Standardizacija na področju DECT tehnologije



Radio technology: ITU includes ETSI standard DECT-2020 in the 5G family

BY MRT ON OCTOBER 20, 2021

ETSI DECT-2020, odobren s strani **ITU-R WP5D** za naslednjo revizijo **ITU-R M.2150 (IMT 2020), 19. oktober, 2021,**

ETSI DECT-2020 NR, je prvi svetovni necelularni tehnološki standard 5G, ki bo vključen v naslednjo revizijo **ITU-R M.2150,** alias **IMT-2020** tehnološkega priporočila, na podlagi zaključka 39. virtualnega srečanja **ITU-R WP 5D** , ki je bilo dne 15. oktobra 2021.

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Standardizacija na področju DECT tehnologije

Priporočilo ITU-R ITU-R M.2150:

Podrobne specifikacije radijskih vmesnikov IMT-2020, 2. februar, 2021

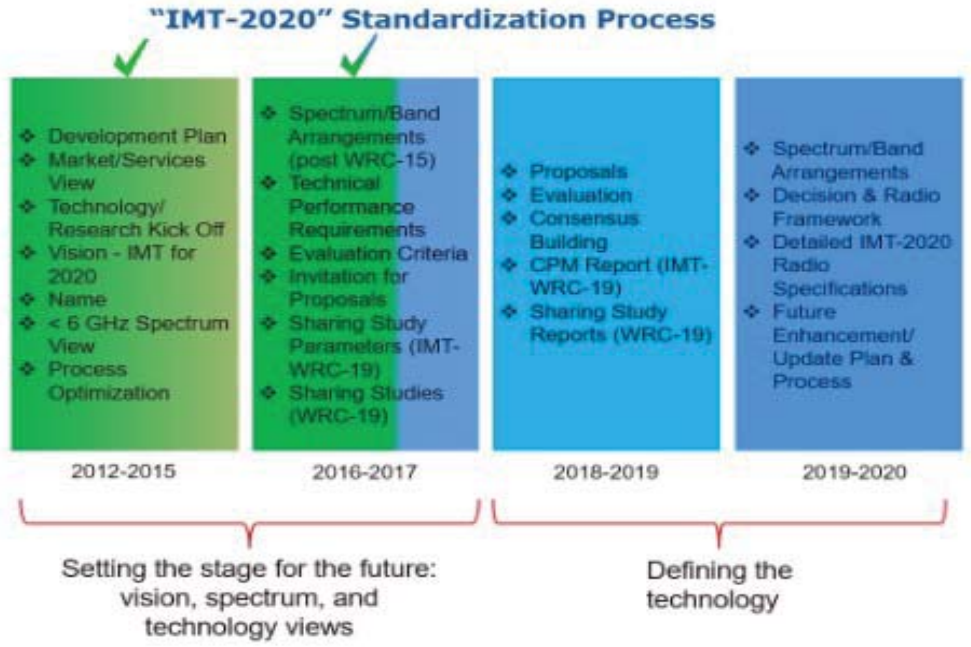
ITU sektor za radiokomunikacije (ITU-R) je nedavno objavil priporočilo ITU-R M.2150 z naslovom "Podrobne specifikacije radijskih vmesnikov IMT-2020 ." Novo objavljeno priporočilo, ki se je prej imenovalo"IMT-2020.specs," predstavlja sklop treh specifikacij zemeljskega radijskega vmesnika, ki so bile združene v en sam dokument.

Trenutna različica tega priporočila o specifikacijah IMT-2020 (Priporočilo ITU-R M.2150) vsebuje 3 tehnologije radijskega vmesnika: **"3GPP 5G-SRIT"; "3GPP 5G-RIT" in "5Gi"** (Indija/TSDSI). Te tehnologije so osnova za izvajanje 5G radijskih dostopnih omrežij (RAN) po vsem svetu. Po obdobju 7-8 let trdega dela v industriji je ocena teh **3 tehnologij IMT-2020 vrhunec odobrila 193 držav članic ITU.**

Še dva predloga radijskega vmesnika, ki sta jih predložila ETSI/DECT Forum in Nufront, sta bila v okviru razširitve procesa IMT-2020 odobrena izjemna revizija.

Na podlagi preučitve dodatnega gradiva bodo, če bodo uspešno zaključili postopek ocenjevanja, vključeni v priporočilo ITU-R M.2150, ki bo v skladu s priporočilom ITU-R M.2150.

Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

ETSI tehnični odbor TC DECT(digitalne izboljšane brezvrvične telekomunikacije) je odgovoren za razvoj in vzdrževanje DECTtm standardov.

DECT standardi se stalno posodabljajo, s tem se upošteva razvoj tehnologije, vključno z DECTTM New Generation, DECTTM Ultra Low Energy (ULE), DECT Evolution, DECT-2020 NR in regionalnimi različicami.

DECT je ETSI-ev standard za radijske komunikacije kratkega dosega, ki ga je mogoče prilagoditi za številne aplikacije in se lahko uporablja za dodelitev frekvenc brez licenc po vsem svetu.

DECT-2020 je najnovejša različica razvoja, ki zagotavlja zelo zanesljiv radijski prenos, ki podpira napredno kodiranje kanalov in Hybrid ARQ s postopnim presežkom, kar omogoča hiter re-prenos. Fizična plast podpira hitro prilagajanje, prenašanje in sprejem raznolikosti, kot tudi MIMO operacije do 8 tokov. DECT-2020 zajema topologijo zvezdnega omrežja,

SIST Standardizacija na področju DECT tehnologije

ETSI

IMT-2020 Proposal

DECT-2020 New Radio (NR) Component RIT

- TS 103 636 Part 1: DECT-2020 NR, Overview
- TS 103 636 Part 2: DECT-2020 NR, Radio reception and transmission requirements
- TS 103 636 Part 3: DECT-2020 NR, Physical Layer
- TS 103 636 Part 4: DECT-2020 NR, Medium Access Control (MAC) Layer
- TS 103 634: Low Complexity Communication Codec plus (LC3plus)

3GPP New Radio (NR) Component RIT

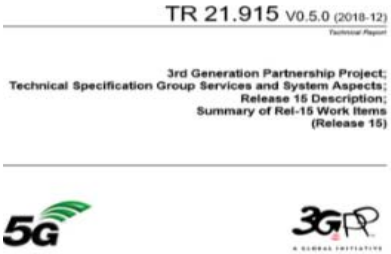
- Release 15 New Radio Specifications
- Release 16 New Radio Specifications



SIST Standardizacija na področju DECT tehnologije

3GPP Standardi za 5G Nov radio, 5G NR:
iz izdaje (**Release 15**) in naprej, 23. november 2021,

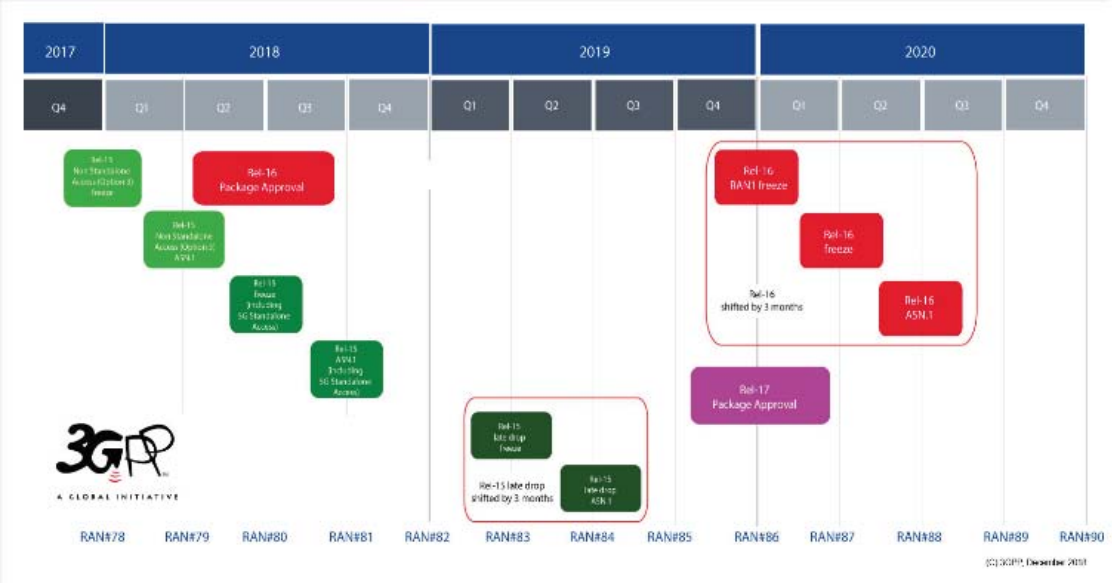
Dogodek za uvedbo postopka standardizacije 3GPP in razpravo o obstoječih in prihodnjih specifikacijah za **5G New Radio**. Peta in zadnja generacija mobilnih komunikacijskih protokolov (5G) naj bi obravnavala primere uporabe veliko po naslednjem desetletju. Prvi sklop tehničnih specifikacij za 5G, imenovan tudi **"Novi radio" ali NR v 3GPP**, je bil dokončan v okviru izdaje **3GPP Release15**. Delo standardizacije za 5G NR se nadaljuje in nove funkcije se nenehno dodajajo, da bi obravnavali naprednejše primere uporabe in vertikale. Ta predstavitev bo zagotovila pregled postopka standardizacije v programu 3GPP in pregled tehničnih značilnosti za izdajo **Release16 in izdajo Release17 specifikacij.**


TR 21.915 V0.5.0 (2018-12)

3rd Generation Partnership Project;
Technical Specification Group Services and System Aspects;
Release 15 Description;
Summary of Rel-15 Work Items
(Release 15)

5G 3GPP

Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

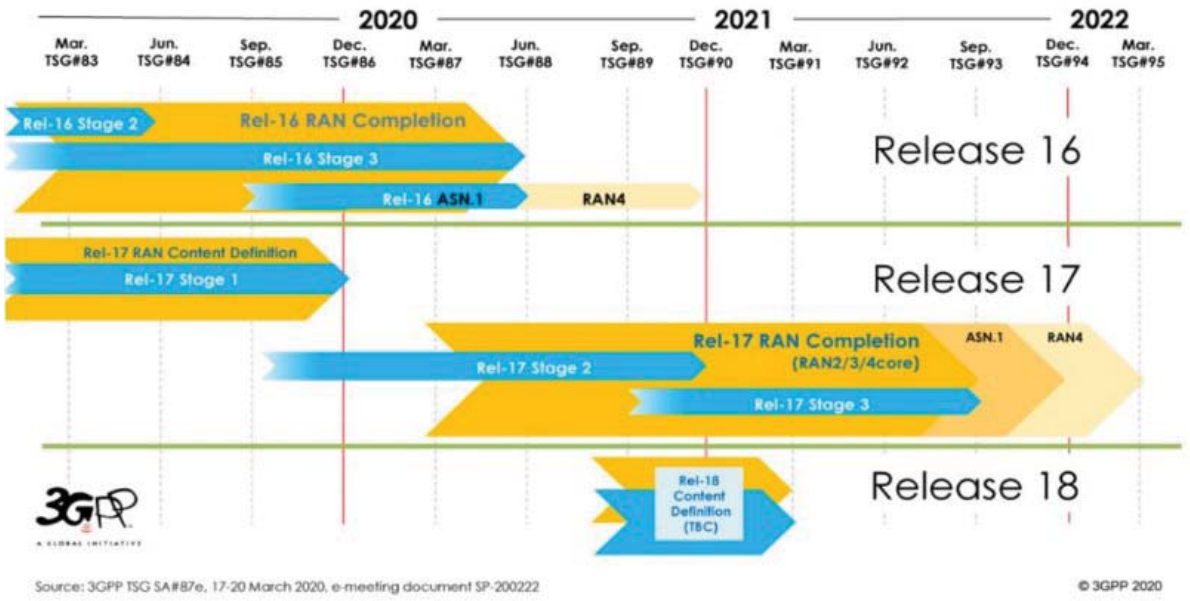
3GPP je finaliziral **Release 16** za **5G NR** Nove radijske tehnologije

Partnerski projekt 3. generacije (3GPP) je globalni organ za brezžične standarde, ki usklajuje razvoj standardov za mobilne telekomunikacijske tehnologije, vključno z dostopom do radia, jedrnim omrežjem in zmogljivostmi storitev. Organizacija združuje sedem drugih razvojnih organizacij in članom zagotavlja stabilno okolje za izdelavo poročil in specifikacij, ki opredeljujejo tehnologije 3GPP. Njegov najvidnejši trenutni projekt je razvoj univerzalnih standardov za tehnologijo pete generacije (5G) za celična omrežja.

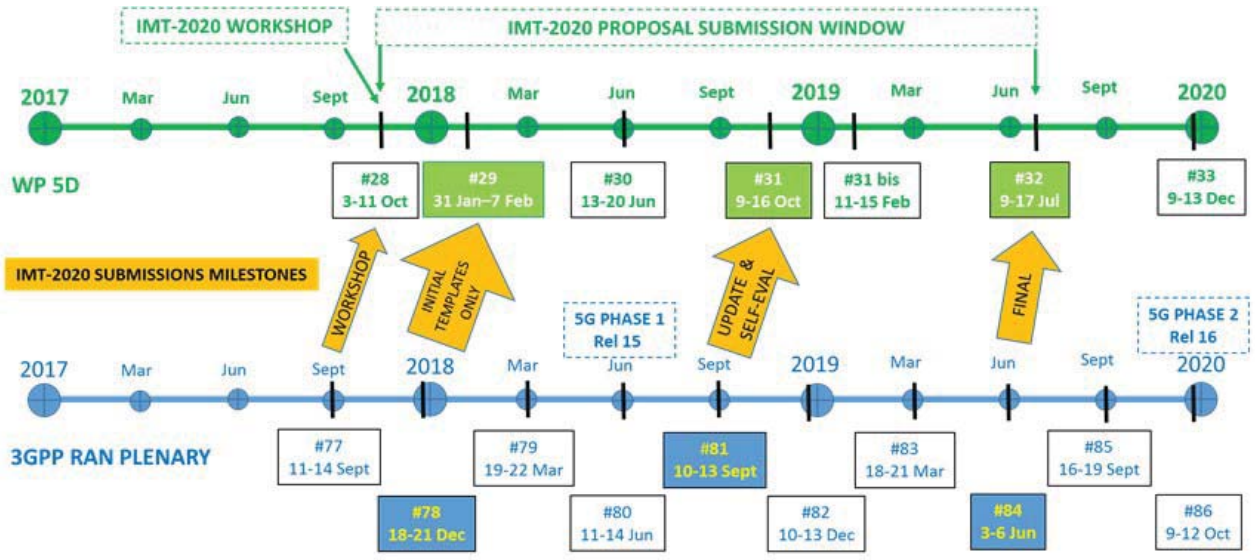
3GPP Rel-16 se osredotoča na ključne tehnologije, ki bodo industrijskim podjetjem pomagale pri njihovi digitalni preobrazbi in pobudah Industrije 4.0 ali Industrijskem internetu stvari (IoT). Ta izdaja bo razširila 5G iz mobilnega širokopasovnega omrežja na nova področja komunikacijskih storitev, ki v preteklosti niso bila v celoti obravnavana.

Rel-16 ima nabor specifikacij za primere uporabe, ki vključujejo mobilno vozilo za vse **(C-V2X), Industrijski IoT, URLLC, NR- dostop do nelicenciranega spektra (NR-U), integriran dostop in backhaul (IAB)**

Standardizacija na področju DECT tehnologije



Standardizacija na področju DECT tehnologije



Standardizacija na področju DECT tehnologije

Standard ETSI DECT-2020 NR,

je sestavljen iz štirih delov, tehničnih specifikacij, objavljenih **aprila 2021**:

MAC: ETSI **TS 103 636-4** V1.2.1 (2021-2004),

PHY: ETSI **TS 103 636-3** V1.2.1 (2021-2004),

Zahteve za radijski sprejem in prenos: ETSI **TS 103 636-2** V1.2.1 (2021-04),

Pregled: ETSI **TS 103 636-1** V1.2.1 (2021-2004),

Opomba: Pripravljajo se posodobitve!

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Standardizacija na področju DECT tehnologije

ETSI TS 103 636-1 V1.1.1 (2020-07)



DECT-2020 New Radio (NR);
Part 1: Overview;
Release 1

ETSI TS 103 636-1 V1.1.1 (2020-07) -

DECT-2020 Nov radio (NR);
Del 1: Pregled

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Standardizacija na področju DECT tehnologije

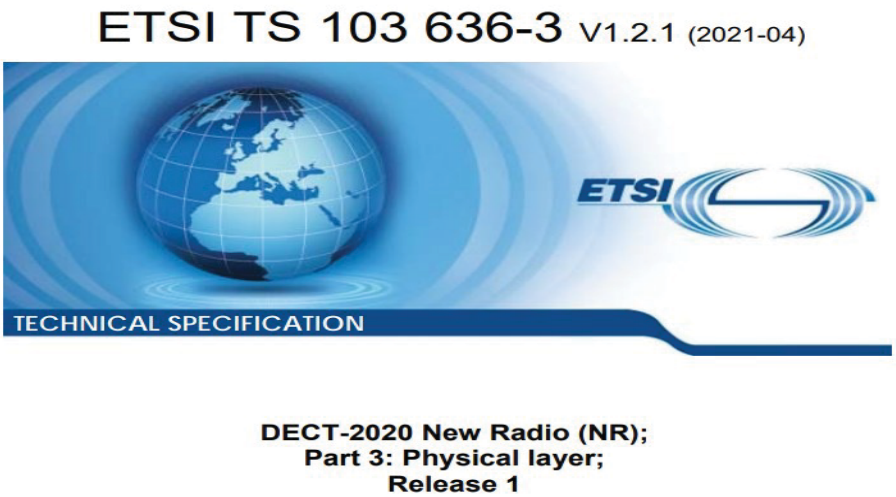
ETSI TS 103 636-2 V1.1.1 (2020-07),

DECT-2020 Nov radio (NR);
Del 2: zahteve za radijski sprejem in prenos; 1. verzija dokumenta,



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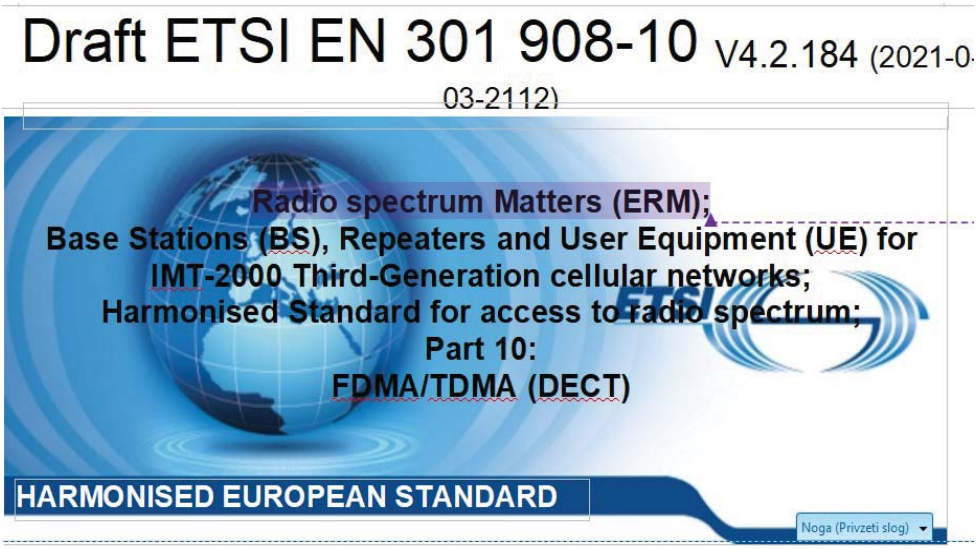
Standardizacija na področju DECT tehnologije



ETSI TS 103 636-3,

DECT-2020 Novi radio (NR)
Del 3: Fizična plast; 1. verzija

Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

DECTTDE(21)000012

Title*:	DECT-2020 rebranding proposals
from **Source***:	Wirepas Oy
Contact:	Jussi Numminen
input for **Committee***:	DECT TDE
Contribution **For***:	Decision: ; Discussion: ; Information: X
Submission date*:	
Meeting & Allocation:	**DECTTDE#3-Meeting 27.4.2021** -
Relevant WI(s), or deliverable(s):	

ABSTRACT: *This contribution provides all proposals considering DECT-2020 NR technology re-naming.*

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SIST Standardizacija na področju DECT tehnologije

ETSI

DECTTDE(21)000012

b) Examples for branding new category could be:

Examples of new category could be: Private 5G, Open 5G, direct 5G, DxG, openD,…

Action: Please provide your proposals for the technology naming for the discussion and decision.

Logo proposals

Regarding the logo the trademark DECT could benefit combined with a logo. A stylish font letter "D" or "DD" as shown below could be considered.
Based on received feedback form ETSI secretariat, progressing with the logo may be quite sticky process at this point of time. However, nothing prevents us to propose something which is an additive, and not essential at first phase.

Some examples on logos

Dect Private 5G Private 5G Private 5G

Action: Consider whether we should continue with logo proposal in the ETSI material context.

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SIST Standardizacija na področju DECT tehnologije

ETSI TS 103 636-4 V1.1.1 (2020-07)

DECT-2020 Novi radio (NR);
Del 4: MAC plast; 1. verzija

ETSI TS 103 636-4 V1.2.1 (2021-04)



**DECT-2020 New Radio (NR);
Part 4: MAC layer;
Release 1**

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Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

V letu 2021 (oktober 2021) zadnji objavljen DECT dokument



Digitalne izboljšane brezvrvične telekomunikacije (DECT);
Kodek za komunikacijo z nizko kompleksnostjo plus (LC3plus)

230

Standardizacija na področju DECT tehnologije

Iz arhiva tehničnega odbora **ETSI TC DECT**:

DECT	564	DECT 2020 nov radijski vmesnik - stopnja 2	ZAPRTO
DECT	552	Izboljšave in razvoj DECT	ZAPRTO
DECT	528	Posodobitev standardov DECT Radio Test	ZAPRTO
DECT	508	Posodobitev harmoniziranih standardov DECT, ki zajemajo bistvene zahteve člena 3.2 in člena 3.3(g) nove direktive RED	ZAPRTO
DECT	388	DECT varnost in vzdrževanje osnovnih standardov	ZAPRTO
DECT	385	Specifikacija testa protokola DECT-NG Del 3 (izboljšane širokopasovne govorne storitve) za certificiranje	ZAPRTO
DECT	382	DECT-Advanced Report & NG-DECT Update	ZAPRTO

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI TS 103 636-1 V1.3.1 (2021-12)



DECT-2020 New Radio (NR);
Part 1: Overview;
Release 1

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI TS 103 636-2 V1.3.1 (2021-12)



DECT-2020 New Radio (NR);
Part 2: Radio reception and transmission requirements;
Release 1

SIST Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI TS 103 636-3 V1.3.1 (2021-12)



DECT-2020 New Radio (NR);
Part 3: Physical layer;
Release 1

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI TS 103 636-4 V1.3.1 (2021-12)



DECT-2020 New Radio (NR);
Part 4: MAC layer;
Release 1

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI TS 103 636-5 V1.3.1 (2021-12)



DECT-2020 New Radio (NR);
Part 5: DLC and Convergence layers;
Release 1

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-1 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 1: Overview**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-2 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 2: Physical Layer (PHL)**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-3 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 3: Medium Access Control (MAC) layer**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

ETSI EN 300 175-4 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 4: Data Link Control (DLC) layer**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-5 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 5: Network (NWK) layer**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-6 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 6: Identities and addressing**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-7 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT)
Common Interface (CI);
Part 7: Security features**

Standardizacija na področju DECT tehnologije

V decembru 2021 je tehnični odbor TC DECT pripravil še naslednje dokumente:

Draft ETSI EN 300 175-8 V2.8.5 (2021-12)



**Digital Enhanced Cordless Telecommunications (DECT);
Common Interface (CI);
Part 8: Speech and audio coding and transmission**

Standardizacija na področju DECT tehnologije

23 standardov DECT tehnologije, ki bodo v letu 2022 posodobljeni:

ETSI EN 300 175-2 V2.8.4	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)	DECT	6- Final draft for approval
ETSI EN 300 175-7 V2.8.2	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 7: Security features	DECT	6- Final draft for approval
ETSI EN 300 175-3 V2.8.2	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 3: Medium Access Control (MAC) layer	DECT	6- Final draft for approval
ETSI EN 300 175-4 V2.8.2	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 4: Data Link Control (DLC) layer	DECT	6- Final draft for approval
ETSI TS 103 636-4 V1.2.4	DECT-2020 New Radio (NR); Part 4: MAC layer; Release 1	DECT	4- Stable draft
ETSI EN 301 406-2 V0.0.7	Digital Enhanced Cordless Telecommunications (DECT); Harmonised Standard for access to radio spectrum Part 2: DECT-2020 NR	DECT	2- Early draft

Standardizacija na področju DECT tehnologije

ETSI TS 103 636-1 V1.2.2	DECT-2020 New Radio (NR); Part 1: Overview; Release 1	DECT	2- Early draft
ETSI TR 103 884 V	DECT; DECT-2020: guide for implementers	DECT	1- Start of work
ETSI TS 102 843 V	Digital Enhanced Cordless Telecommunications (DECT); New Generation DECT; Additional feature set nr.1 for extended wideband speech services; Profile Test Specification (PTS) and Test Case Library (TCL)	DECT	1- Start of work
ETSI EN 300 175-5 V2.8.3	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 5: Network (NWK) layer	DECT	4- Stable draft
ETSI TS 103 706 V0.0.7	Digital Enhanced Cordless Telecommunications (DECT) Advanced Audio Profile	DECT	4- Stable draft
ETSI EN 300 175-8 V2.8.3	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 8: Speech and audio coding and transmission	DECT	4- Stable draft
ETSI EN 301 908-10 V4.3.0	IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 10: Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks	DECT	9- Start of OAP
ETSI EN 300 176-2 V2.3.2	Digital Enhanced Cordless Telecommunications (DECT); Test specification; Part 2: Audio and speech	DECT	2- Early draft
ETSI TS 103 636-2 V	DECT-2020 New Radio (NR); Part 2: Radio reception and transmission requirements; Release 1	DECT	1- Start of work
ETSI TS 103 776 V	DECT DECT-2020 New Radio (NR) Test specification: radio	DECT	1- Start of work

Standardizacija na področju DECT tehnologije

ETSI TS 103 776 V	DECT DECT-2020 New Radio (NR) Test specification: radio	DECT	1- Start of work
ETSI TR 103 777 V	Digital Enhanced Cordless Telecommunications (DECT); DECT-2020 New Radio (NR) interface; Study of additional functionality for the support of new applications in further releases.	DECT	1- Start of work
ETSI EN 301 406-1 V	Digital Enhanced Cordless Telecommunications (DECT); Harmonised Standard for access to radio spectrum Part 1: DECT, DECT-evolution and DECT-ULE	DECT	1- Start of work
ETSI TR 103 513 V	Digital Enhanced Cordless Telecommunications (DECT); DECT Technology Roadmap	DECT	1- Start of work
ETSI EN 300 176-1 V	Digital Enhanced Cordless Telecommunications (DECT); Test specification; Part 1: Radio	DECT	1- Start of work
ETSI TR 103 089 V1.1.2	Digital Enhanced Cordless Telecommunications (DECT); DECT properties and radio parameters relevant for studies on compatibility with cellular technologies operating on frequency blocks adjacent to the DECT frequency band	DECT	4- Stable draft
ETSI TR 103 822 V	DECT DECT-2020 New Radio interface: MAC layer architecture	DECT	1- Start of work

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Standardizacija na področju DECT tehnologije

Primer delovnega gradiva za pripravo novega dokumenta Tehničnih specifikacij **TS 103 636-5**, 3. december 2021

DECT(22)000001

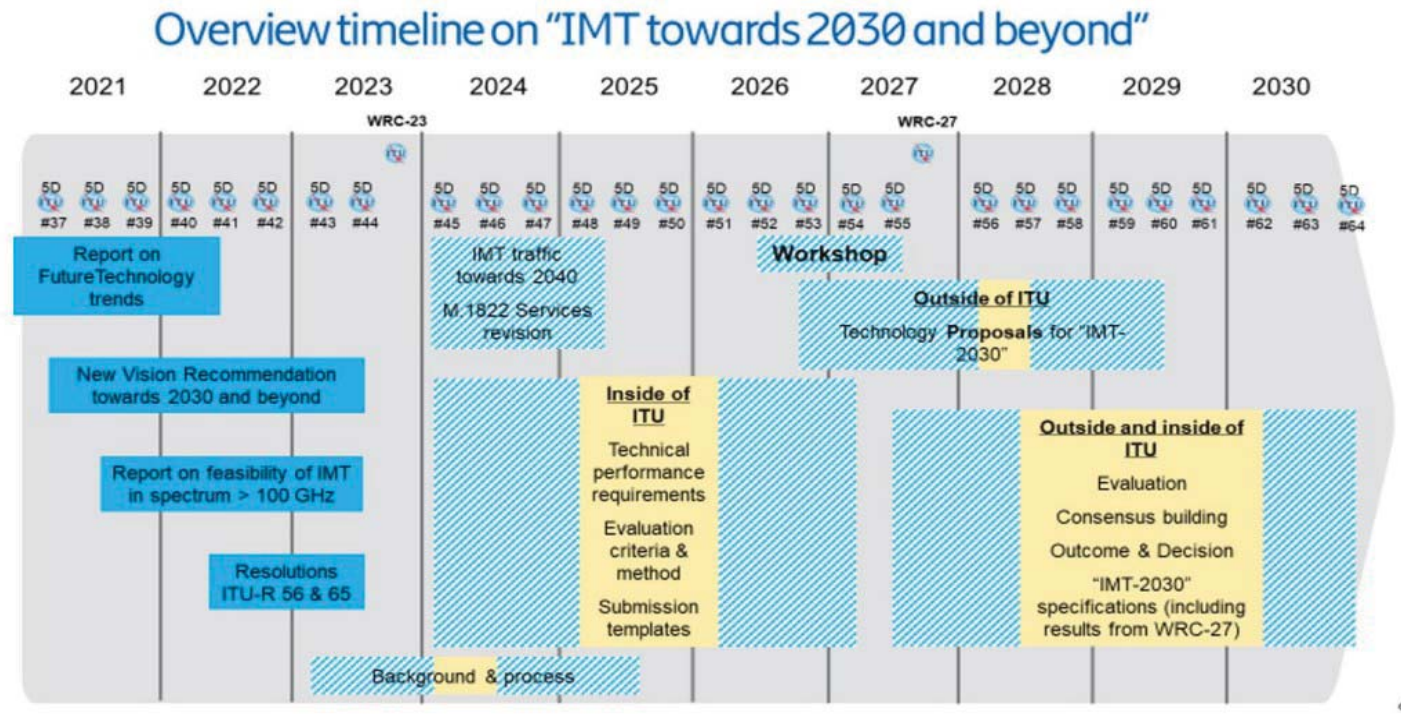
CHANGE REQUEST

TS 103 636-5	Version	1.1.1	CR	1	rev	-
CR Title:	Optimization in the coding of the CVG IE header octet					
Source:	Wireless Partners SLL					
Work Item Ref:	RTS/DECT-00379		***Date:***	03/12/2021		
Category:	F, C, D		***Release:***			
	Use one of the following categories: ***F*** *(correction)* ***A*** *(corresponds to a correction in an earlier release)* ***B*** *(addition of feature)* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*					
Reason for change:	Technical improvement					
Summary of change:	New optimized coding for first octet of CVG layer IEs					

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SIST

Standardizacija na področju DECT tehnologije



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Standardizacija na področju DECT tehnologije

Prihodnji obeti:

Je DECT še vedno pomemben? Ima obetavno prihodnost?

Ta tehnologija je stara že več kot 25 let in je precejšnja značilnost vsakega sodobnega gospodinjstva. Vendar pa je prihodnost DECT pogosto pod vprašajem. Seveda razvoj nikoli ne miruje in tudi evolucija DECT standarda ne.

Nedavno je Zvezna agencija za omrežja razširila splošno dodelitev frekvenc DECT za naslednje obdobje. To pomeni, da se naprave DECT trenutne generacije lahko uporabljajo do konca leta 2025 in zelo je mogoče, da ta razširitev ne bo zadnja.

Standardizacija na področju DECT tehnologije

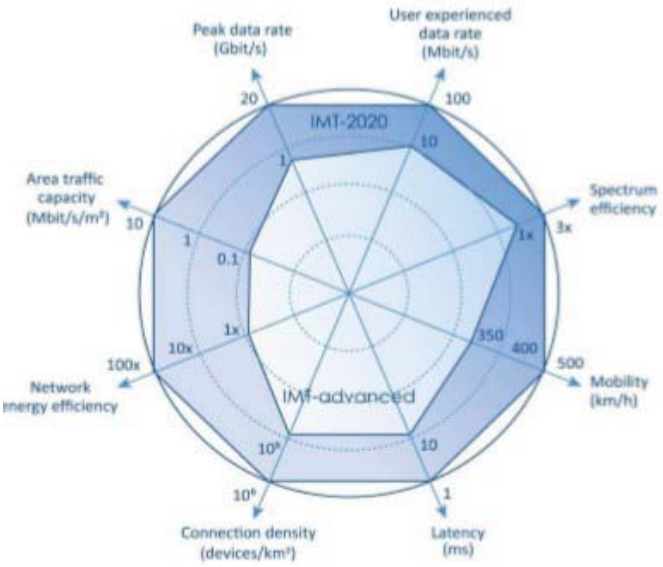
DECT-5G Business Working Group

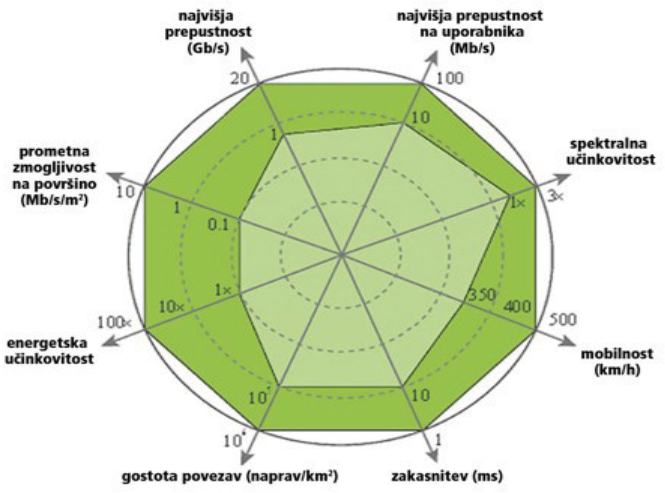
- Mission:
  - Define DECT-5G and its value proposition
  - Define the use cases and uncover DECT uniqueness
  - Facilitate entrance into new regional and application markets
  - Act as a facilitator between industry participants (CEPT, ITU-R, 3GPP, ETSI, ZVEI..)

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Standardizacija na področju Wi-Fi tehnologije

ITU definicija 5G storitev





Osnovne tehnološke zahteve IMT-2020 ali 5G.

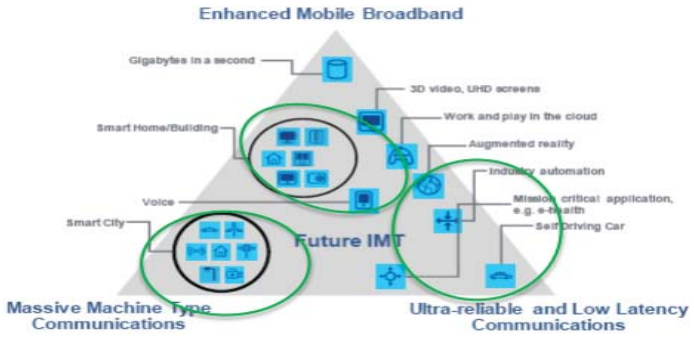
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SIST Standardizacija na področju DECT tehnologije

DECT FORUM

Why DECT as a 5G technology?

5G Usage Scenarios from the ITU-R IMT-2020 Vision Recommendation



IMT2020: Driving DECT to 5G

- Unique technology addressing key 5G use cases mMTC and URLLC
- Local Area 5G: mission critical, operator independent
- Leverages legacy infrastructure, standard and eco system
- Meets and exceeds the requirements of 5G
- Ultra low latency, high reliability, scalable, power optimised

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SIST Standardizacija na področju DECT tehnologije

DECT Forum 2021

Member Meeting October 5, 2021

dect wireless technology

DECT Forum Flower



Flowering and Growth

SIST Standardizacija na področju DECT tehnologije

Pet najpomembnejših področij delovanja DECT tehnologije v prihodnje

dect wireless technology

Solutions to Meet Market Needs

Overview

Telephony

Telephony is the **largest market** for DECT technology today, focusing on HDvoice handsets and Gateway integration. The CAT-iq **certification guarantees the interoperability** and highest quality of service.

Enterprise

This non-residential enterprise market is **growing fast**, driven by the change to Unified Communications and increased use of headsets & accessories. The DECT standard is the best wireless standard for **high density networks**, QoS and **mission critical solutions** in the enterprise environment.

Smart Home

Identified with low power consumption, low latency, **long range**, moderate data rate and value-added **complementary voice** capabilities, ULE is the best-of-class technology for in home networking. It addresses Ultra-Low Energy application requirements by introducing optimized and **ETSI standardized** communication methods.

Pro-audio

For the audio market the DECT solutions provide **real-time communication** with full-duplex audio and exceptional speech clarity. DECT is an optimized wireless technology to solve communication challenges in the pro audio industries and operates in a license and **interference free** band.

Industrial IoT

Industrial automation is a very challenging application field for a wireless protocol. There is often specific needs like human machine interfaces and **real-time** machine control, which are **mission critical** and just must get through on time. DECT is perfect for Integrated systems.
Low latency control and **Voice Data Integration**







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SIST Standardizacija na področju DECT tehnologije

dect wireless technology

Telephony

- Gateway integration
- Audio quality HD-Voice handsets
- Multi-line

Market growth during Pandemic
Parks Associates

Driver for today

Voice is largest DECT technology solutions area

Almost 50 million new residential systems are sold each year

Change from PSTN to IP based telephony

growth during Covid-19 period, multi-line communication

What are the market needs for tomorrow?

Better audio quality: new audio codes for better speech intelligibility

Multi-Microphone solutions to improve group communication in conference rooms

Noise reduction to reduce unwanted background noises

Target:

Improve the communication experience - get as close as possible to natural face to face communication

HD VOICE

Standardizacija na področju DECT tehnologije






Enterprise

~10% CAGR
Growth 2020 – 2025
Note: Frost & Sullivan

Definition: •Nonresidential •Headsets and accessories •Unified Communication

Driver for today

Robust, Reliable & cost-effective voice solutions

Mission critical enterprise communication

Wireless headsets with highest density and highest security makes it perfect for enterprise

High constant growth due to increase of Unified Communication

Twenty million DECT-enabled enterprise systems are sold each year (Parks Associates)

Plan for tomorrow

DECT evolution increasing density

New LC3+ codec for best-in-class audio

Increasing security support (Step-C, FIPS)

IP connected integration into cloud systems for deployment and maintenance/status

Voice dependent cognitive solutions for environment sensitive noise suppression

Seamless integration with for professional use of Alexa, Siri, Google assistant type of systems (superior voice recognition due to superior voice quality)

Application examples

Office · Call-centers · Explosion proof · Cruise ships · Mission critical · Hospitality · Healthcare

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Standardizacija na področju DECT tehnologije

Pro-audio

- **Intercom**
- **Conferencing Systems**
- **PMSE Program Making and Special Events**

Wireless Intercom Market $9.5B
BusinessWire Press release
reesearchandmarkets.com





Drivers for today

License Free with easy setup

High Density (>100 devices)

Low latency (< 5ms one way)

Ultra reliable communication

Advanced Codecs trading off density and latency whilst maintaining fidelity, bandwidth and dynamic range

ADPCM family, MDCT family (Opus, LC3)

Two-way audio communications

Control channels built in

Plans for tomorrow

Everything DECT Evolution is capable of plus DECT 5G improvements

Better Indoor performance

Better Sensitivity, Multipath, Forward Error Correction

Higher bitrates, for better quality at the same density

MIMO allows higher density

Possibility of 5G Non-Public Network deployment outside DECT band

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Standardizacija na področju DECT tehnologije

dect wireless technology

Industrial IoT

- **Integrated Systems**
- **Low Latency Control**
- **Voice Data Integration**



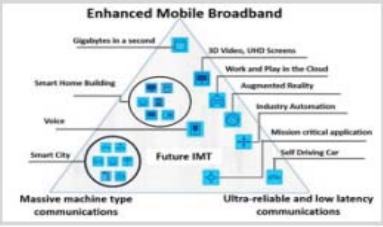
Drivers for today

There are existing industrial use cases today built on ULE (e.g., A-Safe RackEye)

New DECT-2020 ETSI standard gives growth path for long term future

Mesh networking solutions main focus area of ongoing standardization efforts

Aim is to get DECT-2020 approved as IMT-2020 technology



Plans for tomorrow

DECT-2020 approved as IMT-2020 technology and marketed as DECT-5G

URLLC and mMTC main corner stones for future use cases

Building further on DECT strengths: license-free and protected band

URLLC use cases (identified by TC-DECT):

- Building automation
- Industry automation – Factories of the future
- PMSE
- Healthcare

Goal: create interest and traction from Industrial IoT vendors around the globe for this new 'petal' on the DECT Forum Flower

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Standardizacija na področju DECT tehnologije

Hvala za vašo pozornost!

Thanks for your attention!

drago.majcen@gmail.com



*** Or even better: suggestions or objections**

Time-Critical Communications for 5G

Csaba Novak

Ericsson

csaba.novak@ericsson.com

Abstract

A high degree of reliability and consistent low latency is the biggest differentiator for 5G from other wireless technologies. Time-Critical Communication supports a wide range of latency and reliability – from 50 ms - 1ms latency with 99.9 - 99.999% reliability, enabling a variety of latency-sensitivity use cases in real-time media, remote control, industrial control, and mobility automation categories across industries.

Time-Critical Communication (TCC) can be deployed as a software upgrade to existing 5G network infrastructure, on all available frequency bands. The recommended steps that could be considered to start using the TCC in Public Networks:

- Rollout 5G with 5G Core. Consider 5G in multi-layers/bands in areas where capacity is needed.

- Good mid band coverage in wide areas is a good baseline for the introduction of new use cases. This will allow that more dedicated cells/bands could be defined for specific use cases. This is what we call as '5G Territories'.

- Add TCC to 5G Territories. By enabling TCC on those areas, it allows that time critical use cases could be enabled which could bring better end user experience with consistent low latency and better reliability.

- Activate new experiences: Gaming hotspots, stadiums, amusement parks, experience centres.

By following these steps, it is possible for Communication Service Providers (CSPs) to address new revenue streams. This allows to move from eMBB subscriptions as the unique revenue stream (based on Data volume and Best effort latency subscriptions) and start addressing eMBB with TCC subscriptions (based on Creating real-time experiences and Guaranteed latency).

In collaboration with leading CSPs, industry and ecosystem partners such as BT, DT, Telia, ABB, Audi, Boliden, since 2017, Ericsson has been piloting various time-critical use cases categorized in four major areas: Industrial control, Mobility automation, Remote Control and Real-Time media.

Author's biography



Csaba Novák *is the lead 5G expert for Ericsson's Central-European customer unit. Acquired his MSc in electrical engineering at the Budapest University of Technology, and pursued PhD studies at the Department of Broadband Communication Systems – researching broadband spread spectrum radio technologies, CDMA coding systems and interference mitigation receivers, having numerous publications in the topic. He received his MSc in economic sciences at Corvinus University, studying the transformation of value chains into value creating networks in mobile communications B2B market. He joined Ericsson Hungary in 2006, today he is supporting 5G network evolution and sales in the region.*

Time-Critical Communication for 5G



Seminar on Radio Communications SRK 2022

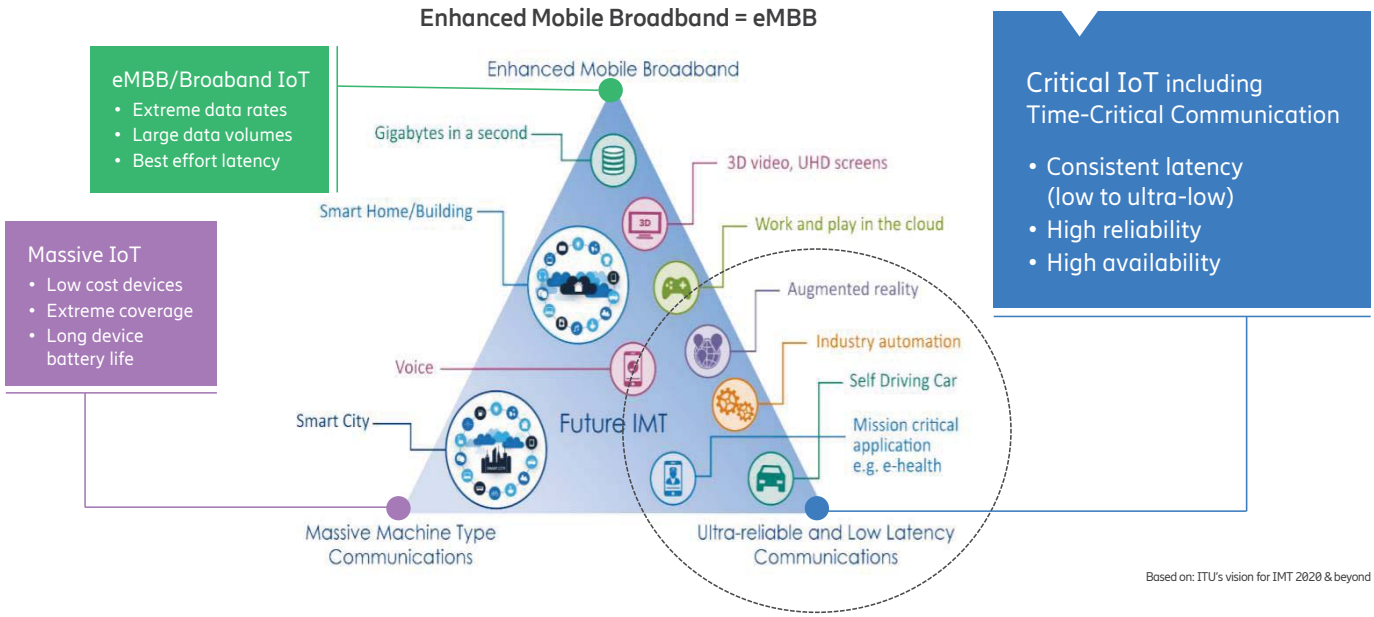
Csaba Novák Ericsson Network Products 2022-01-17

Agenda

- Time Critical Communications definition
- Use Cases and Requirements
- Solution Toolbox E2E 5G NR / URLLC Holistic view
- Deployment Scenarios Examples, References



The three cornerstones of wireless communication according to ITU

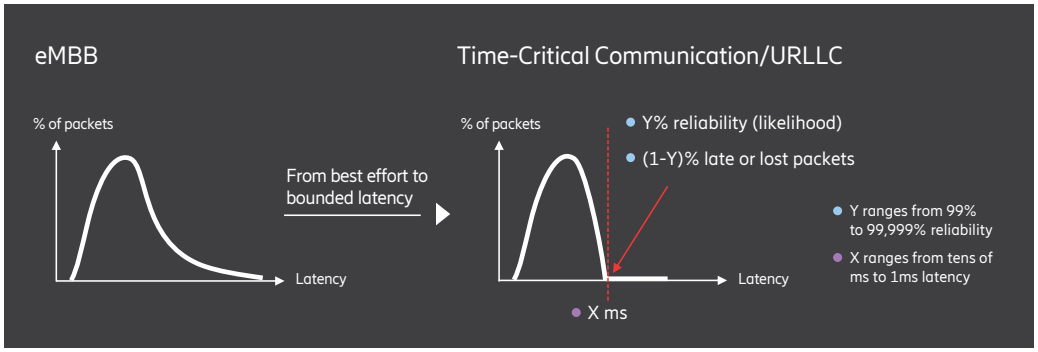


Based on: ITU's vision for IMT 2020 & beyond

Definition of Time-Critical Communication

Data delivery within a specific time window with a required guaranteed level*

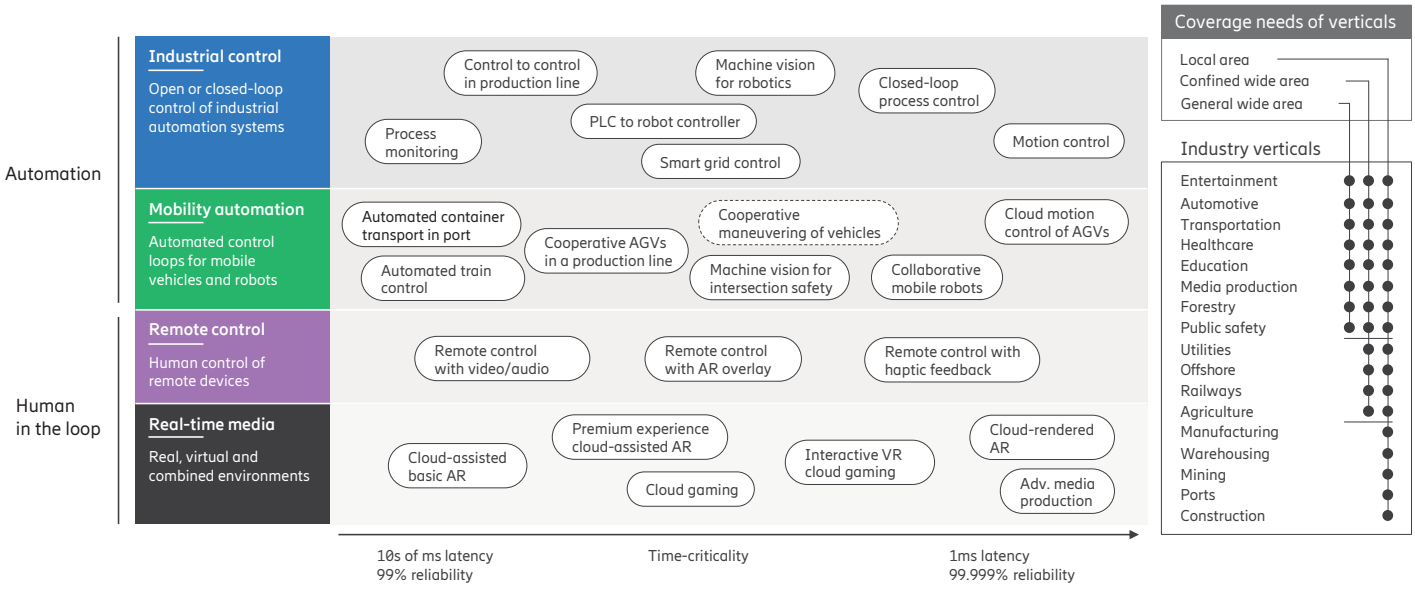
* Example: Data delivered within 30ms with 99.9% reliability



Fundamental trade-offs between latency and other KPIs such as throughput, coverage, and energy efficiency

Latency aspect prioritized over throughput → a fundamental difference vs eMBB

Time-critical use case categories



Toolbox for Time-Critical Communication

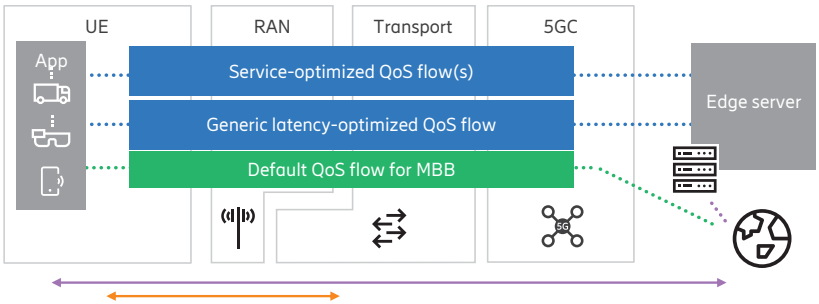
Causes of latency

Congestion	Radio environment	Mobility	Standards /protocols	Power saving	Network topology	Capacity growth
Rate adaptation	Scheduling	Multi-TRP*	UL Configured grant*	DRX optimizations	Edge computing	QoS Adaptiveness
Slicing*	Link Adaptation	Conditional Handover*	Pre-scheduling*	Differentiated gNB energy efficiency	Optimized RAN deployment	TDD pattern
Admission Control	Robust Signaling*	DAPS*	DL SPS*	Traffic prediction	Transport dimensioning	Massive MIMO
Scheduling	Multi-TRP*	L3 Handover improvements	L2 Pre-emption*			ML for Traffic management
	Rate adaptation	Scheduling	Redundancy*			
	Repetitions*		Short TTI*			
	Duplication*					

Note: * 3GPP Standardized features

Ericsson's holistic approach for realizing TCC

- Service separation
- Addressing causes of latency
- Maximum performance



RAN specific tools for TCC

Scheduling	Link Adaptation	L2 Pre-emption
Carrier aggregation	Robust signal formats	DAPS Seamless mobility
Massive MIMO	Multi-TRP & CoMP	Multiplexing
Short TTI	Configured UL grants / DL SPS	

E2E tools for TCC

QoS framework	Rate adaptation
Slicing	Edge computing
Admission control	Real-time Ethernet
Redundancy/Duplication	

Critical IoT = URLLC and additional functionalities to enable Time-Critical Communication use cases

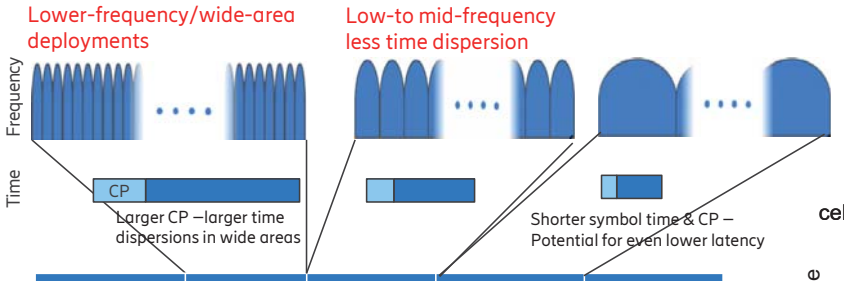
Critical IoT content

URLLC	• Ultra Reliable Low-Latency communications is the core functionality in Critical IoT • URLLC is enabling time critical communications, which will help operators unlock innovative services across end use cases

Other functionalities	• In addition to URLLC, Critical IoT brings other new functionalities, in order to create the prerequisites for enabling critical IoT use cases, e.g.
	  • Precise indoor positioning
	  • New TDD patterns
	  • High availability

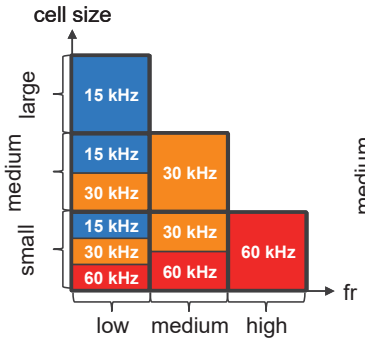
NR Numerology

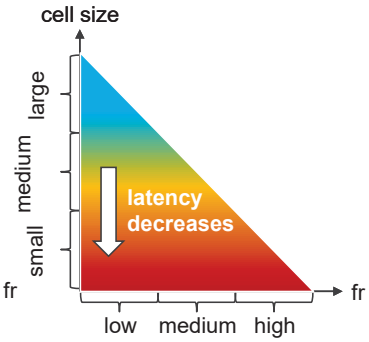
- flexible numerology: $f_{sc} = 15 \cdot 2^n$ kHz, where n={-2, -1, 0, 1, 2, 4, 5}



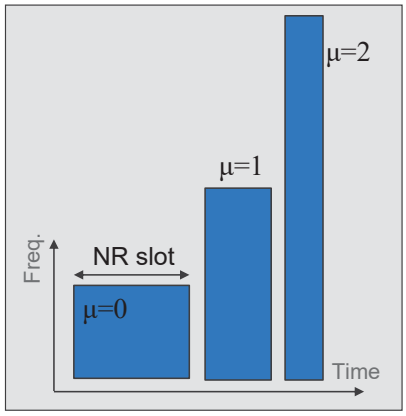
Sub-carrier spacing	15 kHz	30 kHz	60 kHz normal CP/ECP	120 kHz
Cyclic prefix	4.7 µs (6.6%)	2.4 µs (6.6%)	1.2 µs/4.7 µs	0.59 µs (6.6%)
Slot duration	1 ms	500 µs	250 µs	125 µs
Symbols per slot	14	14	14/12	14
Max channel BW	50 MHz	100 MHz	200 MHz	400 MHz

- Phase noise → min. subcarrier spacing
- Time dispersions → required cyclic prefix → max. subcarrier spacing





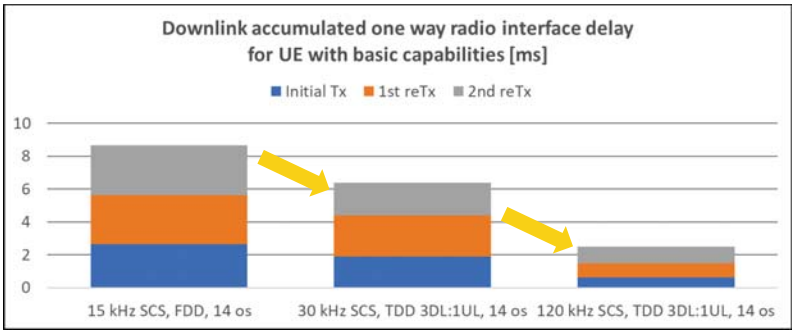
Numerology effect on radio interface delay



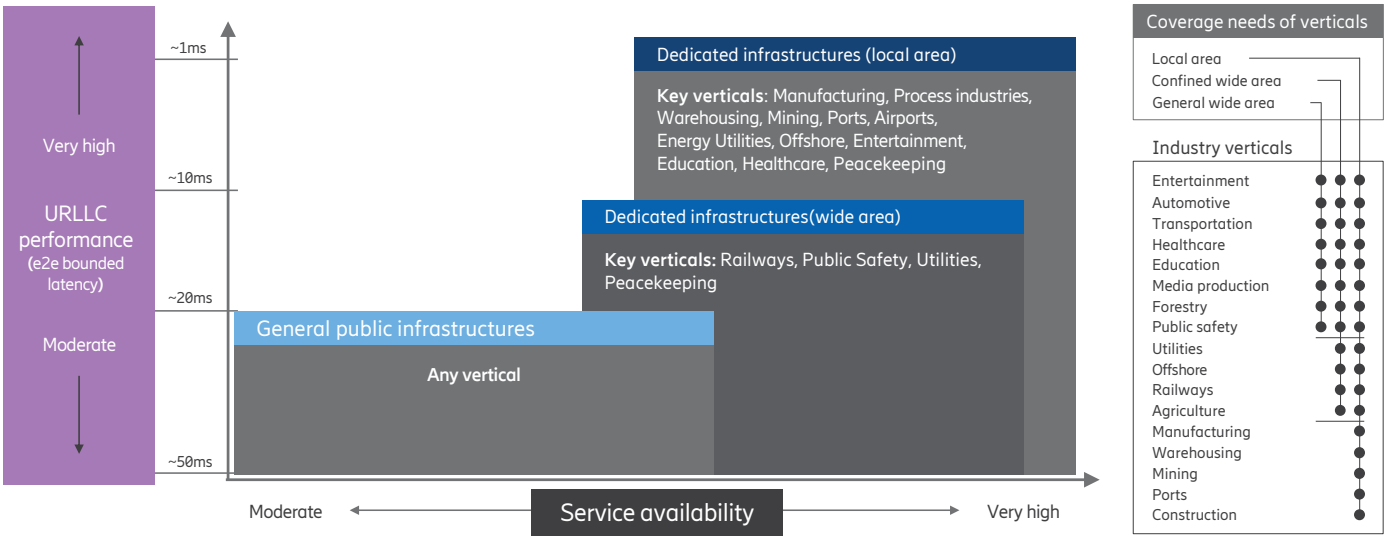
Assumptions:
- Slot allocation (14 os)
- 1 PDCCH per slot
- Processing capability 1

μ	SCS [kHz]	Slot duration	Carrier Frequency	#RBs in 50MHz BW
0	15	1 ms	≤ 6 GHz	270
1	30	0.5 ms	≤ 6 GHz	133
2	60	0.25 ms	All*	66
3	120	0.125 ms	>6 GHz	32
4	240	0.0625 ms	>6 GHz	Not for data**

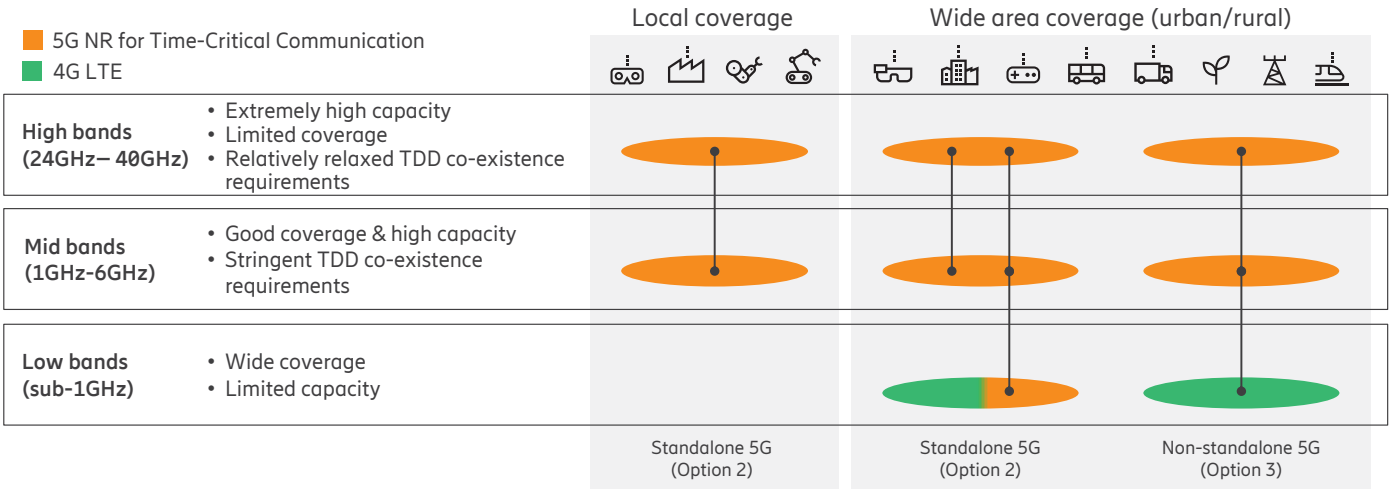
*60 kHz SCS is optional ≤ 6 GHz
**240 kHz is for SS/PBCH block only



Deployment considerations

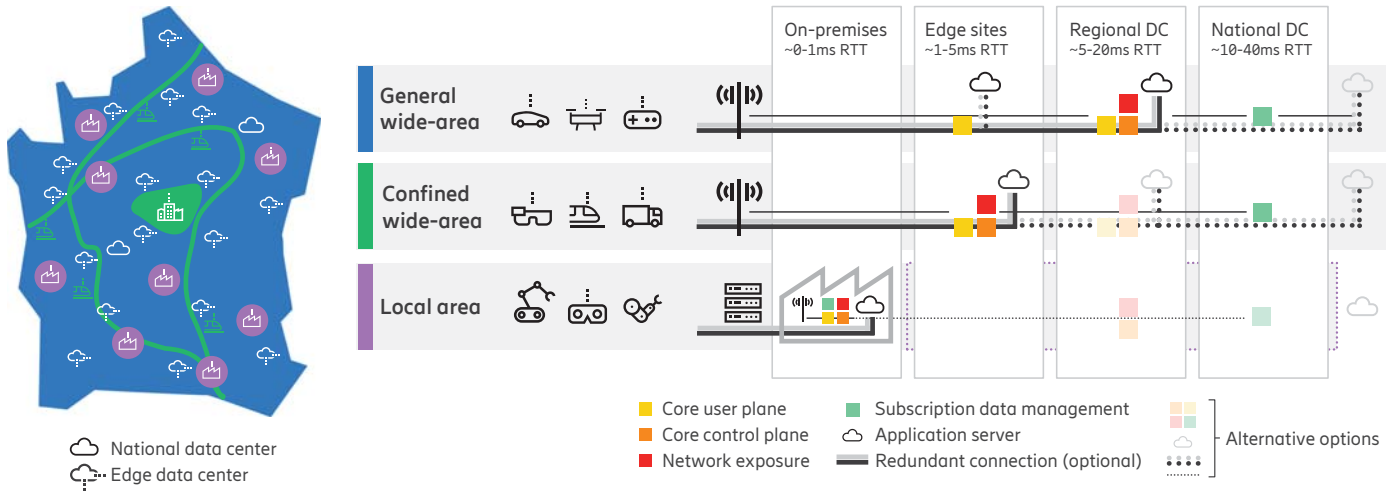


5G NR enables Time-Critical Communication in any 5G band



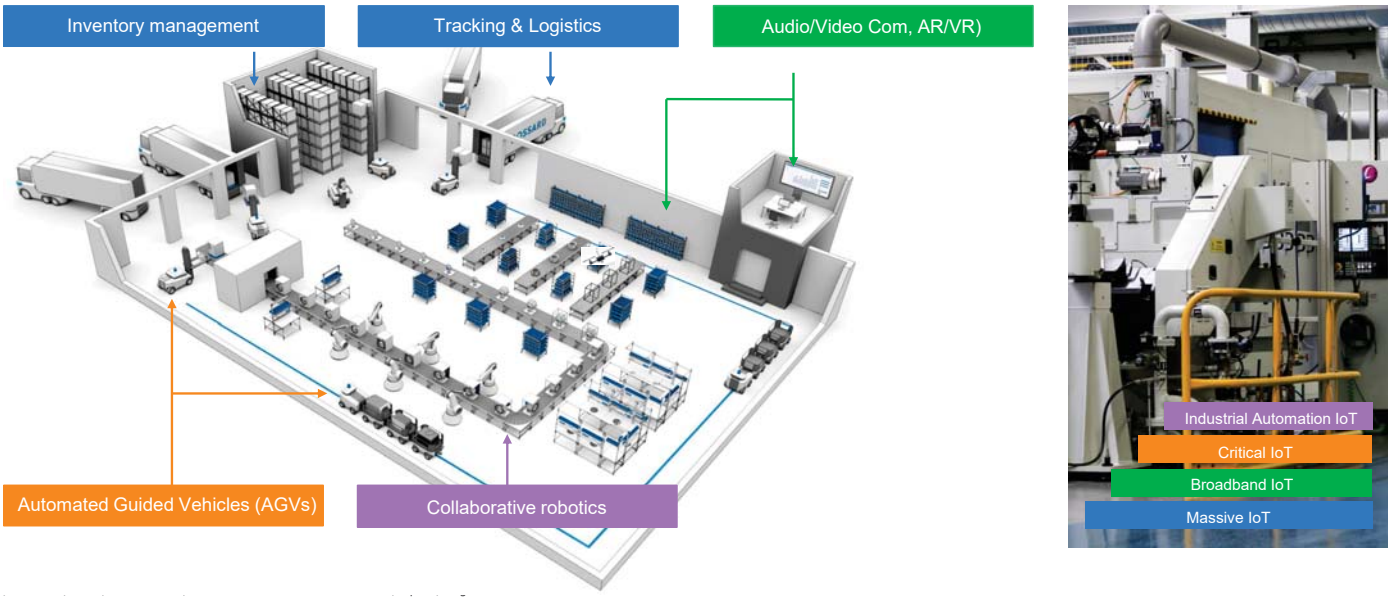
CSPs can take full advantage of their flexible 5G spectrum assets and existing footprint

Reducing transport latency with edge computing



Aggressive time-critical requirements enabled by core network distribution and edge computing

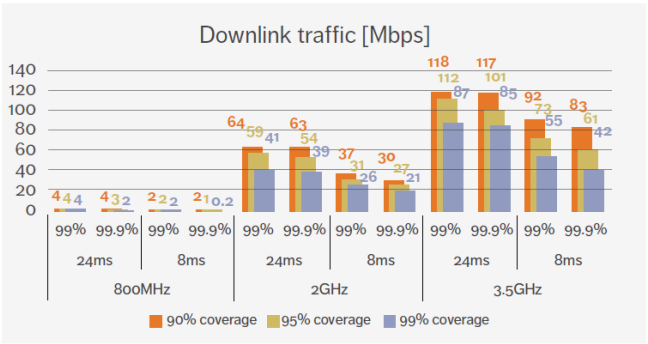
Cellular IoT segments for Smart manufacturing

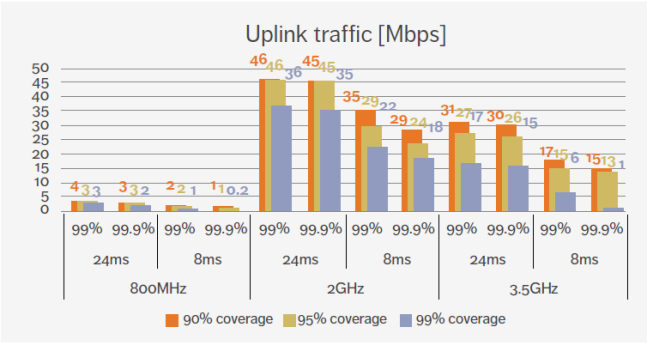


Case Studies for TCC deployment scenarios

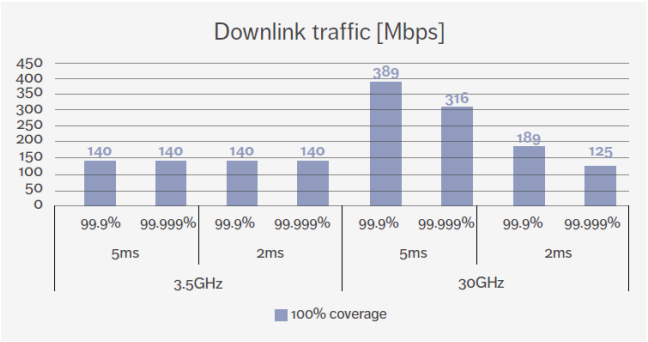
Scenario #1: Central London wide-area

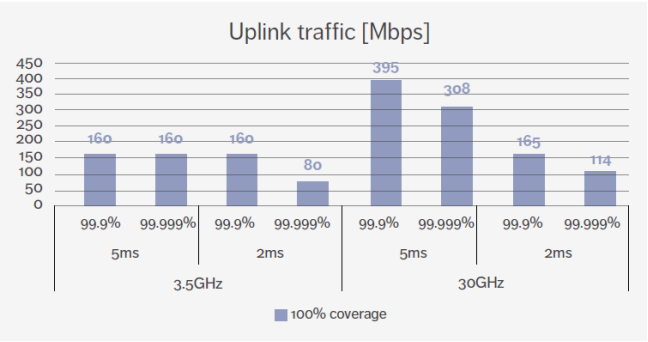
Ref: Critical IoT for time-critical communications - Ericsson





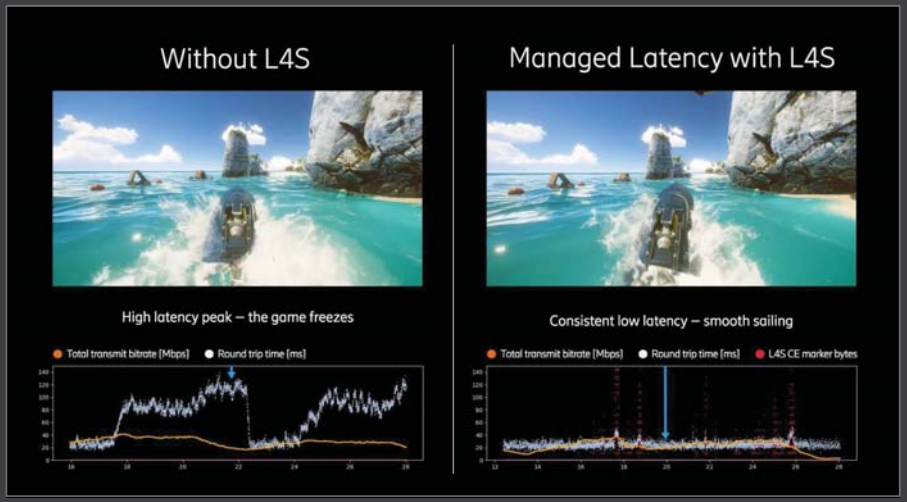
Scenario #2 Factory indoor deployment





Example: L4S-enabled Time-Critical Communication for cloud gaming

L4S feature for fast rate adaptation can significantly improve the performance of time-critical, high-rate applications on 5G networks



L4S: Low-Latency, Low-Loss, Scalable Throughput

news article; white paper

Driving the ecosystem forward

- Piloting time-critical use cases with industry partners since 2017

Industrial control



Manufacturing jet engines
(MTU Aero – Fraunhofer – Ericsson)



Manufacturing of vehicles
(Audi –MediaTek- Ericsson)

Mobility automation



Automated electric buses
(Keolis – Telia – Ericsson)



Intersection safety
(Ericsson – AstaZero - Chalmers)

Remote control



Remote driving
(Einride-Telia-Ericsson)



Remote control of mining equipment
(Boliden – Ericsson)

Real-time media



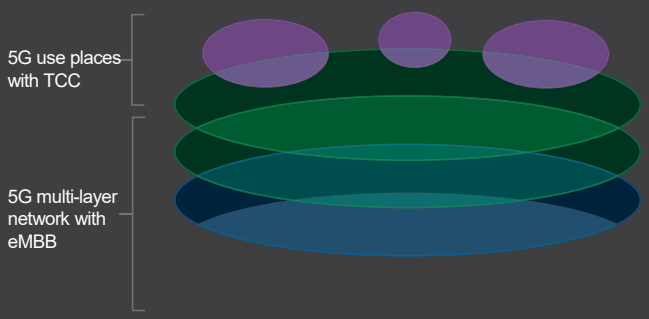
Cloud gaming
(DT – Ericsson)



Virtual reality
(Hyperbat – BT – Ericsson)

Early steps to bring Time-Critical Communication (TCC) to life

Introduce 5G with 5G Core → Add Time-Critical Communication



Good midband coverage in 5G Use Places – gaming centers, gaming hot spots, amusement parks, stadiums, experience centers



From eMBB subscriptions... →	..to eMBB + TCC subscriptions
Enhanced Mobile Broadband • Data volume-based subscriptions • Best effort latency	Time-Critical Communication • Creating real-time experiences • Guaranteed latency

O-RAN: Open path as baseline for future networks

Ivan Lesić

NOKIA

ivan.lesic@nokia.com

Abstract

At a time when connectivity enables all parts of society and the economy to benefit from digital services it is vital to have powerful and secure networks. The European Commission sets goals to develop an open and secure 5G ecosystem and to promote European digital autonomy and technological sovereignty by supporting collaboration between new and traditional vendors and a strong approach towards open specifications in the 5G ecosystem. Open RAN creates opportunities for new and traditional providers to support these goals by helping to foster innovation across industries. This increases the potential to innovate and meet the demands for a fast-growing variety of different use cases and applications. Network operators will need to deploy flexible networks with advanced features and services more quickly, more widely and more cost-efficiently, which is crucial to maintain EU competitiveness and technology leadership. This can only be achieved with interoperable, modular and open network architectures that allow competition and innovation. Open RAN significantly accelerates this development and provides the basis for establishing a dynamic and vibrant ecosystem of European players that can deliver innovative and tailored solutions that are secure, resilient and environmentally sustainable.

Author's biography



Ivan Lesić *went through different roles in the last 15 years (R&D, engineering, architectural and sales). He was supporting smooth evolution of access networks in close collaboration with many mobile operators all around the world. Currently he is head of technical solutions in Nokia, responsible for business in Central Europe region. His professional focus is 5G, RAN & EDGE cloud, network intelligence and automatization of network functions.*

NOKIA

O-RAN

Ivan Lesić, Solution lead, Nokia Mobile Networks

February 2022

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Agenda

- Introduction
- O-RAN: Open Fronthaul
- O-RAN: RIC and network intelligence

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NOKIA

Key trends in the telco industry

RAN Cloudification

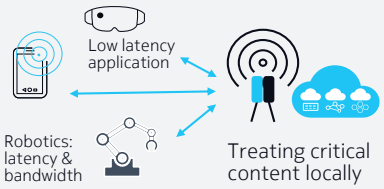
Zero footprint site concept

Shared baseband processing



Compute power at the edge

Applications and Services @ Edge



Treating critical content locally

Network Slicing

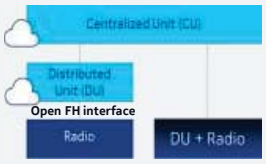


Diverse and extreme use case requirements



Dedicated Slices

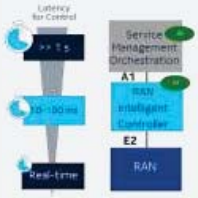
Decomposed RAN Architecture



SW flexibility for fast Innovation leveraging open environment

Open de-composed modular architecture

Intelligence with RIC-MEC



Open API and AI/ML for RAN programmability at the edge

Intelligent, Flexible Resource optimization

Management & Automation



Zero touch and self-optimizing network through Open API into Analytics

Automated operations and cloud agility

NOKIA

Key areas of O-RAN
3 main pillars build on technical specification work

O-RAN Alliance Objective	O-RAN		
Key enablers	**Interoperability (Multi Vendor)**	**HW/SW separation**	**Programmability Intelligence**
Solution	**Open interfaces Open Fronthaul**	**HW agnostic SW functionalities**	**Near Realtime RIC**
Objective	**Global adoption** of O-RAN technical specification with **no market fragmentation** **Avoid overlap** with 3GPP and ONAP		

Nokia internal use

O-RAN was formed by operators to lower TCO

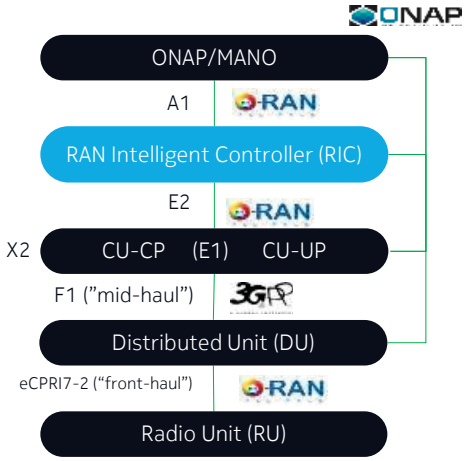
Nokia is the only major radio vendor attending the O-RAN Alliance

- Launched June 2018 by merging xRAN Forum with C-RAN Alliance
- Founded by major CSPs
- Some traditional RAN vendors are not members
- Many small HW and SW companies with limited portfolio

240+ contributors
31 operators

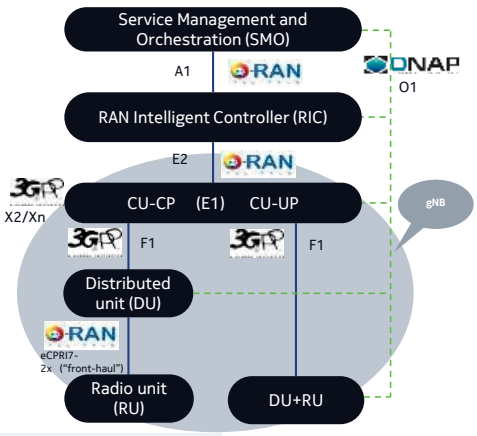


ORAN is disaggregating BTS with open interfaces and adds a new function (RIC)



O-RAN architecture

Functions and interfaces can be selected/deployed independently



F1 applicable in Cloud
- vRAN 1.0: vCU + (DU + RU)
- vRAN 2.0: vCU + vDU + RU

F1 not applicable in Classic
- AirScale BBU: CU+DU

Interface	Status in O-RAN alliance
F1	Spec not completed yet
W1	Spec not completed yet
E1	Spec not completed yet
X2	Spec (partially) available
Xn	Spec not completed yet
FH	eCPRI 7-2x spec available
E2	Spec available
A1	Spec available
O1	Spec available
O2	Spec not completed yet

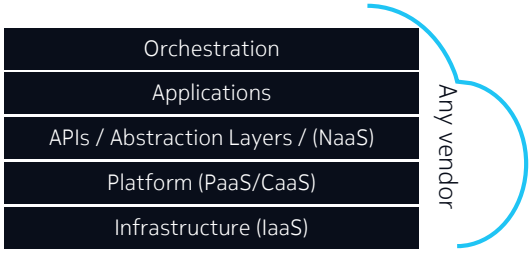
- **RAN Intelligent Controller (RIC)** is a new virtualized function which adds RAN programmability to existing or new RAN networks i.e. **SON type functions, but in near real-time.** The RIC is optional.
- **O-RAN fronthaul** facilitates **different suppliers for the RU and DU,** while optimizing both the cost of fronthaul and RF performance.
- O-RAN defines profiles for 3GPP X2/Xn interface to allow for **dual-connectivity (LTE-NR or NR-NR) between different RAN vendors.**
- O-RAN also defines profiles for the F1 between **CU and DU,** and E1 between **CU-CP and CU-UP.** However, multi-vendor can be complex due to the **tight coupling of these functions in 3GPP.**

What is the difference btw Cloud RAN and O-RAN?

O-RAN and Cloud RAN are often inter-related but different

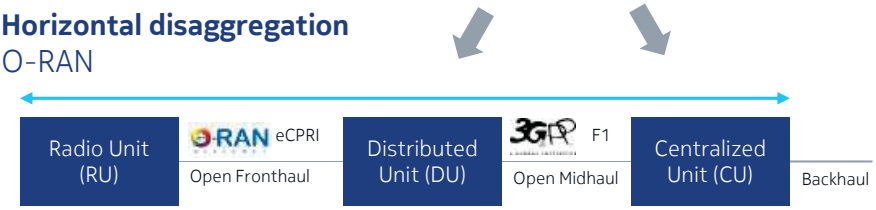
Vertical disaggregation
HW and SW separation

Cloud RAN



Cloud RAN
An option to realize baseband network element(s) with independent HW/SW solutions

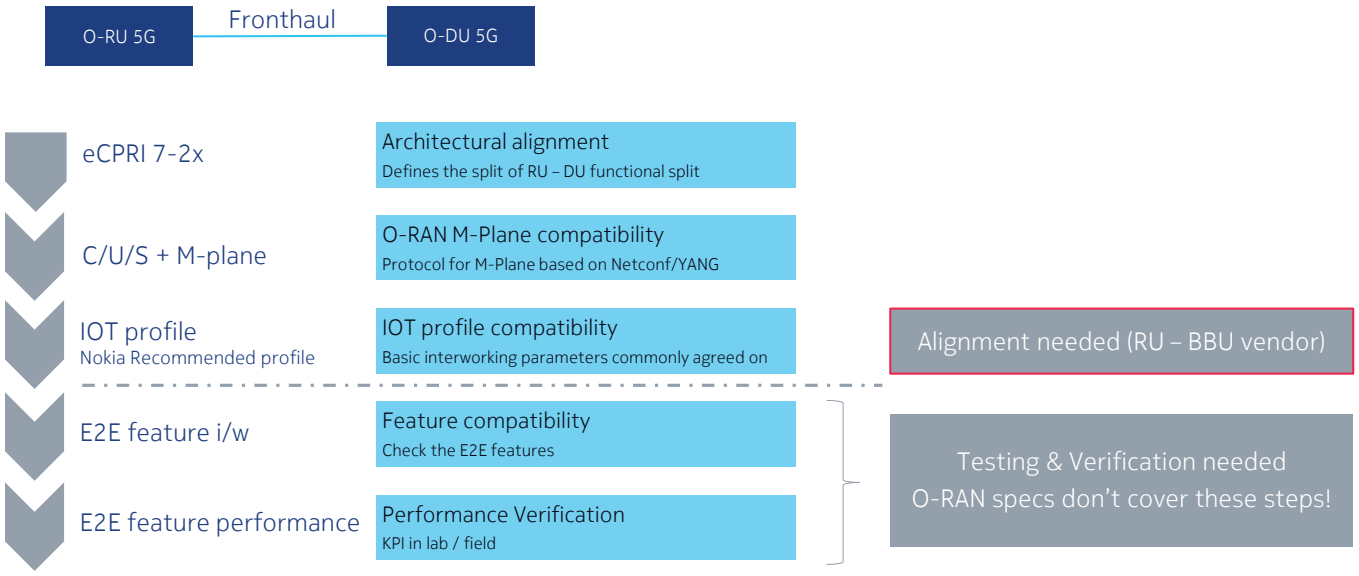
Horizontal disaggregation
O-RAN



O-RAN
an option to interconnect RAN network element(s) from different suppliers
(CU – DU split is not mandatory!)

O-RAN "compliancy" (Open FH)

Several steps towards O-RAN multi vendor interworking



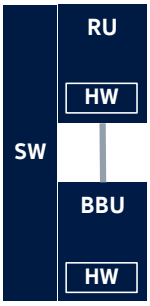
TCO promise of O-RAN

Hype or real? – Few points to be considered

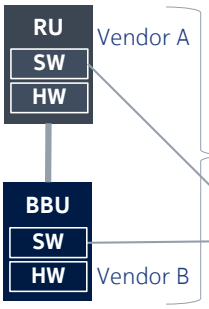
E2E / Single Vendor

TCO =
CAPEX (vendor eq.)
+ OPEX (Operator)

CAPEX:
Integrated and tested E2E System incl. HW and SW



Multi Vendor



OPEX / IMPEX:
- Integration of multiple vendors
- IOT
- Performance Test
- Recurring SW integration
- Alignment of Feature set

CAPEX:
- Feature Content

TCO =
CAPEX (Vendor A)
+ CAPEX (Vendor B)
+ IMPEX (Integrator)
+ OPEX (operational)

CAPEX:
separated per vendor, does not consider E2E System Integration

O-RAN Objective
TCO reduction

Points to be considered:
- What is included in TCO considerations? Integration, E2E TCO, …?
- Does it contain integration cost, multiple vendor management etc.?
- Is the Feature set comparable?

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Agenda

- Introduction
- O-RAN: Open Fronthaul
- O-RAN: RIC and network intelligence

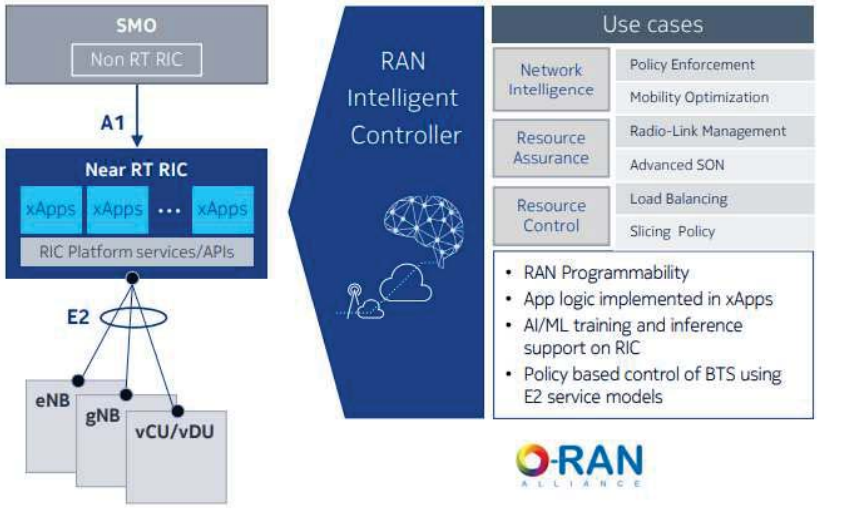
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Near real-time RAN Intelligent Controller (RIC)

O-RAN component for RAN Programmability

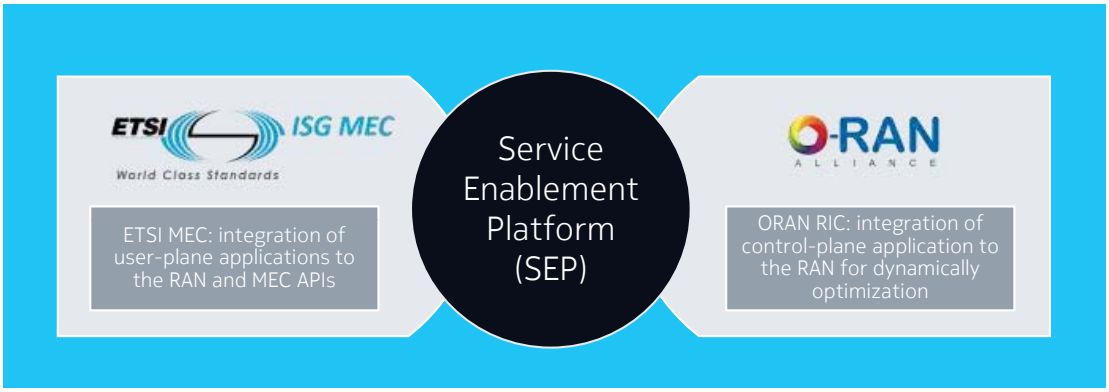
- Near RT RIC is a **control plane element** in the RAN defined in O-RAN WG3
- RIC enables **RAN Programmability** via **3rd pty** application-logic as xApps
- RIC is deployed on Edge Datacenters in mobile networks, supporting **both classical and cloudified RAN**
- **E2** exposes BTS data via RIC Platform and xApps control RAN via imperative E2 policies in a near real-time control loop
- **xApps complement native BTS logic** by implementing sophisticated, typically **AI/ML based algorithms**
- **RIC use-case range** from CSP specific RAN optimization to deployment specific customization supporting Enterprise use-cases
- RIC xApp have a **span of control** over range of BTS-es (nx100) and multiple RAN technologies (4G, 5G, Small Cell, cloud etc.)



Near real-time RIC is a new network element defined in O-RAN standardization (https://www.o-ran.org/)

Service Enablement Platform (SEP)

ETSI MEC and O-RAN RIC



ETSI MEC and O-RAN RIC
two complementary standards

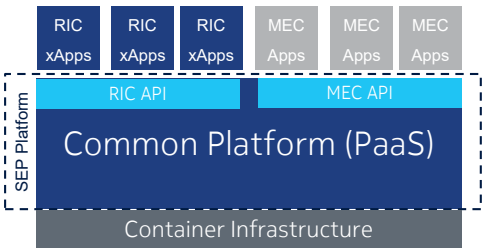
Nokia Service Enablement Platform

Enables user-plane and control-plane application at the edge

Applications at the edge	Platform for AI/ML use-cases	RAN programmability	Operator specific optimization	Service QoE differentiation

Service Enablement Platform:

- Infrastructure independent, containerized platform services
- Standard APIs for applications to interact with the RAN



Single Edge Platform for:

- MEC platform services based on ETSI MEC standard
- RIC services based on O-RAN standardized RAN Intelligence Controller
- Open platform for 3rd party Apps / xApps

Application awareness of MEC combined with RAN awareness of the RIC

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5GtoB Private Network Solution

Tamas Boday

Huawei

tamas.boday@huawei.com

Abstract

Business innovation with 5G private networking technologies - 5G not only brings better customer experience for public consumer networks, but it's revised network architecture enables creation of various private networking scenarios. Unlike legacy radiocommunication systems 5G is capable of accomodating flexible Private networking solutions from VPN, through resource allocation to entirely private networking solutions. In this presentation Huawei is explaining it's technical solutions critical implementation issues and learnings from a few real life commercial projects.

Author's biography



Tamas Boday *is Director of Integrated Solutions at Huawei. After educating in Electrical Engineering (Telecommunications major), he's got a BA in Management in Finance (Corporate strategy), and an MBA (Technology management and Innovation). He believes that bridging the gap between technology and business is a key success factor for all industry players. He specializes in IoT and Industry digitalization, and he is a guest lecturer at University of Obuda and Central European University on the above topics. His interests are ranging from application of Machine learning through Ethics of Big Data to mentoring technology startups.*

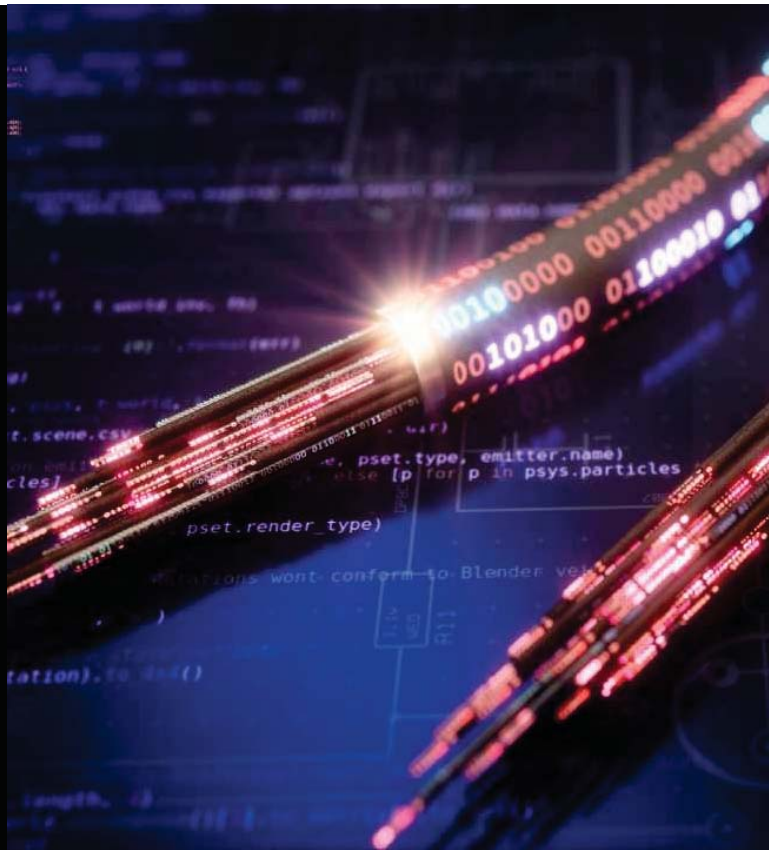
5GtoB Private Network Solution



HUAWEI

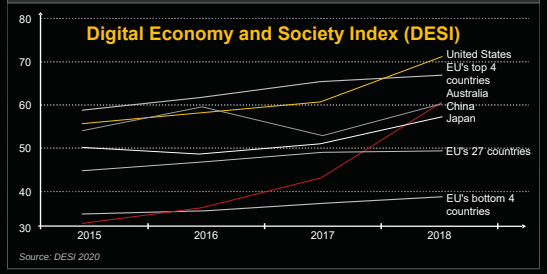
Contents

- Industry Trends
- Solutions and Cases



5GtoB Is the Best Option for Industry Digitalization

Countries Focus on Digitalization



National Strategies

Germany
Industry 4.0 to maintain a leading manufacturing industry

United States
Industrial Internet to boost industries

China
Made in China 2025 to upgrade the manufacturing industry

Industry Vision and Challenges

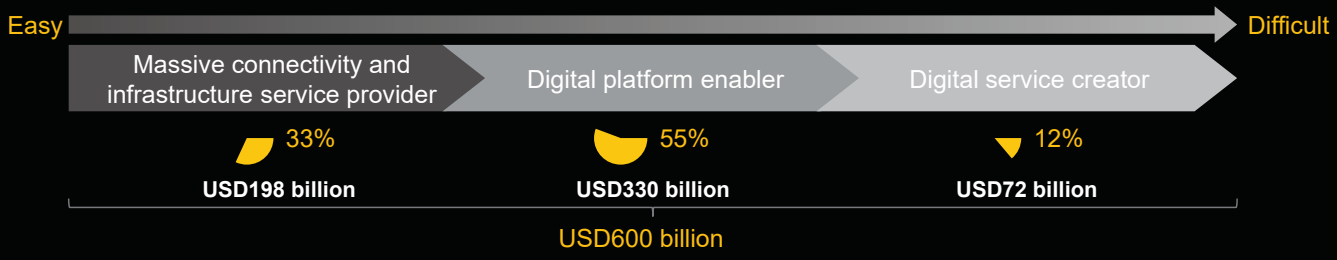
- Cost reduction: difficult deployment and high cost of the 2 million fiber nodes of China Southern Power Grid
- Efficiency improvement: manual operations still required for some processes; demands for flexible production and wireless equipment
- Digitalization: siloed system and ineffective use of data
- EHS: needs for improved working environment and reduced labor strength

5G Offers the Optimal Performance and Cost for toB Industry Private Networks

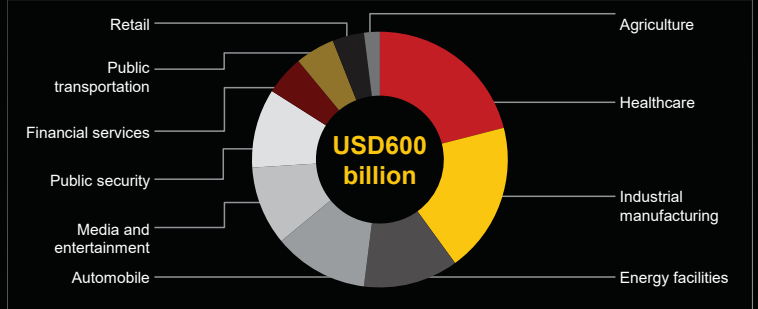
	Mobility	Stable and Low Latency	High UL Bandwidth	E2E Reliability	Security	Indoor Positioning	Cost
Fiber	●	●	●	●	●	●	●
Wi-Fi	●	●	●	●	●	●	●
3G/4G public network	●	●	●	●	●	●	●
Conventional LTE private network	●	●	●	●	●	●	●
5G	●	●	●	●	●	●	●

● Good ● Medium ● Poor

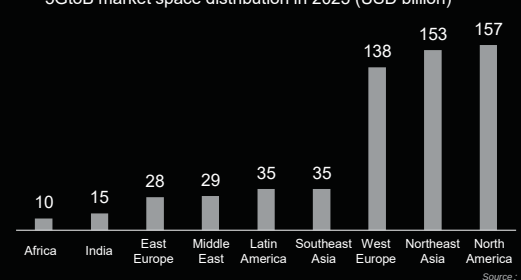
Market Space for Operators in 2025



Healthcare, manufacturing, energy, automobile, media, and security industries account for over 80% of the total market space.



Top 3 markets: Northeast Asia (China, Japan, and South Korea), West Europe, and North America



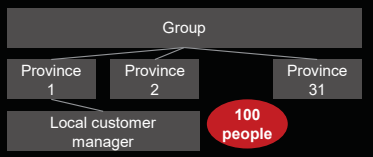
Operators' Strengths and Inherent Advantages in Expanding toB Market

5G vs. Wi-Fi: 1.7X Spectrum and 1.2X Spectral Efficiency

China Mobile : 440 MHz **Wi-Fi: 256 MHz**

Local Services and Customer Relations at City and County Levels

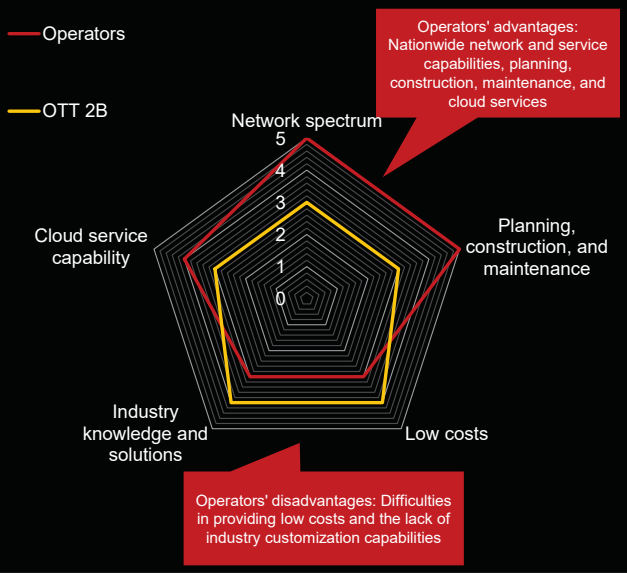




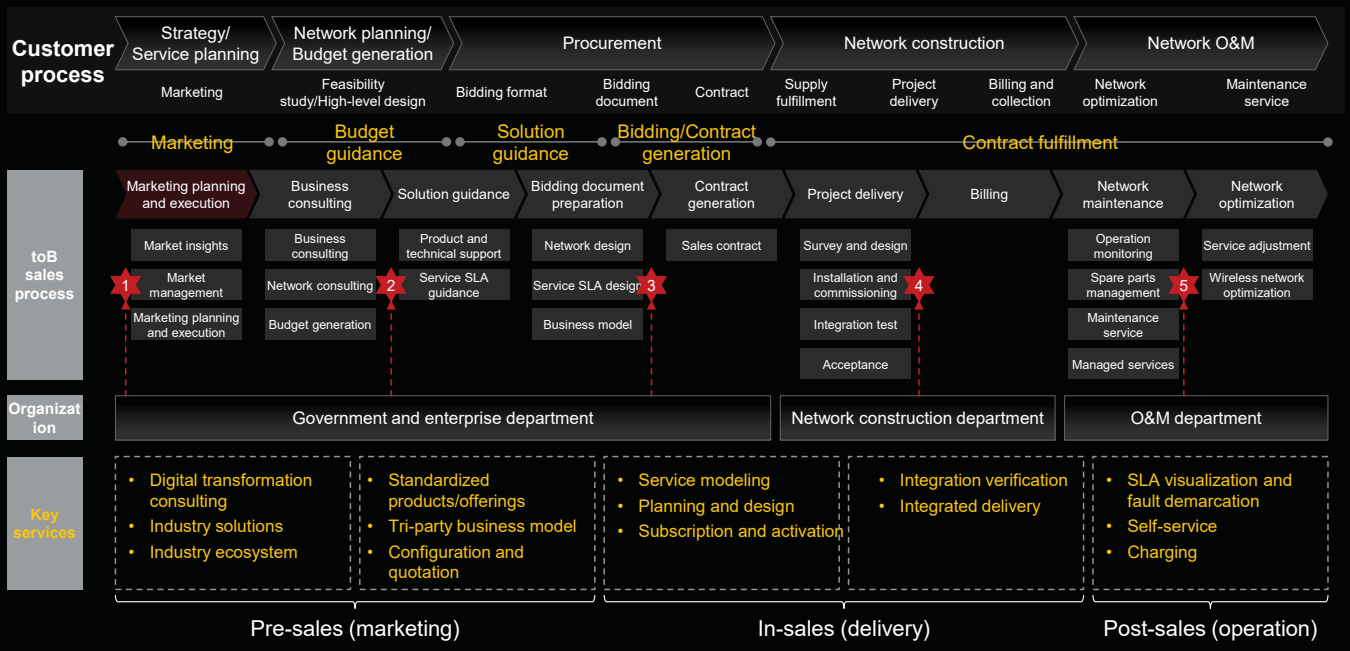
Abundant Sites and Equipment Rooms in China

Operator X: 2.1+ million		Campus
Local core equipment room	**600+**	**Campus:** Self-owned equipment room **Small and medium-sized enterprise (SME):** Insufficient capabilities in providing resources, relying on cooperation
Important aggregation equipment room	**6000+**	
Common aggregation equipment room	**> 40,000**	
Access equipment room	**100,000**	
Site equipment room	**2 million**	

toB Market Expansion Capability Matrix



Challenges Persist Despite a Large 5GtoB Market Space



Quickly Match Industry Requirements in Any Scenario

Industry	Mine	Port	Iron and steel	Electric power	Public security	Transportation	3C manufacturing	
	①④⑤⑥⑧	①④⑤⑥⑦	①②④⑤⑥	①②⑥⑦⑧	①④⑥⑦	②⑤⑥⑦	①②⑤⑥⑧	…
	B E K L M J	B D H J K L M	B D J K L M	B D K L M J	B D K L M J	B D K L M J	B C D E K L M	



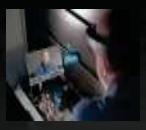
① Personnel/Device inspection
Surface inspection, positioning, identification, and measurement



② Data gathering/loading
Data collection/Software loading



③ Device and vehicle dispatching
Campus, warehousing, workshop logistics, train control and dispatching



④ AR/VR
Remote maintenance, training, and gaming



⑤ Device control
Remote control of devices in dangerous and harsh environments



⑥ HD video
Video surveillance, video conference, and live broadcast



⑦ Mobile inspection
Robot or UAV inspection



⑧ C2C control
Collaboration between multiple devices

…

Core capability	A	B	C	D	E	F	G	H	I	J	K	L	M
	Low latency 30–50 ms	Lower latency 10–30 ms	Ultra-low latency < 10 ms	High UL bandwidth 20–150 Mbps	Ultra-high UL bandwidth > 150 Mbps	Large connections Hundreds per cell	Massive connections Thousands per cell	Positioning Meter/submeter level	High-precision positioning Centimeter level	Edge computing LBO/MEC	5G LAN L2/L3 communications	High reliability Backup routes	Slice

Private network	5G base station	Network	Cloud core	PCMO	Operation

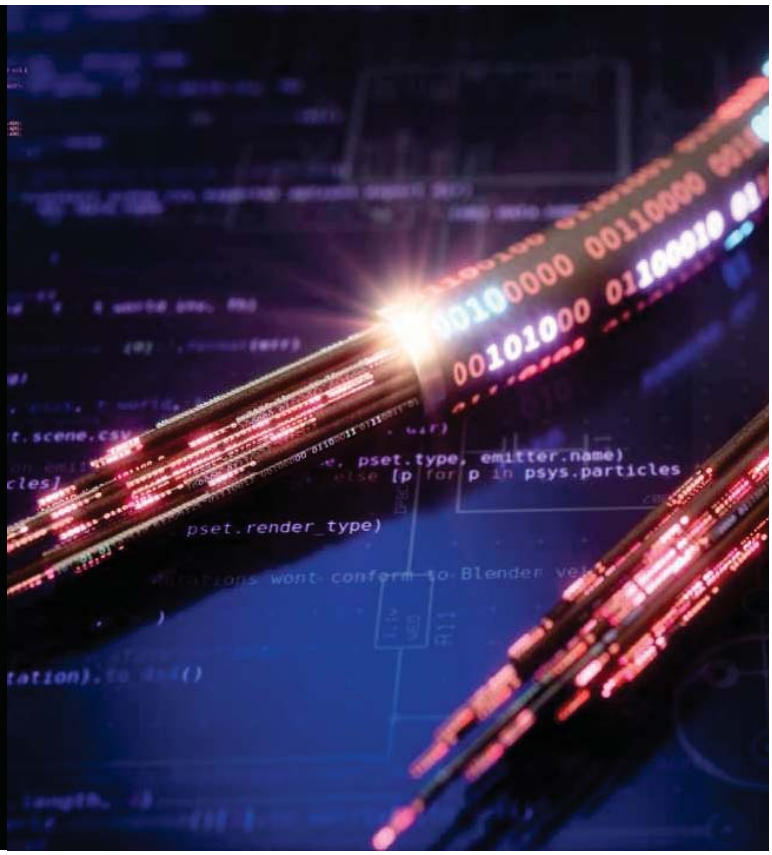
Building 5G private networks to meet differentiated requirements of various industries

China's Three Major Operators Launch 5GtoB Products and Offerings

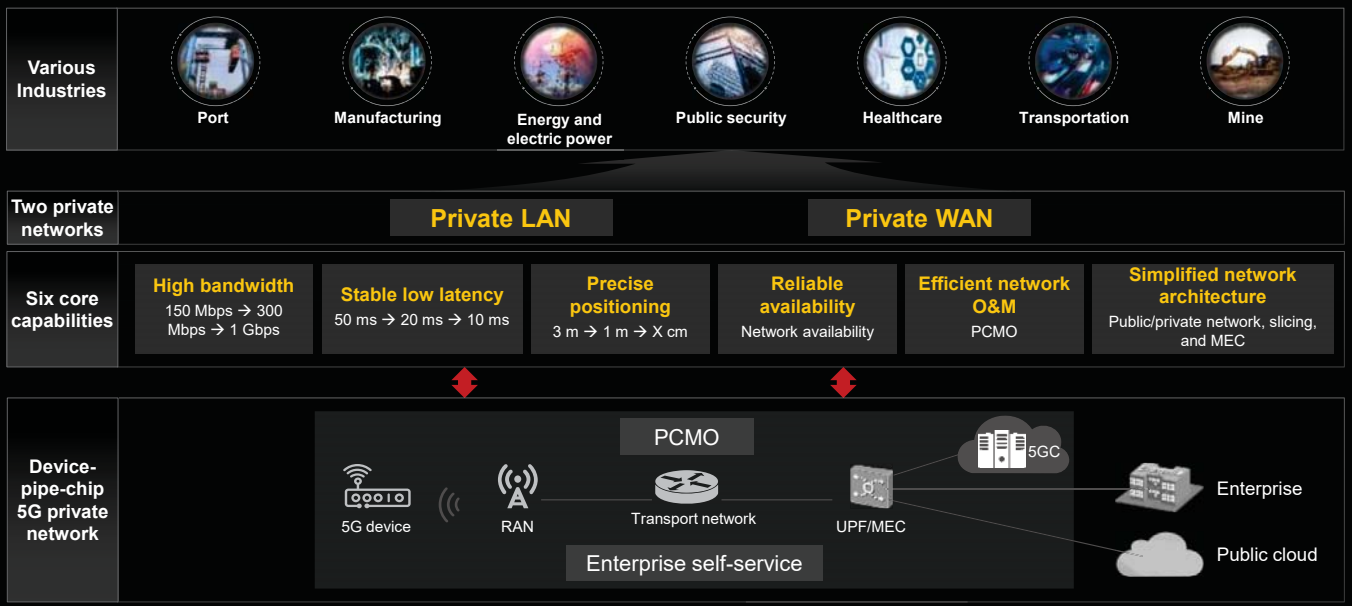
		Overview of Private Network Products and Offerings		
中国移动 China Mobile	July 22 Release and Promotion	**B1: Public network** Industry traffic card	**B2: Public network for private use** Resource reservation in LAN scenarios	**B3: Private network for private use** Private LAN scenarios
		A1 to A7: Network features Service acceleration | Service isolation | Local service assurance | Data protection and more	**A8 to A11: Specialized services** Network design | Network optimization | Network O&M | Key service assurance and more	
		F: Premium	**F: Dedicated**	**F: Exclusive**
China unicom 中国联通	August 18 Release and pilot	**5G VPN** Public network + slicing	**5G hybrid private network** 5G private networks with some exclusive resources, locally deploying MEC on campuses	**5G independent private network** E2E construction of a private network completely isolated from the public network
中国电信 CHINA TELECOM	November 7 E-Surfing Expo	**Standard customization** Use the 5G public network to provide preferential resources and differentiated service experience for customized network customers through virtual sharing.	**Scenario customization** Use the 5G public network and LAN customization (slicing and data processing within the campus) to preferentially meet the service requirements of customized network customers, dynamically share the remaining resources with 5G public network users, and support edge-cloud synergy.	**Service customization** Customize E2E resources for the entire 5G network based on customer service requirements, perform construction and O&M based on deterministic SLA indicators, and support edge-cloud synergy.

目录

- Industry Trends
- Solutions and Cases
  - 5G Private LAN Solution
  - 5G Private WAN Solution
  - Common Capabilities

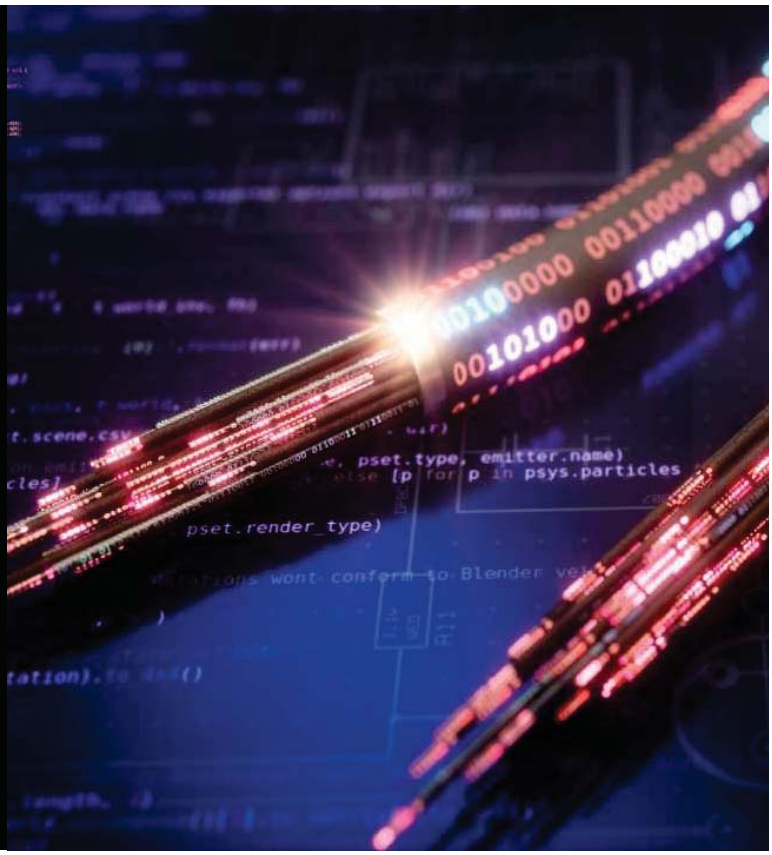


Two Private Networks and Six Core Capabilities Accelerate 5G for Enabling Various Industries

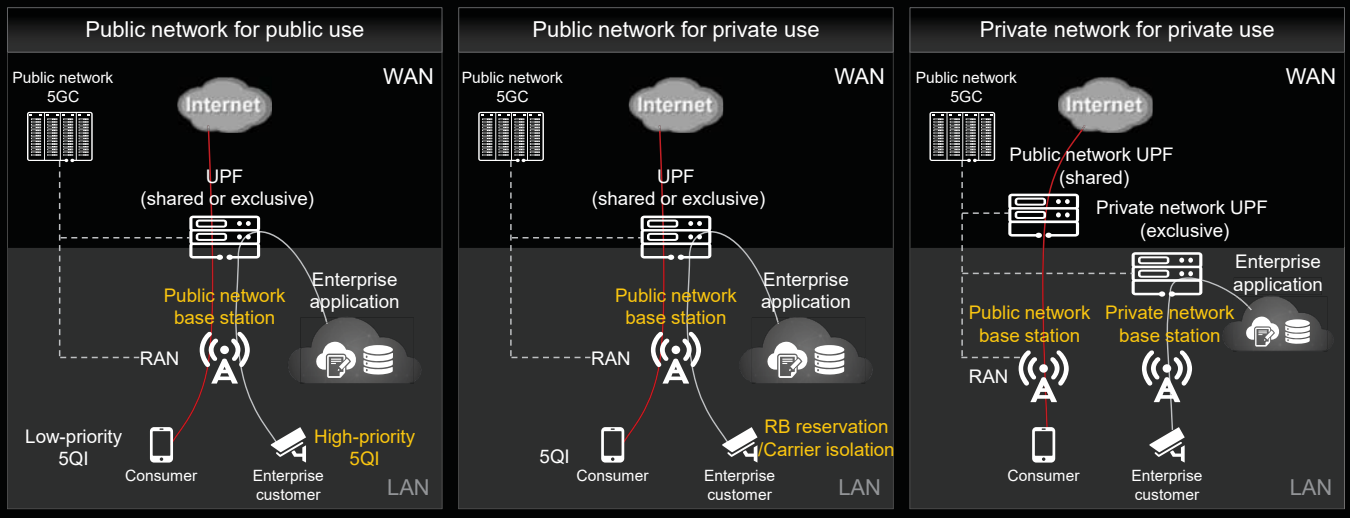


目录

- Industry Trends
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  - 5G Private WAN Solution
  - Common Capabilities



Three Deployment Modes for Private LAN Based on Different RANs



- RAN: shared base stations with 5QI-based service priorities
- Core network: shared 5GC, shared or exclusive UPF
- Transport network: shared
- Typical industries: education, healthcare, and government

- RAN: shared base stations with dedicated RBs/carriers for hard isolation of resources
- Core network: shared 5GC, shared or exclusive UPF
- Transport network: shared, with FlexE isolation
- Typical industries: electric power (substation), steel, coal mine, and 3C manufacturing

- RAN: dedicated base stations for hard isolation of devices
- Core network: shared 5GC and dedicated UPF
- Transport network: shared, with FlexE isolation
- Typical industries: steel, coal mine, and 3C manufacturing

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

UL Capacity Solution for All Scenarios

Outdoor

- Networking: macro AAU in back-to-back mode
- AAU density: 3 AAUs/km2
- Capability: 9 Mbps/10,000 m2

1X

- Macro site densification: 15 AAUs/10,000 m2 with 5X capacity
- Pole site deployment: 20 pole sites added with 2X capacity
- Capability: 7X capacity

7X

- Networking: 1 RRU and multiple cascaded DAS
- Coverage area: 4000 m2
- Macro RRU density: 1 RRU for 3 to 4 floors
- Capability: 250 Mbps/10,000 m2

1X

- RRU cell splitting: 1 cell → 2 cells
- Capability: 2X capacity

2X

Indoor

- Model: pRRU 4 x 250 mW
- headend spacing: 40 m pRRU spacing
- Headend density: 6 pRRUs/10,000 m2
- Capability: 360 Mbps/10,000 m2

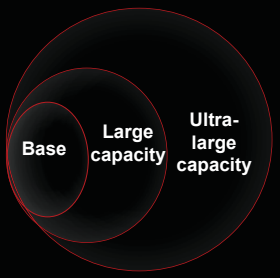
1X

- Headend density: 20 m headend spacing (1.5X capacity)
- Distributed MIMO: 3X capacity
- Cell splitting: 2X capacity
- Capability: 9X capacity

9X

- Ultra-dense headend: 10 m headend spacing (1.5X capacity)
- Anti-interference feature: 1.3X capacity
- Engineering solution: external directional antenna and hood, 1.3X capacity
- Capability: 2.5X capacity

22X



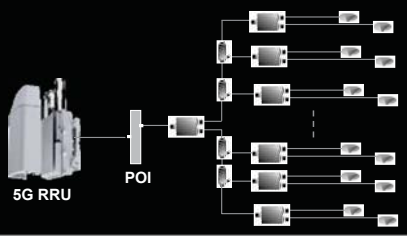
Basic capacity: < 0.4 Gbps/10,000 m2 → **Large capacity: < 10X** → **Ultra-large capacity: 10–30X**

This analysis uses the example of uplink capability based on 100 MHz and 8:2 UL-DL subframe configuration. If there are additionally available spectrums, spectrum overlapping (capacity multiplication) is preferred.

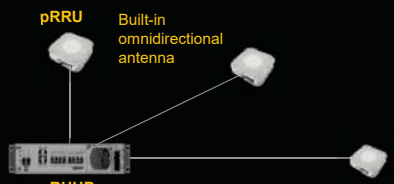
Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Basic Capacity for Indoor Open Spaces

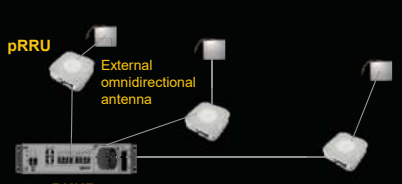
Solution 1: Sharing Public-Network RRUs + DAS



Solution 2: Sharing Public Indoor Networks



Solution 3: Private Indoor Networks



Scenario 1: Apartment, Office, and Residential Buildings

- **Macro RRU: 1 RRU for 3 to 4 floors and cascaded DAS**
- RRU deployment: 3 m height and 30–40 m headend spacing
- Coverage: 1000+ m2 for each floor, a total of around 4000 m2
- Public network for public use: **20–50%** of network resources for toB, and the rest for toC
- Experience assurance: 5+ Mbps UL edge service rate for toB

Scenario 2: Areas with Both Private and Public Networks (Hospitals/Schools)

- Ceiling height: around 3–5 m (typical: 3 m)
- pRRU density: 30–50 m pRRU spacing (typical: 40 m)
- **Built-in omnidirectional antenna: 3–5 dBi antenna gain (typical: 3 dBi)**
- Public network for public use: **20–50%** of network resources for toB, and the rest for toC
- Experience: **10+ Mbps** UL edge service rate for toB

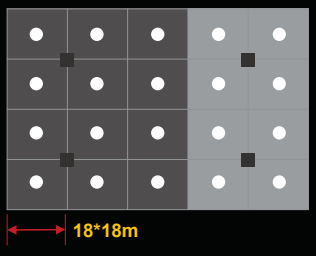
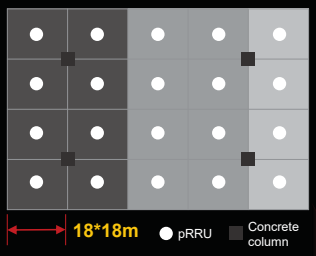
Scenario 3: Factories, Manufacturing, and Logistics Campuses

- Ceiling height: around 8–15 m (typical: 12 m)
- pRRU density: 50–80 m pRRU spacing (typical: 60 m)
- **External directional antenna: 10 dBi gain, 65° beamwidth**
- Exclusive private networks: **90%+** of network resources for toB
- Experience assurance: **20+ Mbps** UL edge service rate for toB

Overall capacity density < 0.4 Gbps/10,000 m2

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Large Capacity for Indoor Areas with High Capacity Density

	China Region (spectrum prioritized)	Regions outside China (features prioritized)
Scenario Example	 18*18m	 18*18m ● pRRU ■ Concrete column
Service Deployment	• Machine vision: 2–4K for quality inspection • Speed: 20–30 Mbps • Interference control: 12 pRRUs in one cell • Solution: anti-interference and UL multipath enhancement	• Machine vision: 2–4K quality inspection • Speed: 20–30 Mbps • Interference control: 8 pRRUs in one cell • Cell capacity: subframe configuration, distributed MIMO, and densification
Scenario Adaptation	• Scenario: standard workshops/production lines • Indoor coverage: high density, with the priority to eliminate strong interference • pRRU density: 20–30 m headend spacing • Capacity density: < 10X capacity	• Scenario: standard workshops/production lines • Indoor coverage: high density, with the priority to eliminate strong interference • pRRU density: 20–30 m headend spacing • Capacity density: < 10X capacity

Large Capacity

Scenario	• Capacity density: < 10X basic capacity density • Recommendation: standard workshops/production lines
Spectrum	• Three tier-1 operators in China region: around 300 MHz* • Regions outside China: around 100 MHz
Feature	• China region: spectrum overlay • Regions outside China: subframe configuration**, distributed MIMO, and anti-interference
Engineering	• Interference optimization: CoMP and SFR • Features: IRC and link direction

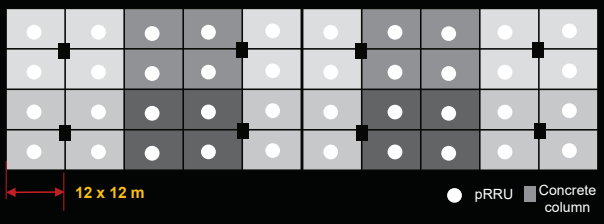
* Note: around 300 MHz for China Mobile (2.6/4.9/2.3 GHz) and around 300 MHz for China Unicom (3.4–3.7 GHz)

** Note: The 1:3 subframe configuration can be considered for pRRUs in 2.6/4.9/3.5 GHz.

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Ultra-Large Capacity for Narrow Indoor Spaces with Ultra-Large Capacity Density

High-precision inspection workshops/production lines

Scenario Example	 12 x 12 m ● pRRU ■ Concrete column
Service Deployment	• **Machine vision: 8K quality inspection/3D VR** • **Experience demand: 40+ Mbps (100+ Mbps for some services)** • **Interference control: 4–6 pRRUs in a cell (headend densification for evolution)** • **Densification/cell splitting (horizontal) + spectrum overlay/feature combination (vertical)**
Scenario Adaptation	• Scenario: narrow and enclosed indoor areas, such as high-precision inspection workshops and production lines • **Indoor coverage: high density, with the priority to eliminate strong interference and ensure edge experience** • **pRRU density: 12–15 m headend spacing (6–10 m spacing for evolution)** • **Capacity density: 10–30X basic capacity density (over 30X in some scenarios)**

Ultra-large Capacity

Scenario	• **Capacity density: 10–30X basic** • **Recommendation: high-precision inspection workshops/production lines**
Spectrum	• **Three tier-1 operators in China region: around 300 MHz*** • **Regions outside China: Sub-3 GHz and C-band**
Feature	• **Horizontal: headend densification/cell splitting** • **Vertical: spectrum overlay/feature combination**
Engineering	• **Software: 2:3 subframe configuration and distributed MIMO** • **Engineering: IRC and link direction**

* Note: around 300 MHz for China Mobile (2.6/4.9/2.3 GHz) and around 300 MHz for China Unicom (3.4–3.7 GHz)

Multi-Fold Capacity Increase with Innovative Solutions

Super Uplink: 270 Mbps* Increase

Sub-3 GHz enables uplink data transmission in all timeslots



2.6G	D	D	D	D	D	D	D	S	U	U
1.8G /2.3G	U		U		U		U			

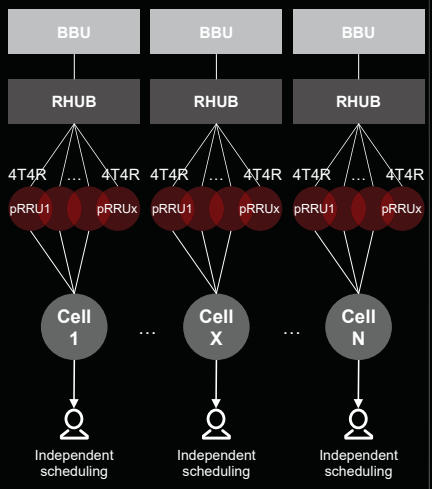
Increased uplink capacity

- 2.6 GHz + 1.8 GHz (25 MHz): 90 Mbps uplink increase
- 2.6 GHz + 2.3 GHz (50 MHz): 180 Mbps uplink increase

* Taking China Mobile as the example.

Multi-pRRUs for Distributed MIMO: 3–4X Better

Multiple pRRUs in one cell simulate distributed MIMO



Multi-user pairing: SDMA pairing -> small-scale pairing

2:3 Special Subframe Configuration: 2–3X Increase

2:3 subframe configuration for enclosed scenarios with controllable configuration inconsistency



Private Network Capacity Closely Related to Planning, Design, and Engineering Deployment



Experience assurance for more 5GtoB private LANs and WANs

Product Selection

- Spectrum range
- Carrier aggregation
- Special subframe configuration
- Massive MIMO/Distributed MIMO
- Power range

Network Planning

- Staggering frequency/Inter-frequency
- Multi-band aggregation/Capacity redundancy
- Service frequency division/Slice camping
- Multi-module cell
- Water surface model calibration/Interference reduction

Software Features

- HCell feature/Soft handover
- Adaptive power/downtilt
- Public/private network adaptation
- Frequency/Cell lock
- IRC/MRC

Engineering Deployment

- RAN link directional coverage
- External antenna for UE air interface
- Precise coverage of module covers
- Obstacle/Working surface interference reduction
- Overshoot coverage control

Devices, Base Stations, Transport Network, and Core Network All Support On-Demand Improvement to Network Availability

High Network Availability Requires Cooperation Among Devices, Base Stations, Transport Network, and Core Network

5G device — Dual links

5G base station — Redundancy backup

5G transport network — Ring networking

5G core network — Kite solution and load sharing

Device Redundancy Backup

Two working modes

Dual fed and selective receiving: 0 ms switching and zero packet loss

1+1 backup: link switchover within 100 ms

Three connection modes

① AR — 5G RU, 5G RU

② AR — 5G CPE, 5G CPE

③ AR — 5G card, 5G card

All three connection modes offer the same level of reliability, and can be flexibly selected based on availability.

Base Station Redundancy Backup

① A/B network inter-frequency active-active (micro/macro): BBU-1, BBU-2; Radio, Radio, Radio, Radio

② Intra-frequency active/standby (macro): Main control board, Main control board, Power supply, Power supply, Fan, BBP, BBP; Radio, Radio

③ Intra-frequency active-active (micro): Main control board, Main control board, Power supply, Power supply, Fan, BBP, BBP; RHUB, RHUB'

Version 22A/B plans to support solution 2 (RF backup) and solution 3 (baseband backup).

Core Network Redundancy Backup

Kite solution

5GC (public network): PCF, UDM, AMF, SMF — Centralized O&M system — Operator

Control-plane public network and local disaster recovery — Enterprise

UEG+: Lite AMF, Lite SMF, Local UDM, UPF (Emergency module) — UE

MEC Load sharing

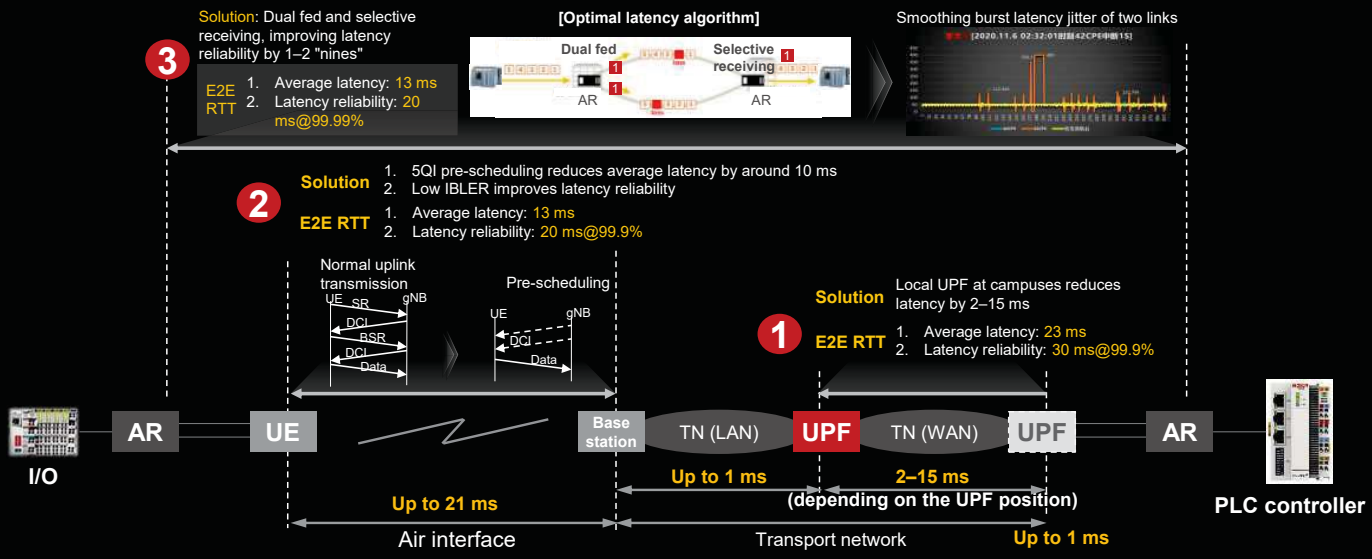
BBU — MEC1, MEC2

Build Standard Availability Solutions for Private LAN Based on NE Redundancy Rate

	Basic Availability > 99.9%	High Availability > 99.99%	Ultra-High Availability Approx. 99.998%
5GC	• Public network control plane pooling	• Public network control plane pooling	• Public network control plane pooling **+ Kite solution**
MEC (UPF + Lite AMF /SMF/UDM)	• **MEC load sharing**	• MEC load sharing	• MEC load sharing
Transport network	• **Ring networking**	• Ring networking	• Ring networking
Base station	• Single-mode base station (macro or micro)	• **Intra-frequency active/standby (macro) or intra-frequency active-active (micro)**	• **A/B network inter-frequency active-active (macro/micro)** or intra-frequency active/standby (macro) or intra-frequency active-active (micro)
CPE / AR	• No redundancy for devices	• **Dual fed and selective receiving or 1+1 backup**	• Dual fed and selective receiving or 1+1 backup

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

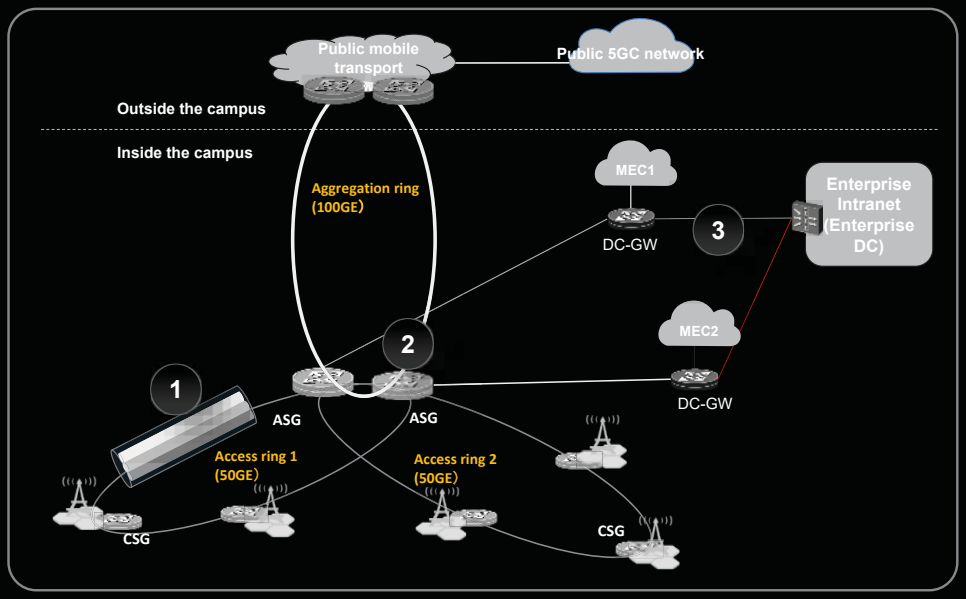
Stable Low Latency Solution: Local UPF, Pre-scheduling Air Interface Optimization, and Dual Fed and Selective Receiving



Requirements for E2E RTT of low-latency services at or near the cell center: RSRP > –85 dBm, SINR > 10 dB, and the number of low-latency UEs ≤ 5

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Ring Networking and Hot Standby Support Different Sizes of Campuses, Facilitating the High Availability of Transport Networks

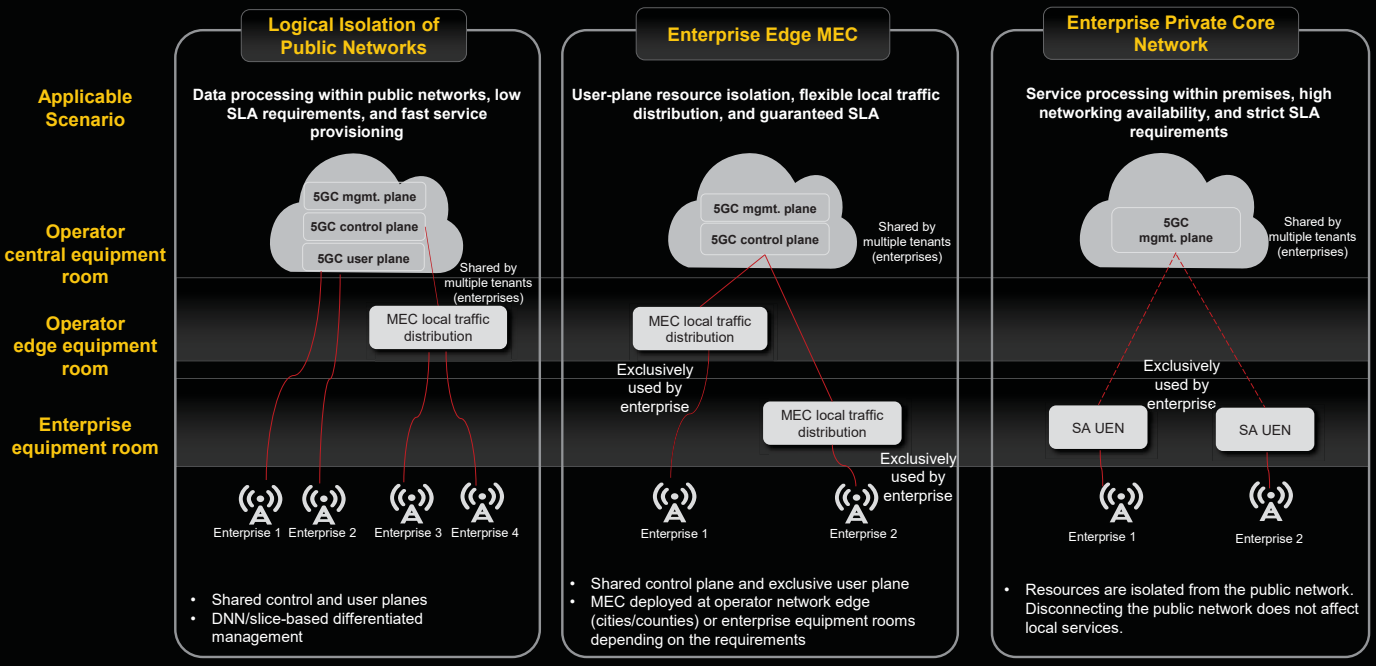


Key points for transport networking

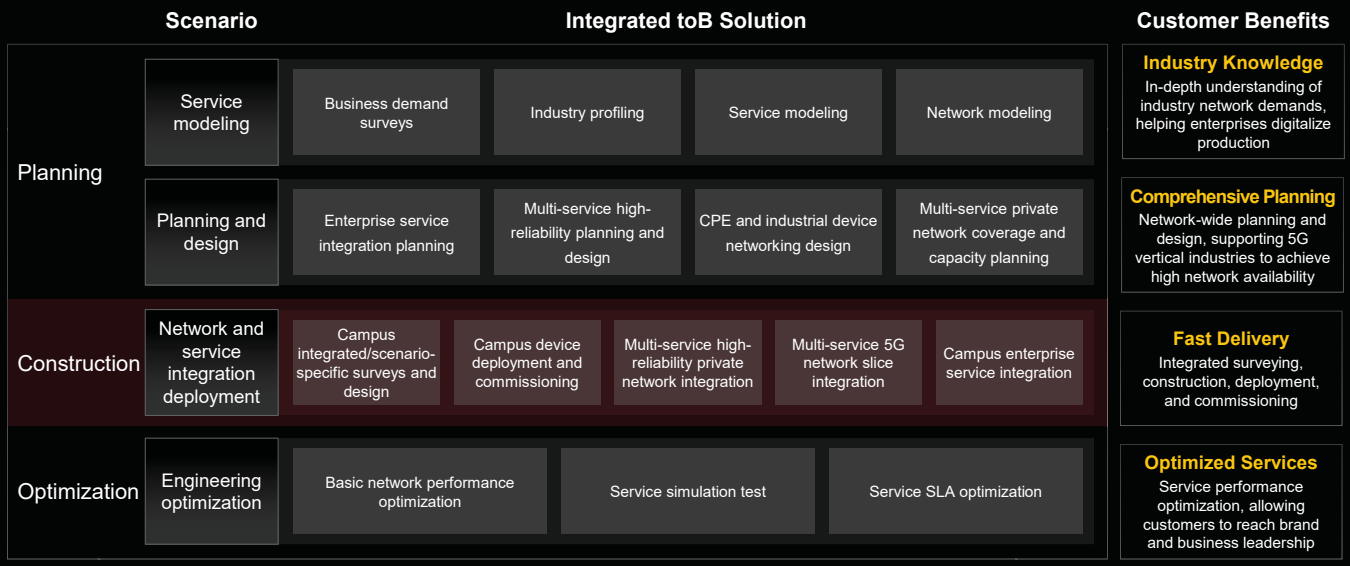
1. **Cell site gateway (CSG) carries base stations**
   Connects to 5G base stations, with on-demand FlexE hard slicing
2. **Aggregation site gateway (ASG) to interconnects public networks**
   ASG interconnects CSG and public 5GC networks
3. **DC-GW interconnects** enterprise intranet
   Carries MEC server networking and streamlines enterprise intranet

(Note: The CSG and ASG can be integrated based on the campus size.)

Typical Networking Scenarios of Core Networks, Meeting Various Enterprise Requirements



Turnkey Integrated Solution Makes the Delivery of Private Networks More Efficient



Turnkey: One solution, survey, design, installation, and optimization, making delivery more efficient

All-in-One PCMO Tool Platform Enables Operators to Build SLA Batch Delivery Capabilities

Planning

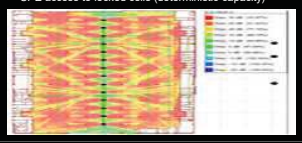
Intelligent and Accurate Planning

Precise connection-level planning (SLA breakdown and planning, cross-domain coordinated planning and simulation)

- Service- and connection-oriented cross-domain multi-RAT comprehensive planning
- Multi-scenario complex environment planning and network simulation

The combination of six key technologies supports ultra-large capacity in complex wireless environments

- 2.6/4.9 GHz networking (interference reduction)
- Back-on-back AAUs (coverage control)
- Directional ant./Ant. radome of CPEs (coverage control)
- 8-layer uplink of UEs (capacity increase)
- Pendulum design of CPEs (coverage control and interference reduction)
- CPE access to locked cells (deterministic capacity)



Construction

Integrated Construction

Test tool building based on integrated surveying and design, enabling pre-integrated fast delivery

- Smart Industry Link streamlined surveying, construction, integration, deployment, and commissioning
- High reliability, pre-integration, fast delivery, and visible and manageable progress

Integrated surveying, design, simulation, and verification

toB service test tools: simulation tools (simulated PLC and video services) and single- and multi-connection service test solutions for connection-level indicators
Integrated planning and construction delivery: one team to complete site surveying for multiple products at a time; multi-domain coordination for site solutions design and testing



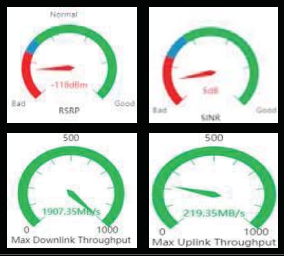
Maintenance

E2E SLA Visualization

E2E multi-dimensional SLA visualization
Fault locating and demarcation in minutes

- Service-/slice-/network-level E2E SLA visualization and management
- Real-time performance alarm reporting for fault locating and demarcation in minutes

Multi-dimensional SLA visualization and management



Optimization

Device-Network Proactive Maintenance and Optimization

E2E network performance optimization: solutions for latency, rate, and connection-level signaling

- Visualized solution for the optimization of connection-level rate and latency
- Lightweight network scrambling tool and E2E network availability test; and AI-based proactive fault prevention

AI-based proactive prediction and prevention of abnormal KPIs

NOE/MAE

Suggestions on hardware fault rectification	Hardware fault RCA	Expert experience + ML/AI
Suggestions on parameter modification	Air interface quality RCA	Big data analytics

Configuration Restoration command

Real-time dotting report

CHR, LWM2M

Smart Industry Link: toB Campus Network Integrated Operation Tool Enables Operators, SIs, and O&M Service Partners to Implement Fast Network Construction and Efficient O&M

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Campus Self-Management Platform Enables Visualized, Manageable, and Controllable Service SLA

One-Stop Self-Service

Enterprise Personnel Portal

Operator Onsite Personnel Portal

Self-Service

- Order fulfillment status query
- SIM card management
- New subscription (slice/private line/SIM card)

Service Management

- Interconnection with operator's fault reporting system
- Operator change notification and approval

Reports

- Monthly running report
- Service report

Campus Network Topology

- Campus E2E topology visualization
- Service resources (slice/private line)
- Operator network resources
- Campus 5G device resources
- Campus independently owned network resources

SLA Monitoring Management

- Visualized SLA monitoring view
- Service SLA
- Service SLA (slice/private line)
- Network KPI
- Device experience monitoring

Troubleshooting

- Interruption
- Poor QoE due to rate
- Poor QoE due to latency
- Closed-loop assurance

SIM card management API | Resource API | Performance data API | Alarm and event reporting API | APP LCM API | IaaS provisioning management API | AAA configuration management API

BOSS/PCF/UDM | Management plane (MAE-CN) | MEAO | 5G LAN AAA

Customer Benefits

Self-Service and Self-O&M

Management: self-service requirements of enterprise users, such as self-operation, self-maintenance, and device management

Premium Services

Visualization: monitoring of 4+ types of service SLAs (video backhaul/PLC remote control/prediction and prevention/AI quality inspection)

Intelligence and Automation

Control: service fault detection in minutes
Fault detection: < 1 min
Fault demarcation: < 30 mins

Security Compliance

Security: local tool deployment and security isolation to meet enterprise requirements on information security (data processing within premises)

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Automated and Intelligent O&M Services to Achieve Service SLA Targets (Management Service Scenarios Outside China)

ISOAP-based O&M Value Stream to Guarantee E2E SLA of 5GtoB Private Networks

Offerings

- Basic Network O&M
- Onsite Infrastructure
- Onsite Infrastructure
- Applications: Video surveillance | PLC control | SME private line | Machine vision | … | Device positioning

Mgmt. services

- **Orchestration**
  - Design: Slice template design
  - Provisioning: Slicing instance provisioning | Slicing service provisioning
- **Availability**
  - Preventive maintenance Management: Predictive maintenance | Preventive maintenance
  - Fault management: Alarm monitoring | Troubleshooting
  - Performance mgmt.: Performance monitoring | Performance exception handling
  - Issue management
- **Presentation**
  - Maintenance reporting: O&M quality reports | Network quality reports
  - Operation reporting: Tenant usage reports | Slicing quality reports
- **Safety & Security**: BCM | Network security | O&M security
- **Infrastructure**: Resources | Assets | Capacity expansion/upgrades

Platform capabilities

- Centralized delivery platform GNOC/RNOC/LNOC
- Automatic and intelligent tool platform SOC/AUTIN/NSMF+ (N+) /CME (M+)

Customer Benefits

Various O&M Scenarios
- Campus private networks, toB private lines, and more
- Video surveillance, PLC control, and more

O&M Value Stream Implementation
- Advanced ISOAP value stream
- Efficient O&M helps operators gain benefits for industry customers

Centralized O&M Platform
- Mature centralized delivery platform
- Automatic and intelligent tool platform

Scenario-specific toB Digital Maintenance
- Unattended warehouse, spare parts e-site
- Remote expert support for toB maintenance and proactive services

Architecture | High Bandwidth | High Availability | Stable Latency | Transport Network Deployment | Cloud Core Deployment | *PCMO | Business Model

Five Products and Four Business Models of Private LAN

Planning		Basic network		O&M		Value-added services		SIM card	
Item	Dimension	Item	Dimension	Item	Dimension	Item	Dimension	Item	Dimension
Service modeling	Service	Equipment	NE	Fault recovery 8/4/2H	NE	Self-service	License	Card fee	Card
Planning & design	km^2	UL capabilities	Mbps	Routine inspection	NE	Positioning	Connection	eSIM fee	eSIM
Optimization	Connection	DL capabilities	Mbps	SLA assurance	Connection	Security	Service		
Other		Other		Other		Other			

Five products and four business models

Resource buy-out (resale)

Network transferred to customers: no opportunity for potential revenues

Independent private networks for mining enterprises (e.g., Shanxi Coking Coal Group)

Not recommended

ICT integrated lease

Project-specific flexible quotation

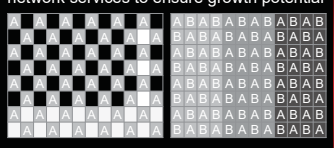
5G	
Quotation Item	Dimension
Main wireless equipment	NE
Main transport equipment	NE
Fiber (base station)	m
Miscellaneous	Length

Edge computing	
Quotation Item	Dimension
MEC	NE
Network design	NE
System integration	NE
Network O&M	NE

Now

Graded network services

New dimensions embedded for graded network services to ensure growth potential



90/180/360 Mbps/purchased area

1080 Mbps/purchased area

Future

Revenue sharing

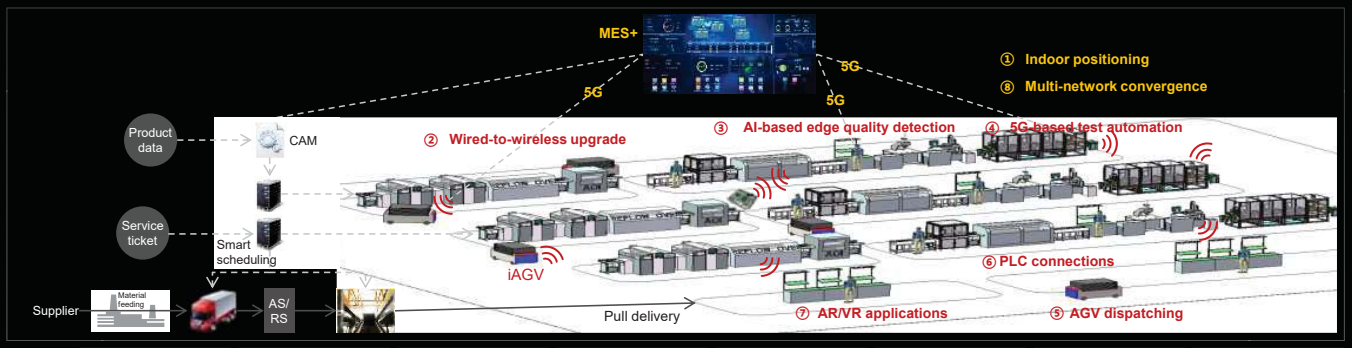
Huge initial investment, very volatile revenue

Revenue sharing units
Example: Share 35% of revenues from self-driving tickets in the Yanoda Tourism Zona project.

Exploring

Network capabilities, value-added features and functions, and graded network services for continuous revenue growth

Huawei Campus T: Project Overview and Core Requirements



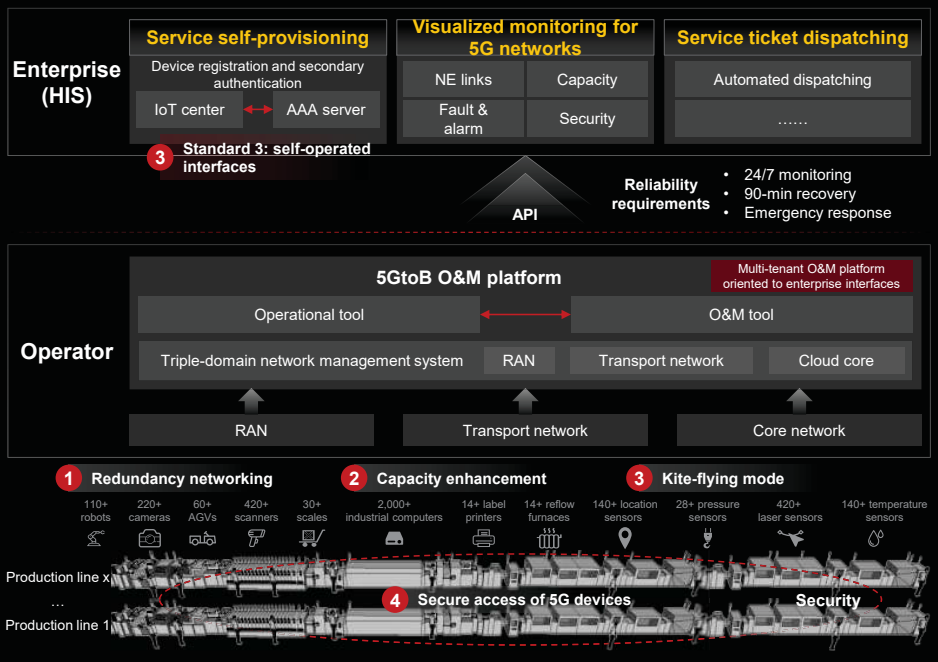
Application scenarios

Indoor positioning	Wired-to-wireless upgrade	Test automation	PLC connections	Multi-network convergence	AR/VR applications	AI-based edge quality inspection	Smart logistics
• Asset auditing • Resource scheduling • Visualized material management • Staff heat map	• Flexible manufacturing • 5G LAN • Commonality, automation, wireless connections	• Automated aging • Automated OS loading • Automated loading test	• PLC control • PLC collaboration • PLC on cloud	• Wired • Wi-Fi • UWB • Others	• Remote guidance • Online repair • Factory visit & acceptance	• Print defect • Material defect • Assembly defect • Package defect	• AGV dispatching • Logistics dispatching • 5G-based autonomous driving

Core requirements

- **High bandwidth**: UL: 13 Gbps, DL: 3.5 Gbps
- **Positioning**: Sub-meter level
- **High availability**: 99.99%
- **Security**: Isolation, Secondary authentication
- **Self-service**: Local portal, Card issuing

Huawei Campus T: E2E Private Networks for Manufacturing



E2E high availability networking

- Above RHUB: active/standby and pooling for redundancy
- Below RHUB: fewer pRRUs configured for an RHUB, discrete cross-connection for pRRUs
- Air interface: 2.6 GHz + 4.9 GHz AB dual-net design

High-density high uplink to enhance capacity

- High density (12 m/pRRU, distributed MIMO, directional antennas)
- Different subframe configurations: 2:8 (2.6 GHz, 160 MHz) + 3:1 (4.9 GHz, 100 MHz), cell splitting (2 to 24), frequency-staggered networking

5GC Edge (kite-flying mode)

- Service continuity upon mobile network signaling interruption, and on-premises data processing

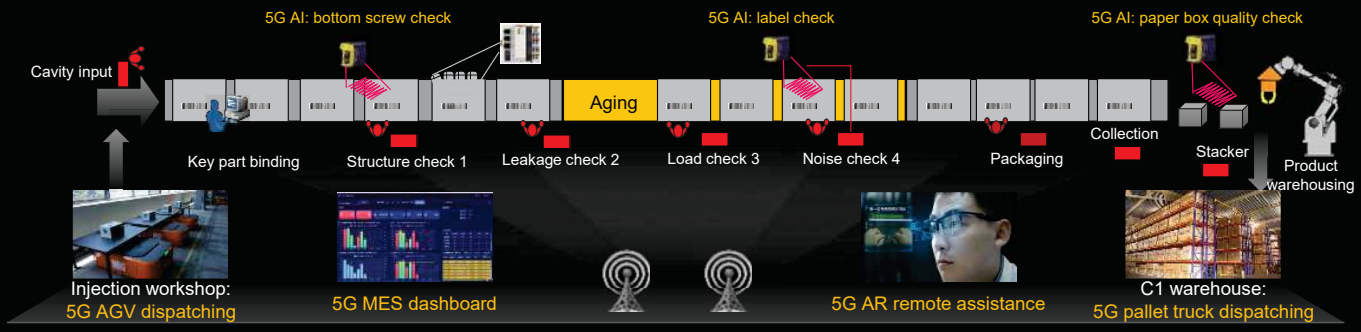
Secondary authentication for 5G devices

- Secure access to ensure trustworthiness

Plans for 2021: testing 2:3 uplink-downlink subframe configuration on the 4.9 GHz band, 5G LAN, 5G indoor high-precision positioning, and more

Midea: Project Overview and Core Requirements

Microwave oven production procedures from cavity input to finished product warehousing



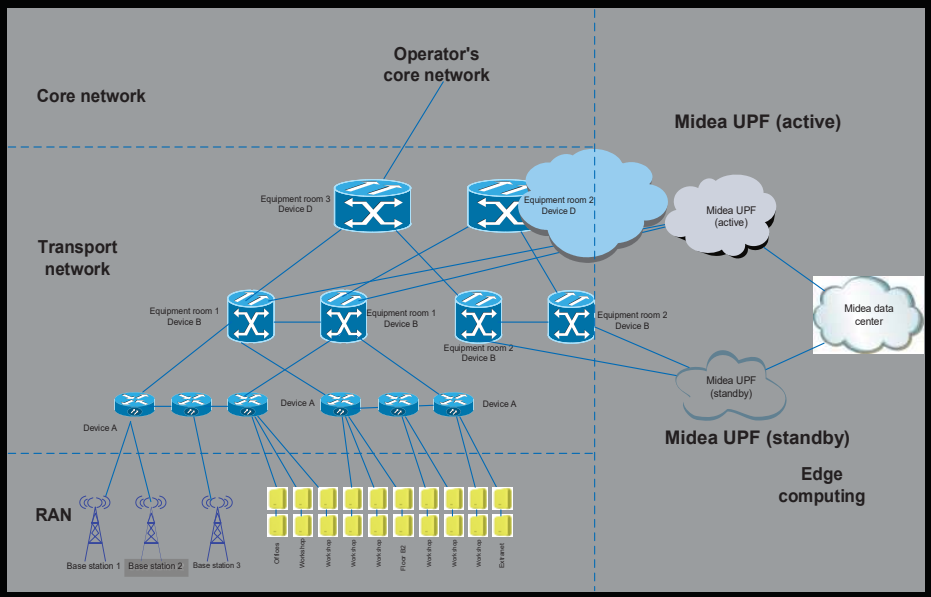
11 Application Scenarios

1. AI quality check of key parts (high uplink bandwidth)
2. 5G on-cloud PLC (stable low latency)
3. 5G AGV (5G replaces Wi-Fi)
4. 5G pallet truck dispatching + positioning (positioning)
5. 5G production data collection (massive connectivity)
6. 5G MES dashboard (wireless)
7. 5G scanners (wireless)
8. 5G smart security
9. 5G smart inspection
10. 5G robots
11. 5G AR remote assistance

Core Requirements

Low latency	High uplink	Positioning
10 ms (99.99%)	640 Mbps	0.5 – 1 m
PLC on cloud 10 ms (99.99%)	AI quality check of key parts 640 Mbps	Pallet truck and personnel positioning

Midea: 5G E2E Private Network Solution for Smart Manufacturing



Infrastructure: evolving from 5GtoC to 5GtoB private networks

- Phase 1: single-point UPF + basic coverage
- Phase 2: active/standby UPF + in-depth coverage

High-availability design

- E2E active/standby redundancy for transport networks
- Active/standby redundancy for UPFs
- AR dual feeding and selective receiving to reduce jitter

Coverage optimization in special scenarios

- Coverage enhancement for AI quality check, 5G positioning, and other special scenarios with high network requirements

Plans for 2021: testing network slicing, 5G LAN, 5G indoor positioning, stable low latency, enterprise self-service platforms, and more

XISC: Project Overview and Core Requirements

Project Overview

Hunan Valin Xiangtan Iron and Steel (XISC): China's No. 7 and Hunan's No.1 steel enterprise, with an annual output of 10 million tons and annual revenue exceeding CNY60 billion, started building its 5G Smart Factory in August 2019.



Four Goals & Typical Scenarios

①"Speaking" devices



- Sensor data transmission and inspection
- Remote device monitoring
- Predictive maintenance

②Autonomous devices



- Unmanned bridge crane
- Automated steel spinning
- 5G AGV

③Better working conditions



- UHD factory monitoring
- Remote bridge crane
- Remote robotic arms

④Higher efficiency



- AR remote assistance
- AI surface quality check
- Scrapped steel rating

Core Requirements and Challenges

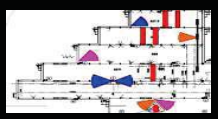
High requirements of network SLA (UL bandwidth, latency, and &reliability)

Remote bridge crane	• One 4K 360° camera: 8 Mbps/channel; five 4MP cameras: 4 Mbps/channel • PLC latency of 50 ms; 99.99% reliability; single-crane UL bandwidth of 120 Mbps
Unmanned bridge crane	• One 4K 360° camera: 8 Mbps/channel; five 4MP cameras: 4 Mbps/channel • Ranging & scanning: 10 Mbps; PLC latency 20 ms; 99.99% reliability • Single-crane UL bandwidth of 130 Mbps

Network Planning and Product Selection: Complex Scenarios and Interference



Metallic structure: signal blockage, strong attenuation

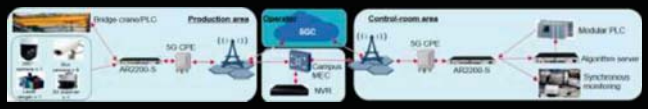


High site density, difficult to control interference

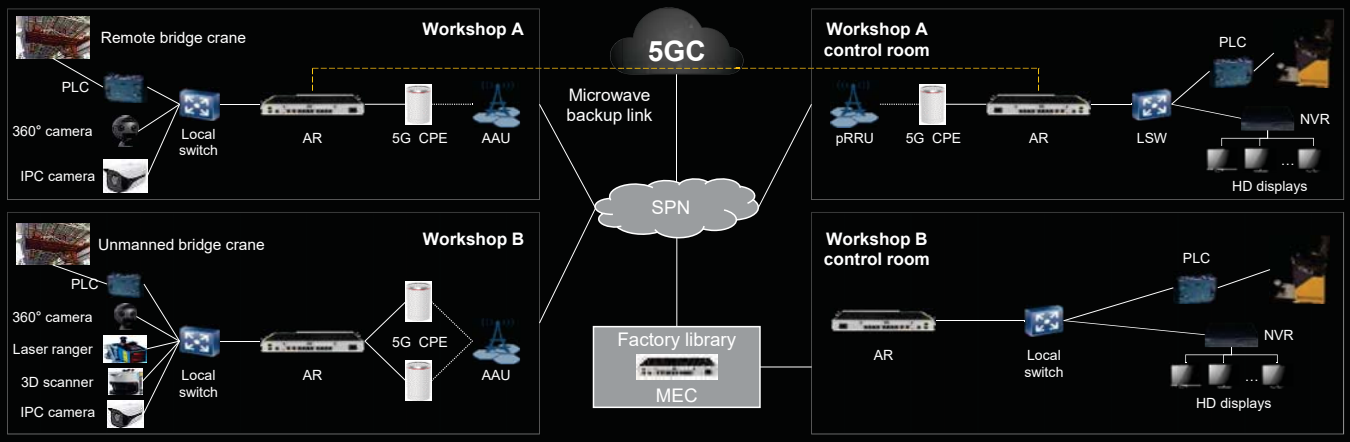


Low UL capacity due to strong inter-CPE interference

Difficult to Troubleshoot Faults E2E (CPE Included) Self-Service O&M Required



XISC: E2E Network Solution



Air interface Solutions

- Base station selection: Macro AAUs to reduce power (interference and radiation control); 64T64R to ensure large capacity (meeting high uplink bandwidth requirements)
- Inter-frequency networking: 2.6 GHz + 4.9 GHz, dual 2.6 GHz frequencies, AAU back-to-back deployment
- Device configuration: 5G CPE (ins2.0) directional antenna, CPE cover, probe-based frequency locking, SPID-based carrier camping (dual 2.6 GHz frequencies)

Reliability Solutions

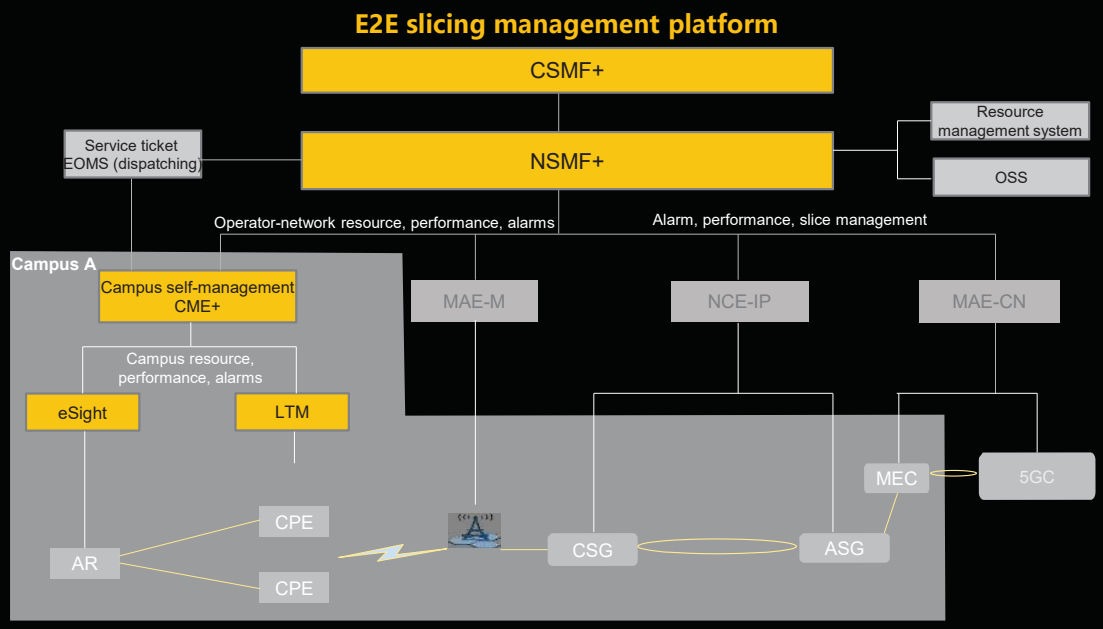
High-reliability (99.999%) AR replaces low-reliability (99.9%) AR

- BBU cold backup, high-reliability SPN rings, MEC pooling
- One cell connected to two CPEs, with dual 5G links for load sharing
- Existing microwave links for active/standby redundancy for 5G links
- Private network base station exclusive to toC services, slicing isolation for services of different SLAs

XISC: O&M Solution

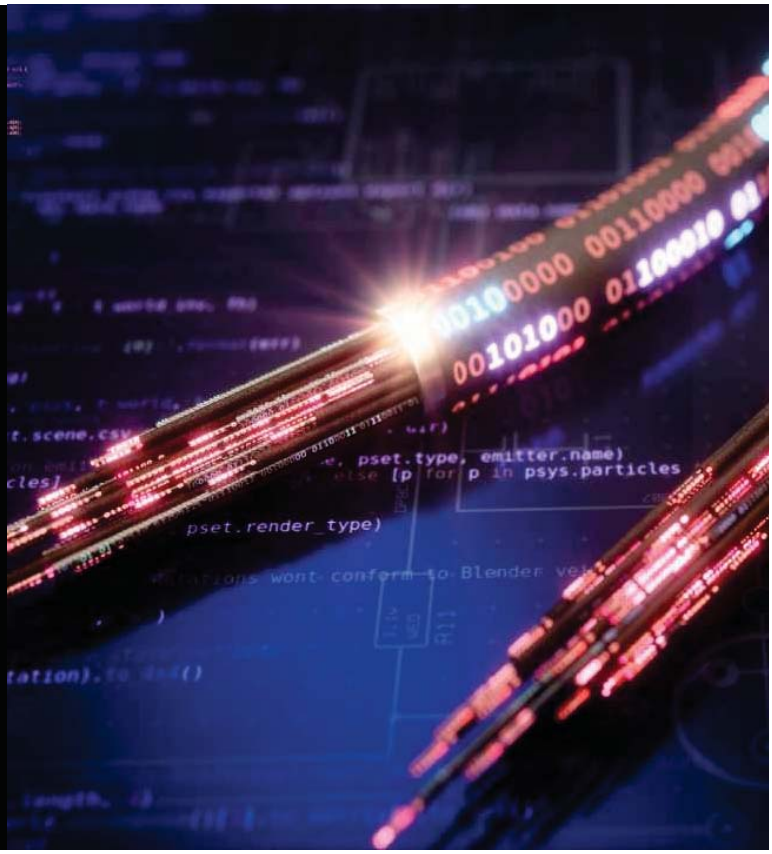
One-stop lightweight campus self-management platform

① Centralized campus topology visibility
② Campus network and device monitoring
③ Air interface analysis and simulated tests
④ Campus service SLA monitoring
⑤ E2E network fault troubleshooting



目录

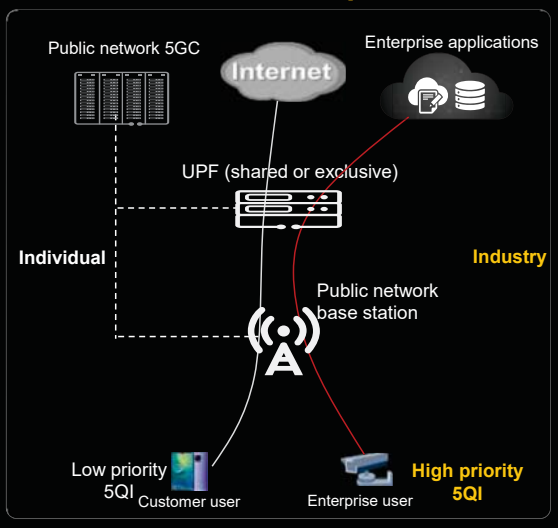
- Industry Trends
- Solutions and Cases
  - 5G Private LAN Solution
  - 5G Private WAN Solution
  - Common Capabilities



Architecture | High Availability | Stable Latency | DGPA* | Business Mode

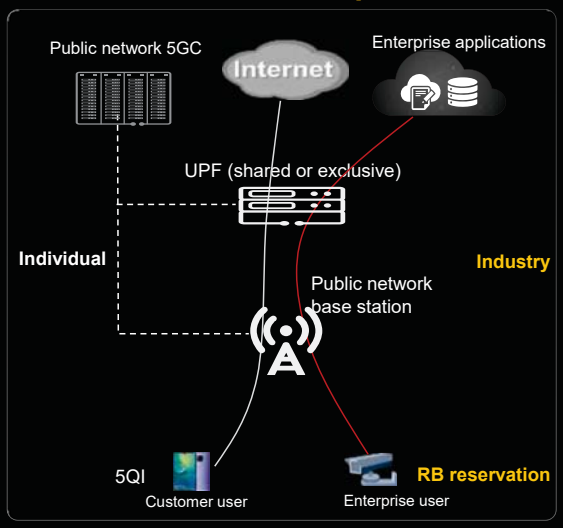
Two Construction Modes for Private WAN

Public networks for public use



- RAN: **base station sharing**, 5QIs used to differentiate **service priorities**
- Core network: 5GC sharing, UPF for sharing or exclusive use
- Transport network: sharing
- Typical industries: policing, transportation, and waterway

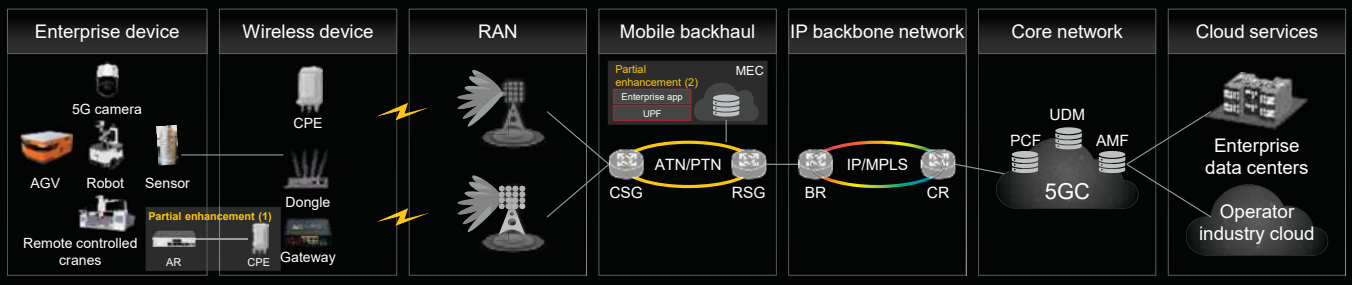
Public networks for private use



- RAN: **base station sharing**, dedicated RBs for **hard resource isolation**
- Core network: 5GC sharing, UPF for sharing or exclusive use
- Transport network: sharing
- Typical industry: electric power

Architecture | High Availability | Stable Latency | DGPA* | Business Mode

Public Networks Partially Enhance Availability of Private WAN



Private WAN Availability

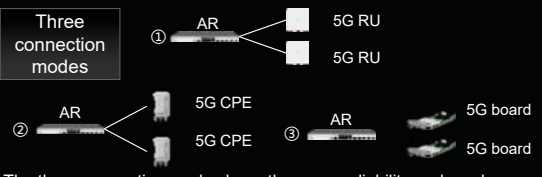
1. The private WAN base station, mobile backhaul, and core network reuse the infrastructure of public networks.
2. In scenarios with high SLA requirements, partial enhancement is achieved through dual links on the device access side.
3. For some MECs that are deployed to the edge, partial enhancement is achieved by deploying MEC load sharing.

Device Redundancy Backup (Enhancement 1)

Two working modes

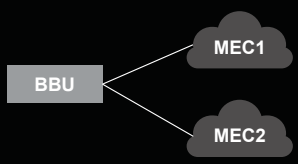
Dual fed and selective receiving: 0 ms switching and 0 packet loss
1+1 backup: link switchover within 100 ms

Three connection modes



The three connection modes have the same reliability and can be flexibly selected based on availability.

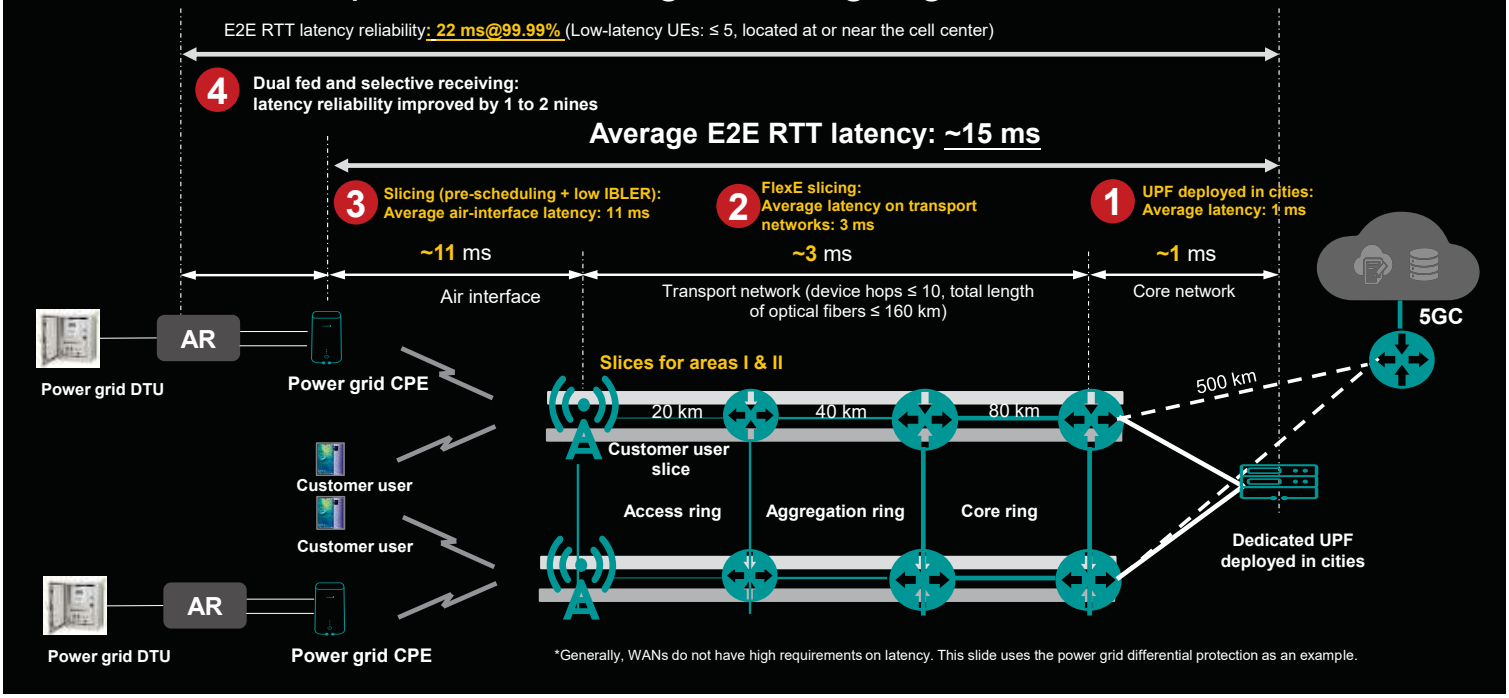
User-Plane Load Sharing (Enhancement 2)



- MEC load sharing provides up to 60 ms service switchover
- WAN provides better equipment room location and conditions, and does not use the kite solution.

Architecture | High Availability | Stable Latency | DGPA* | Business Mode

Stable and Low-Latency Private WAN — Air Interfaces and Transport Networks Require Hard Slicing, Causing High Costs



*Generally, WANs do not have high requirements on latency. This slide uses the power grid differential protection as an example.

Architecture | High Availability | Stable Latency | DGPA* | Business Mode

Agile Rollout of Industry Applications and SLA Assurance

Applications

- Smart policing: UAV, Unmanned vehicle
- Yangtze waterway: law enforcement ship, Command ship
- Telemedicine: Ambulance, Remote B-scan
- toB private line: Large EPL, SME private line

Five phases & eleven steps

Consulting & evaluation	Planning & design	Generation & provisioning	Service assurance	Service operations
Business evaluation	Service model analysis	CPE site selection	Topology visualization	Opportunity insight
ROI analysis	Capacity planning	Private line self-provisioning	SLA monitoring	Service self-provisioning
Business mode	Coverage planning	SLA testing	Health assessment	
Network evaluation	Interference suppression	Optimization & acceptance	SLA demarcation and locating	Service monitoring
	Rate simulation			
	Slice planning & design			

Tool platform

CWR (SaaS): Lightweight Discovery, Lightweight SOC

Customer benefits

Design: WAN service modeling, accurate capacity calculation, **LOD3 map forming**, upstream rate simulation, and E2E latency reliability
Generation: connection level, **analog industry protocols**, and **SLA Tester/UAV test solutions** for industry applications
Provisioning: SaaS cloud services, map forming, simulation, test tools, and provisioning reports
Assurance: connection-level SLA (measurable), **visible SLA status in real time**, and automatic fault demarcation based on the rule library and fault tree

Architecture | High Availability | Stable Latency | DGPA* | Business Mode

Business Model of Private WANs: Combined Sales for Three Products, Features, and Resources

5G Network UAV Library of Xiamen Public Security Bureau
5G network connection services: 5 TB traffic + IaaS — CNY2,180 /year

5G Video Collection of Guangzhou Tianhe Public Security Bureau
5G vehicle-mounted video collection, 1080p (10 Mbps) — CNY12,000/5 years

Guangzhou Power Supply Bureau of China Southern Power Grid — Negotiation Draft
Provisioning fee CNY3,000/ID | Function fee CNY1,000/ID/month | 5% RB CNY1,700/site/month

Traffic | **Bandwidth** | **Slice**

DNN: CNY**1,000**/function
5QI: Acceleration fee: CNY**15**/month
Computing power: Annual resource service fee

Included Traffic	Tariff (CNY/Month) General Traffic	Sponsored Traffic
30 GB	120	70
100 GB	200	120
200 GB	380	230
1 TB	1,700	1,000

How to sell

Single-site monthly service fee × (Service bandwidth / Cell uplink bandwidth × 3) × UL resource ratio × Resource reuse coefficient × 5QI preferential scheduling coefficient

How to sell

Provisioning fee/slice + Function fee/slice/month + Wireless RB usage fee/site/month + UPF usage fee/month

Sponsored traffic: 40% cheaper than general traffic | Quarterly/Annual tariff plan | Traffic pool: + function fee/card

UL ratio: 20%-30% | Multiplexing coefficient: > 6 | Priority coefficient: 1.1–1.5

Wireless resources (including site transmission) | Mgmt. scope-based slice number (such as city) | 4+ UPF levels

Telemetry, remote communication, and remote control of DA
Law enforcement (law enforcement recorder)

UAV transmission line inspection
Video surveillance
1080p-10 Mbps CNY490/month vs. CNY2,900/month (3 TB)

Differential protection and network load interaction
Major event security

China Southern Power Grid: Project Background and Key Requirements

Background and Progress of 5G Smart Grid Project

- Power supply scope: Guangdong, Guangxi, Yunnan, Guizhou, and Hainan, connecting power grids in Southeast Asia
- Power supply area: 1+ million km2 supplying 254 million people
- Five service processes: power generation, transmission, transformation, distribution, and consumption, including 50+ sub-service scenarios.

Introduction to China Southern Power Grid



First commercial use in Guangzhou and Shenzhen

Major 5G services

Power generation	Inspection, status monitoring, and protection		Power distribution	Differential protection, three remote control functions, and PMU
Power transmission	UAV inspection and transmission line status monitoring				
Power transformation	UAV inspection and intelligent substation inspection		Power consumption	Power consumption data collection

5G Smart Grid Solution

Challenges

- Blind adjustment of power distribution
- Unbalanced power supply and demands
- Heavy operation load in substations
- Difficult power transmission inspection
- E2E security challenges

Key Solutions

Slicing	High bandwidth	Timing	Low latency	Security
Private WAN E2E network slicing	One substation: 0.7–1 Gbps	PMU service timing precision: 1 us	Differential service latency: 15 ms	E2E security secondary authentication

Benefits


Transmission: 80X efficiency

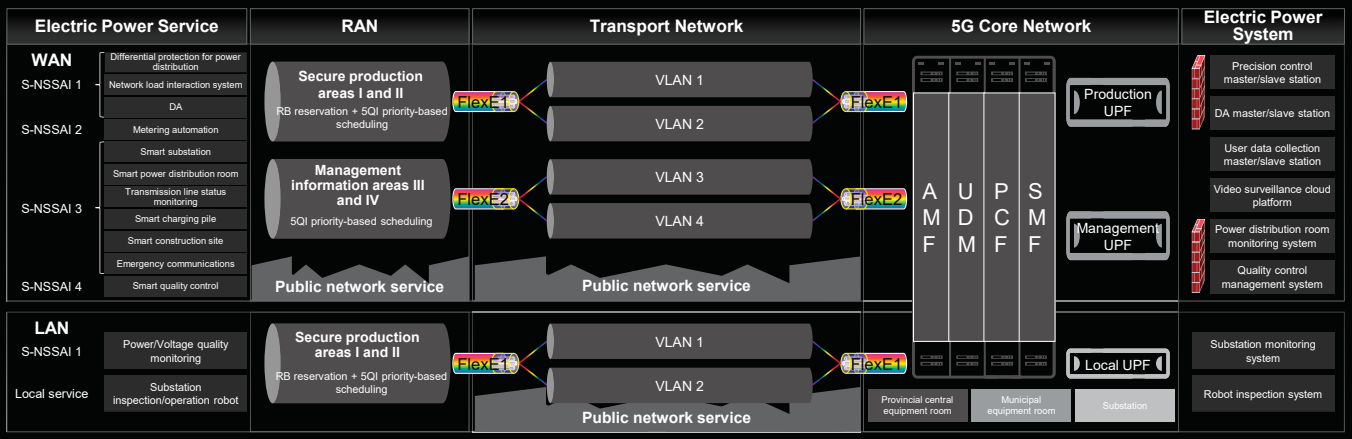

Transformation: 2.7X efficiency


Distribution: impact-free power recovery

Progress: By the end of 2020, Guangzhou had launched and verified 24 5G smart electric power services, and Shenzhen had commercialized 101 private WAN service sites.

Plan: In 2021, 10,000+ and 4000+ service sites are being planned in Guangzhou and Shenzhen, respectively.

China Southern Power Grid: Private Networking and Slicing Planning



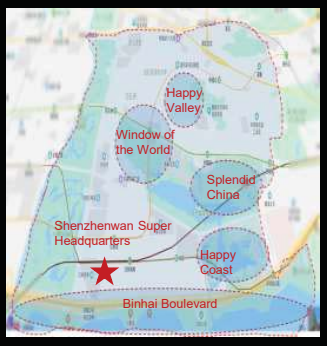
Electric Power Service Area	Typical Service
Secure production area I	Production control (differentiated distribution network protection, PMU, automation, and three remote control functions)
Secure production area I	Production non-control (metering automation, etc.)
Management information area III	Construction sites, surveillance, robots, UAVs, and smart power distribution rooms
Management information area IV	Smart quality control
Private LAN	Substations, power plants, and campuses

Slicing planning solution:

- Four slices correspond to the secure production areas I and II and management information areas III and IV, respectively.
- A DNN is allocated to each service among the four slices. Slices and UPFs are selected based on the S-NSSAI and DNN.
- Generally, there are two UPFs dedicated for a power grid in a city: production UPF for slicing services in areas I and II and management UPF for slicing services in areas III and IV.
- In substations, the UPF is deployed closer to users and data is transmitted within the campus.

Shenzhen Policing: Project Background and Scenario Requirements

Project Background





Introduction to Shahe Policing Area:

- Area: 27.5 km2; total population: 230,000+
- Heavy customer flow: annual population of 22+ million; maximum daily population of 250,000
- Complex scenarios: tourist attractions, park malls, star hotels, coastlines, urban villages, and high-end communities

Challenges:

- Insufficient law enforcement resources
- Slow law enforcement dispatching speed
- Video upload freezing
- Inaccurate identification

Private WAN Scenarios and Requirements

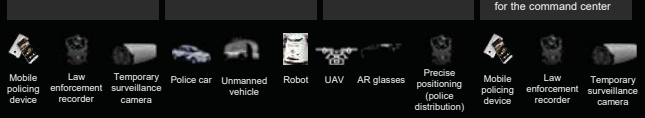
Four 5G Policing Scenarios

Routine patrol
- Unmanned: alleviating police shortage issue
- Intelligent: facial and behavior recognition

On-site law enforcement
- Personnel query
- Audio and video recording for tracing

Incident reception and handling
- Quick response: onsite investigation and evidence collection with UAVs
- Search for key personnel with facial recognition through AR glasses

Major security protection and emergency response
- Wireless network quality assurance (smooth and preferential access)
- Real-time on-site audio and video upload, ensuring management and control for the command center



5G Network Requirements

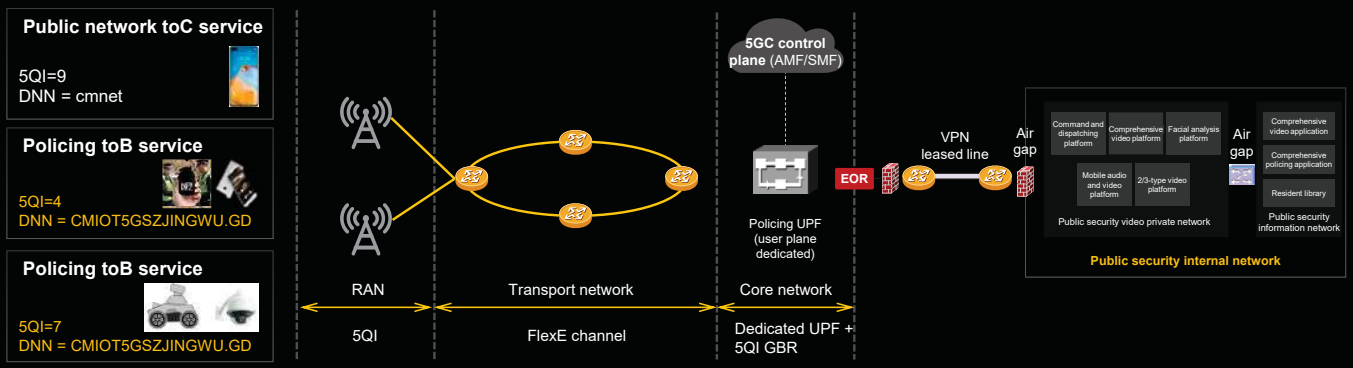
Uplink high bandwidth (100 Mbps to 1 Gbps)
Broadband-based mobile policing and HD video surveillance

Low latency (10 ms)
Policing UAVs and remote control of unmanned vehicles

Security (data, user, and architecture)
Trustworthiness mechanism for policing requirements

Positioning precision (3D, meter-level)
Precise incident handling

Shenzhen Policing: Private Policing Network Architecture and Slicing Solution



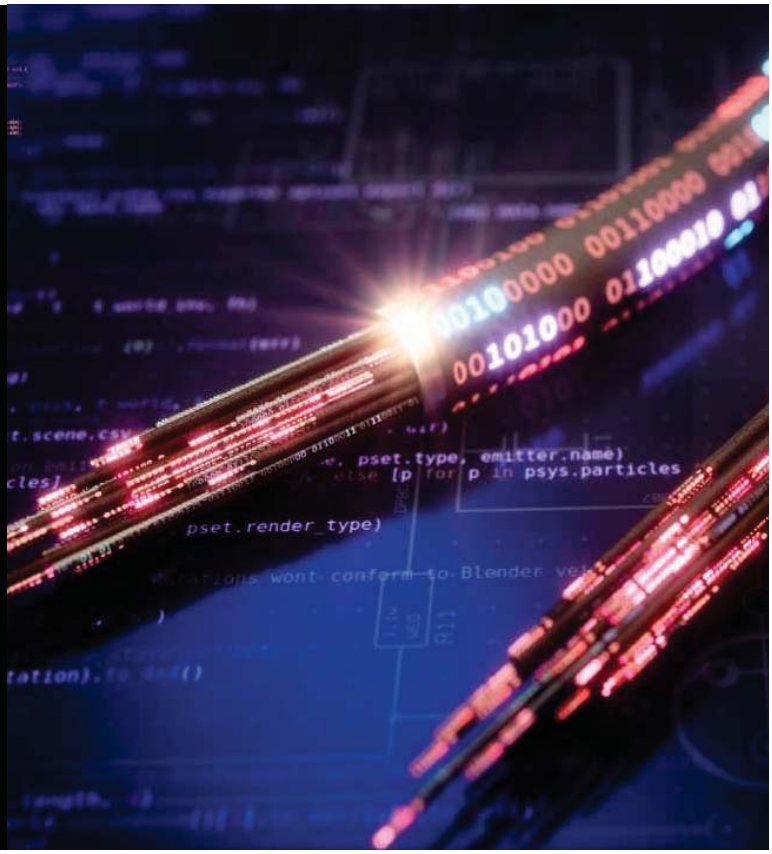
- 5G slicing: Wireless 5QI + Transport FlexE channel + Dedicated UPF/GBR

Service	DNN	5QI	FlexE Channel	Assurance Mode	Remarks
Public services	cmnet	9 (default)	/	/Non-guaranteed, public user by default	
Policing (law enforcement recorders and mobile policing devices)	CMIOT5GSZJINGWU.GD	Dedicated bearer 5QI = 4 (GBR)	Bandwidth: 1 Gbps (shared)	5QI = 4, GBR = 10 Mbps (uplink)/20 Mbps (downlink)	Dedicated for policing
Policing services (unmanned vehicles and 5G cameras)	CMIOT5GSZJINGWU.GD	Dedicated bearer 5QI = 7 (GBR)	Bandwidth: 1 Gbps (shared)	5QI = 7, GBR = 20 Mbps (uplink)/10 Mbps (downlink)	Dedicated for policing

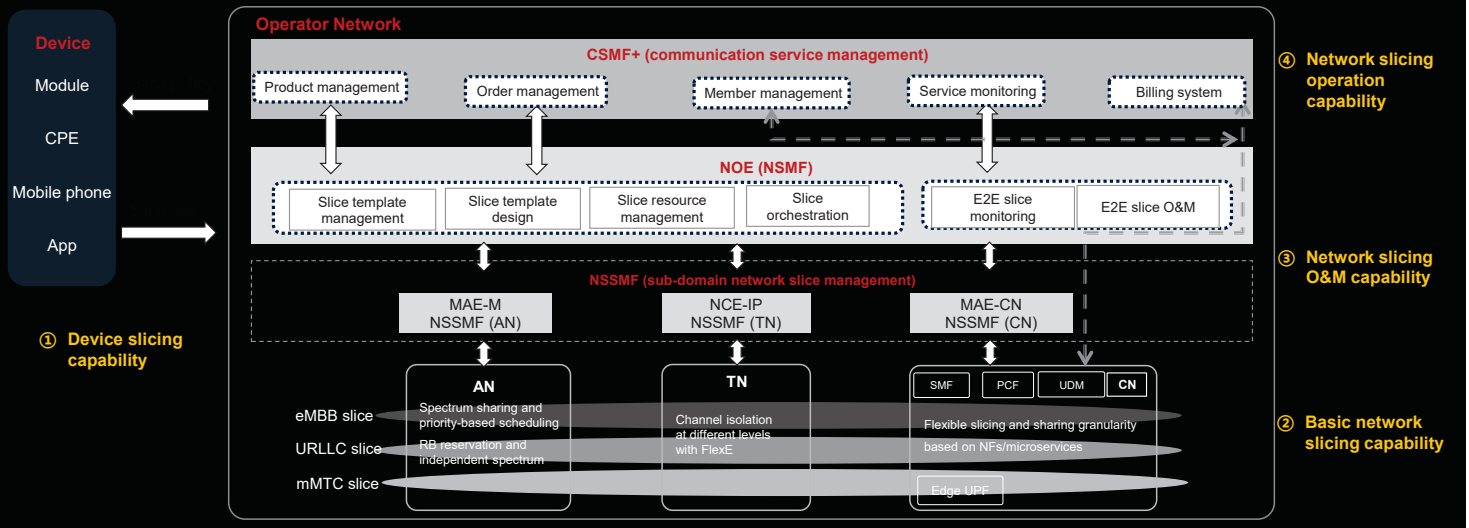
- In the initial phase, the QoS + GBR slice mode is used to ensure the priority and bandwidth quality of policing services. In the future, the static/dynamic RB reservation solution will be used to further improve policing service assurance.

目录

- Industry Trends
- Solutions and Cases
  - 5G Private LAN Solution
  - 5G Private WAN Solution
  - Common Capabilities



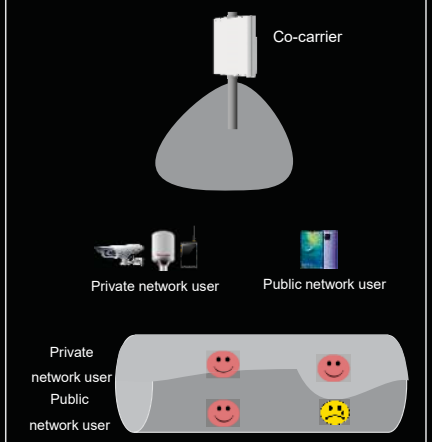
System Architecture of the E2E Slicing Solution



Benefits: The basic network provides on-demand logical slices for differentiated scheduling, while the O&M system enables quick provisioning of logical networks and slice services.

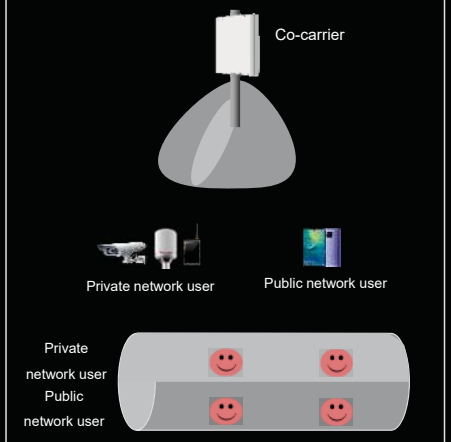
RAN: Three Solutions for Flexible Resource Scheduling

QoS Scheduling



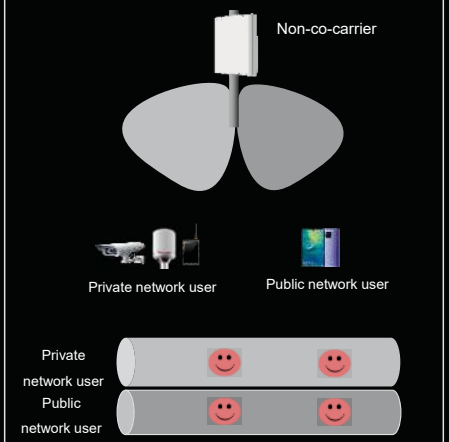
- **Spectrum:** sharing of the public network carrier spectrum
- **RB:** sharing, higher-priority QoS for private network users
- **Advantages:** high spectrum efficiency that meets the SLA requirements of most private networks

RB Reservation



- **Spectrum:** sharing of the public network carrier spectrum
- **RB:** configurable exclusive RBs for private networks
- **Advantages:** resource assurance with RBs exclusive to private network users; RB-level physical isolation between public and private network users

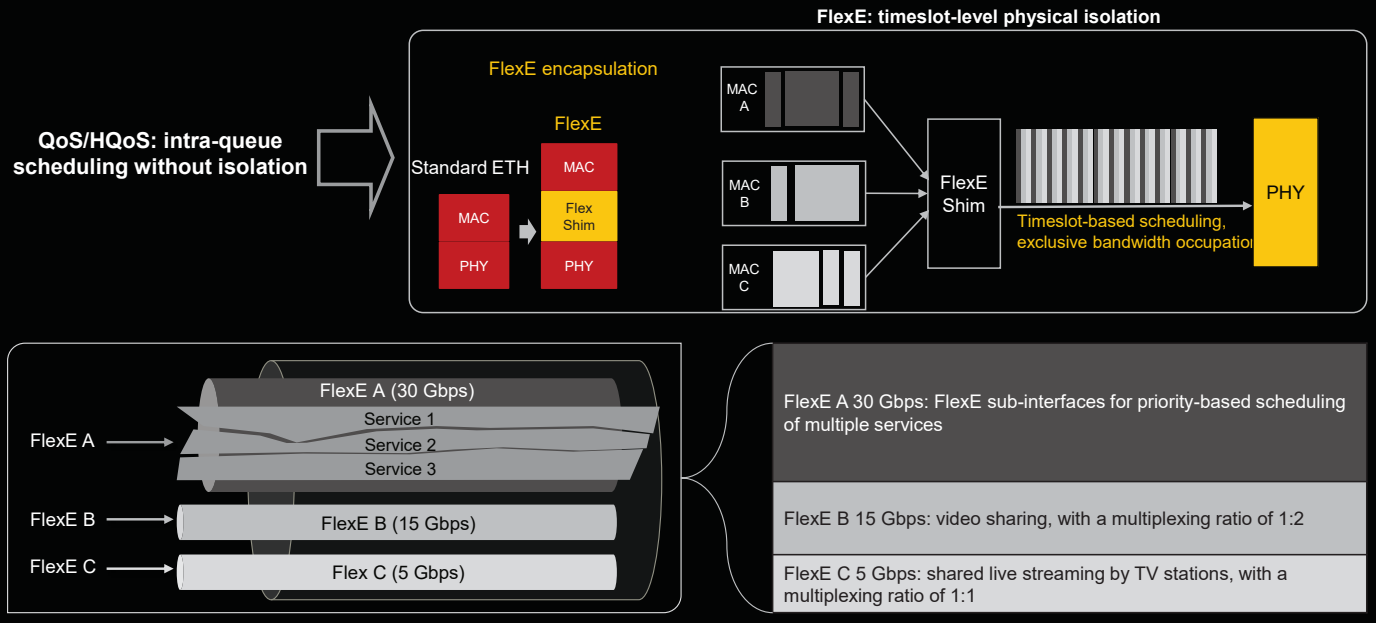
Carrier Isolation



- **Spectrum:** independent carrier spectrum for private networks
- **RB:** independent carriers for private networks
- **Advantages:** restricted access for public network users to private networks; high security with complete physical isolation

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

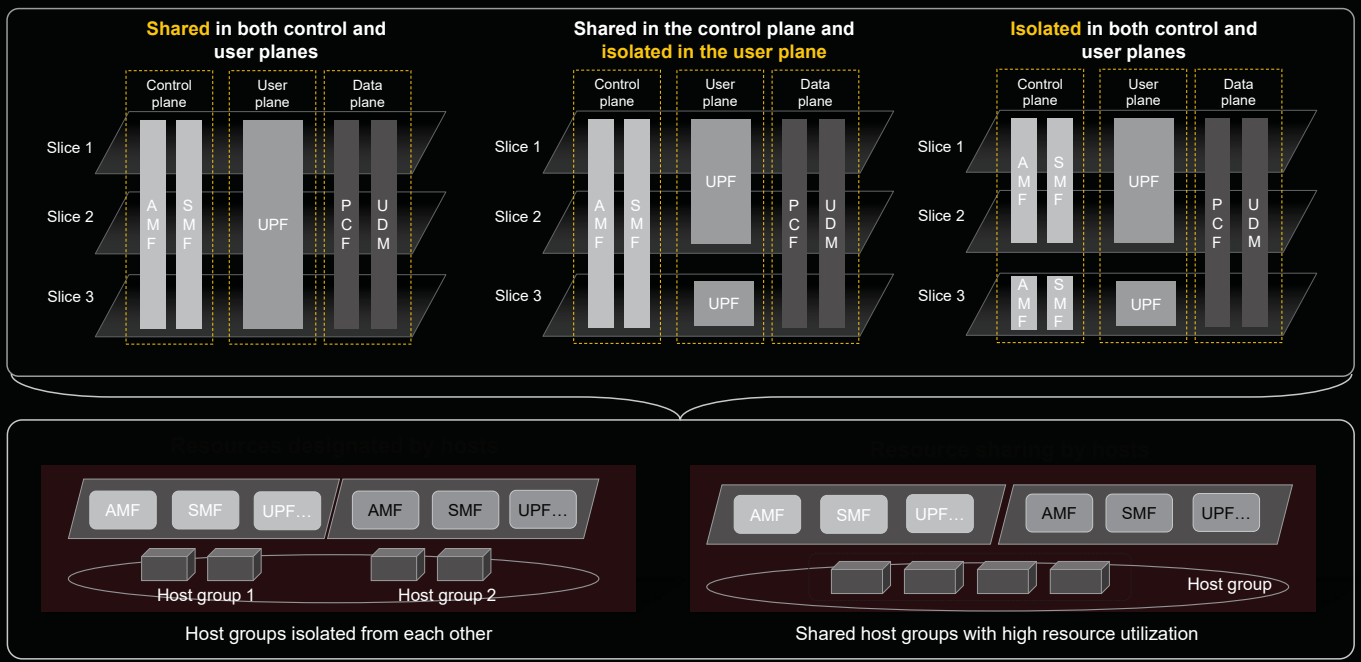
TN: Channel Isolation at Different Levels



1. **Resource allocation and isolation by bandwidth and latency with FlexE hard pipes based on timeslot scheduling;**
2. **Priority-based scheduling of different users or services in a single FlexE hard pipe with FlexE sub-interfaces**

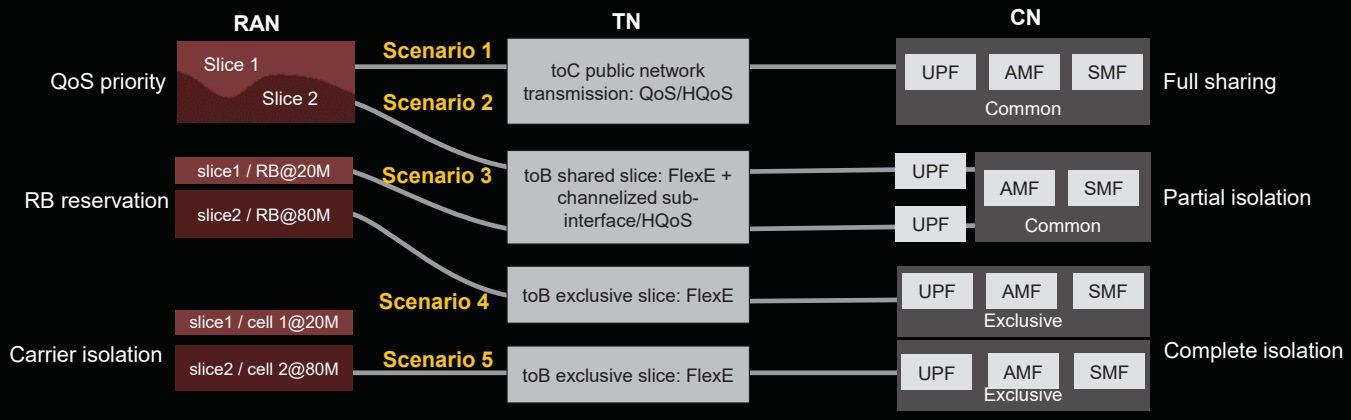
Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

CN: Flexible Isolation Based on Service Requirements



Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

On-Demand Resource Isolation with Slices: 5 Typical Combinations for Differentiated Industry Requirements

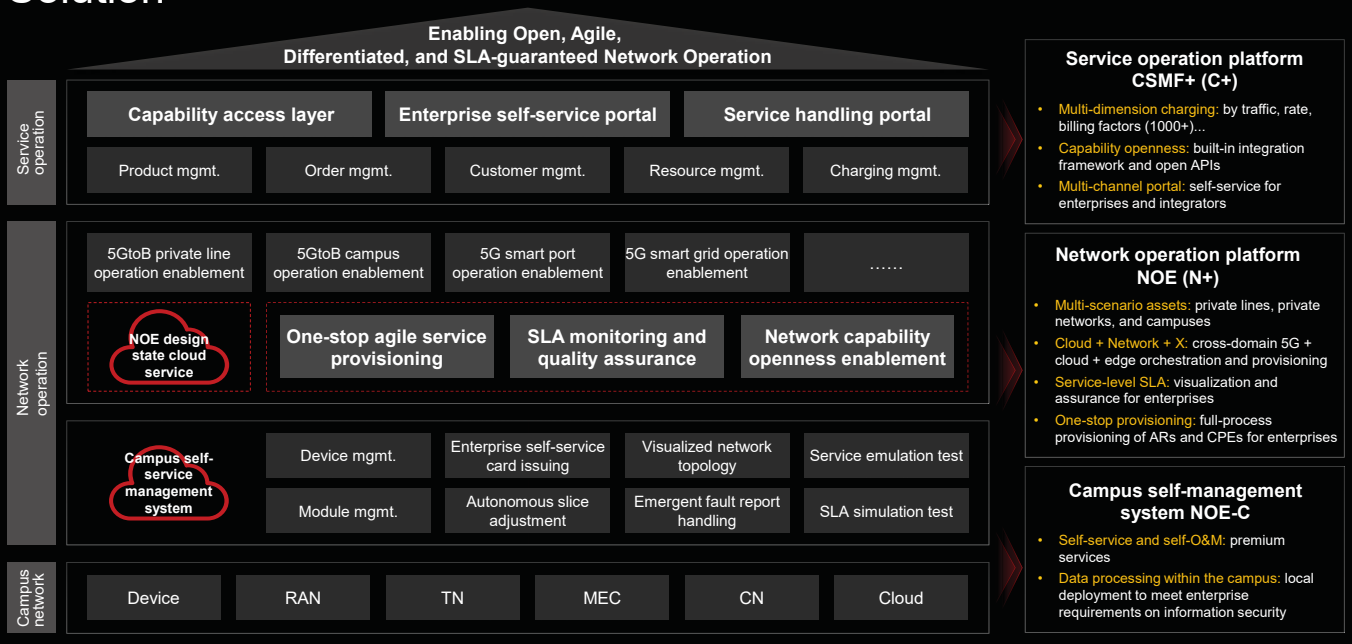


Typical scenarios:

- **Scenario 1:** toC public network slice, focusing on network resource sharing and QoS priority-based scheduling (enterprise broadband, mobile rescue, and mobile surveillance)
- **Scenario 2/3:** toB shared slices, enabling on-demand resource reservation (such as RBs reserved by cell) within the sharing range (power grid inspection and media live broadcast)
- **Scenario 4:** toB exclusive slice, requiring high level of service isolation (power distribution automation)
- **Scenario 5:** toB private network slice, with independent carriers (cells) or base stations (production services in mining areas or factories and departments with high security requirements)

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Operation Enabling Platform: Open, Cross-Domain, and One-Stop toB Solution



Service operation platform CSMF+ (C+)

- Multi-dimension charging: by traffic, rate, billing factors (1000+)...
- Capability openness: built-in integration framework and open APIs
- Multi-channel portal: self-service for enterprises and integrators

Network operation platform NOE (N+)

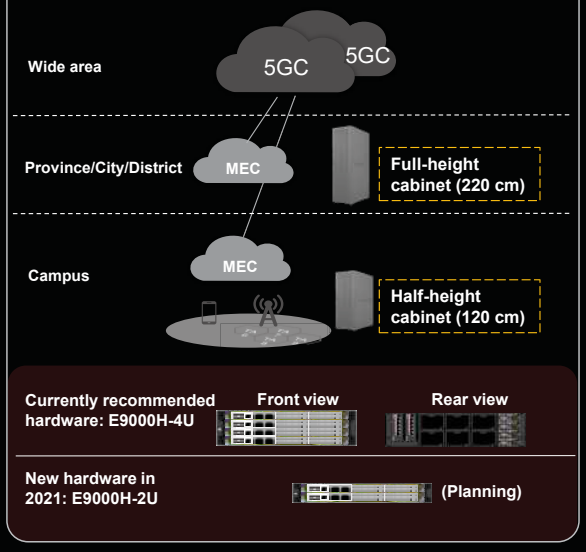
- Multi-scenario assets: private lines, private networks, and campuses
- Cloud + Network + X: cross-domain 5G + cloud + edge orchestration and provisioning
- Service-level SLA: visualization and assurance for enterprises
- One-stop provisioning: full-process provisioning of ARs and CPEs for enterprises

Campus self-management system NOE-C

- Self-service and self-O&M: premium services
- Data processing within the campus: local deployment to meet enterprise requirements on information security

MEC Hardware Offerings and Enhanced Connection Capabilities

Various MEC Cabinets and Offerings for Different Scenarios

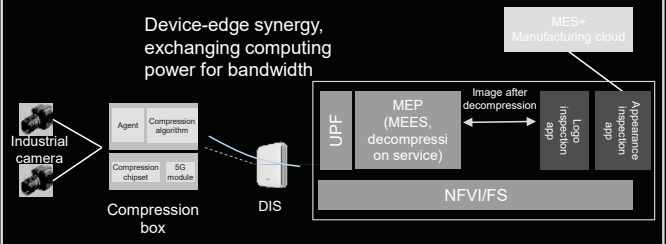


Key Capability	Key Feature	Typical Scenario
Flexible service splitting	• Location-, subscriber-, and service-based traffic splitting • Traffic splitting capability openness	Campus access Campus video surveillance Stadium live broadcast
toB Layer 2 networking	• 5G LAN Layer 2 communication • Wide 5G LAN Layer 2 communication	Industrial control Industrial vision
Low latency assurance	• Stable forwarding latency of 1.5 ms (99.99%) • Stable forwarding latency of 1 ms (99.999%) to be implemented	Power differential protection Industrial control
Tenant isolation	• E2E slice-based network isolation • Controllable and guaranteed bandwidth for different enterprises	SME access in the campus
One-stop integration	• Integrated DNS • Integrated NAT • Integrated IPsec	Edge deployment Enterprise one-stop integration services
Security assurance	• Enterprise access via secondary authentication	Campus access High-level protection requirements

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

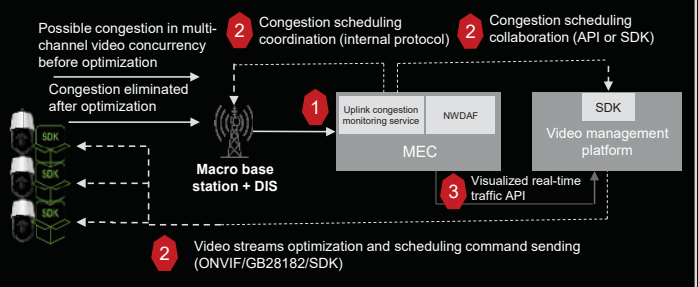
MEC Enhancement in Industrial Vision and Video Surveillance

Lossless Uplink Bandwidth Compression in Industrial Vision



- **Pain points:** High requirements on uplink bandwidth (70–600 Mbps) and limited devices that can access a single cell
- **Solution capabilities:** lossless compression algorithm used in the compression box on the device side and decompression on the edge side to reduce requirements on wireless uplink bandwidth; **3X to 6X lossless compression**; **compression duration < 100 ms**

Intelligent Detection of Uplink Congestion in Video Streams



- **Pain points:** congestion on the air interface caused by multi-channel video I-frame collision, increasing uplink bandwidth and latency and deteriorating user experience
- **Solution capabilities:** Real-time congestion monitoring and video center scheduling optimization for **higher bandwidth utilization, lower latency, and less frame freezing or artifacts**

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

MEC Builds an Open Edge Ecosystem Through Self-Construction and Aggregation

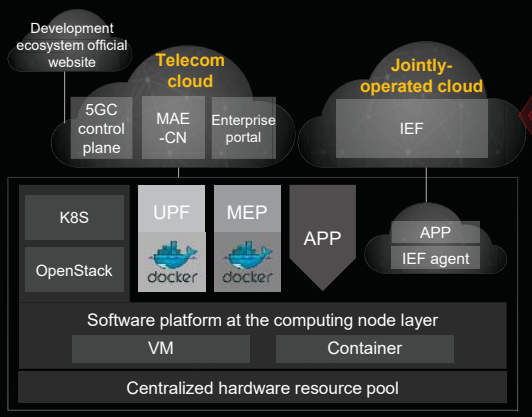
Self-developed ecosystem

Application: Provides one-stop services for app development and rollout
- Tool chain
- Development center
- Authentication center

Open source: Incubates the MEP open-source project
- Edge Gallery open-source project
- Independent community operation

Industry: Works with vertical industries and the industry chain
- Founding unit of the 5GDN industry alliance
- 100+ alliance members working with GSMA/3GPP, etc.

Aggregated ecosystem



APP | APP

Intelligent Edge Fabric (IEF) framework

Industrial vision | Power line inspection | Vehicle recognition | Cloud gaming

Applications with the public cloud IEF framework can be seamlessly migrated to MEC
- Unified operation and maintenance
- Unified container image
- Unified container communication
- Unified service access

Campus surveillance — Huawei Machine Vision; 中盛益华

Industrial vision — Microview

Industrial control

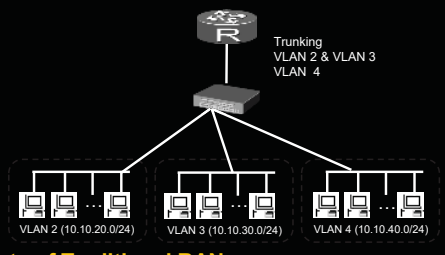
Live streaming

* Note: The list is subject to update. Some undisclosed partners are not displayed.

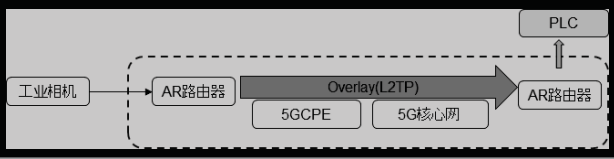
Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Public Network for Private Use — Ubiquitous 5G LAN

Traditional Enterprise Local Network
- A LAN is the basic networking unit of a local host or device.
- Devices in the factory support only Layer 2 networking and communicate with each other through broadcasts.

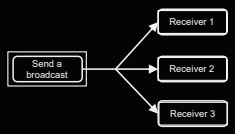


Pain Points of Traditional RANs
- Only Layer 3 interworking is supported. The Layer 2 protocol stack is not supported.
- Complex deployment of access routers (ARs) is needed to convert Layer 3 to Layer 2.

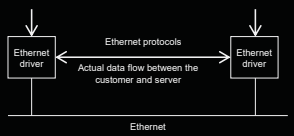


Typical Scenarios for Industrial/Campus L2 Networking

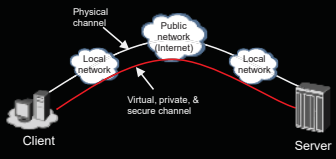
Scenario 1: broadcast messages
- Video surveillance IP camera (IPC) networking notification/discovery
- Industrial vision camera networking notification/discovery



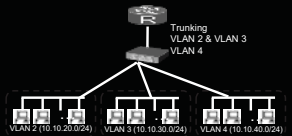
Scenario 2: Ethernet-based communication
- PLC industrial Ethernet communication
- Multicast GOOSE power communication



Scenario 3: Inter-domain/branch communication
- Cross-campus/branch communication
- Access anytime, anywhere



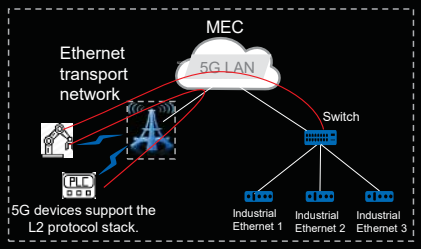
Scenario 4: LAN management in an enterprise
- Fixed IP address
- VLAN division and management



Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Ethernet Networking, LAN Management, and WAN Interconnection

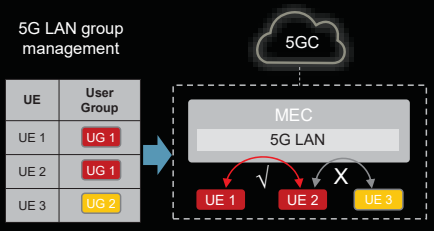
L2 Networking: L3 → L2/L3



Add an Ethernet layer to enable 5G in the OT/industrial vertical domains

- L2 broadcast/unicast and applications
- Compatible with L2 industrial Ethernet and applications
- Local switching and dynamic generation/update of the route table
- Simplified networking, deployment- and management-free AR enterprise routers

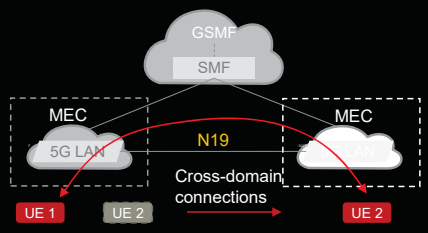
Private Network Management: Wired → Wireless



Enable 5G networks to self-manage as wired private networks

- 5G LAN group subscription/management and multi-VLAN management
- DNN-based isolation and 5G LAN group/VLAN isolation
- Fixed IP addresses allocated by collaborative enterprises' DHCP
- Enterprise portal for self-management
- Flexible provisioning, configuration, and O&M management tools

Cross-Domain Connection: LAN → WAN



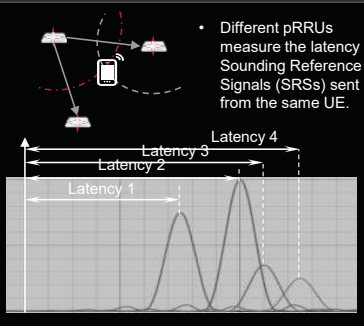
Enterprise mobile private networks for cross-region roaming and access anytime, anywhere

- 3GPP Release 16: N19 interface between A-UPFs
- Campus interconnection in a region with single SMF
- UEs access the enterprise network without dial-up anytime, anywhere.

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

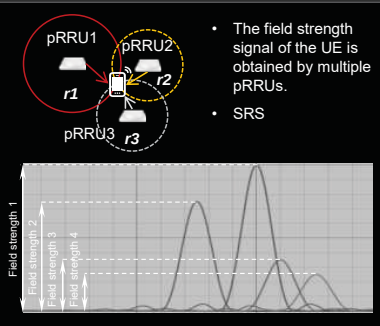
Three Positioning Algorithms to Continuously Improve Precision and Stability

U-TDOA-based Positioning



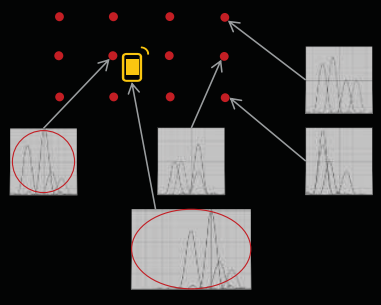
- Different pRRUs measure the latency of Sounding Reference Signals (SRSs) sent from the same UE.
- Calculates the distance between UEs and pRRUs based on the latency
- Main method for highly precise cellular positioning

Field Strength Triangulation-based Positioning



- The field strength signal of the UE is obtained by multiple pRRUs.
- SRS
- Calculates the distance between UEs and pRRUs based on the path loss formula
- Assisted method for higher stability

Fingerprint Positioning

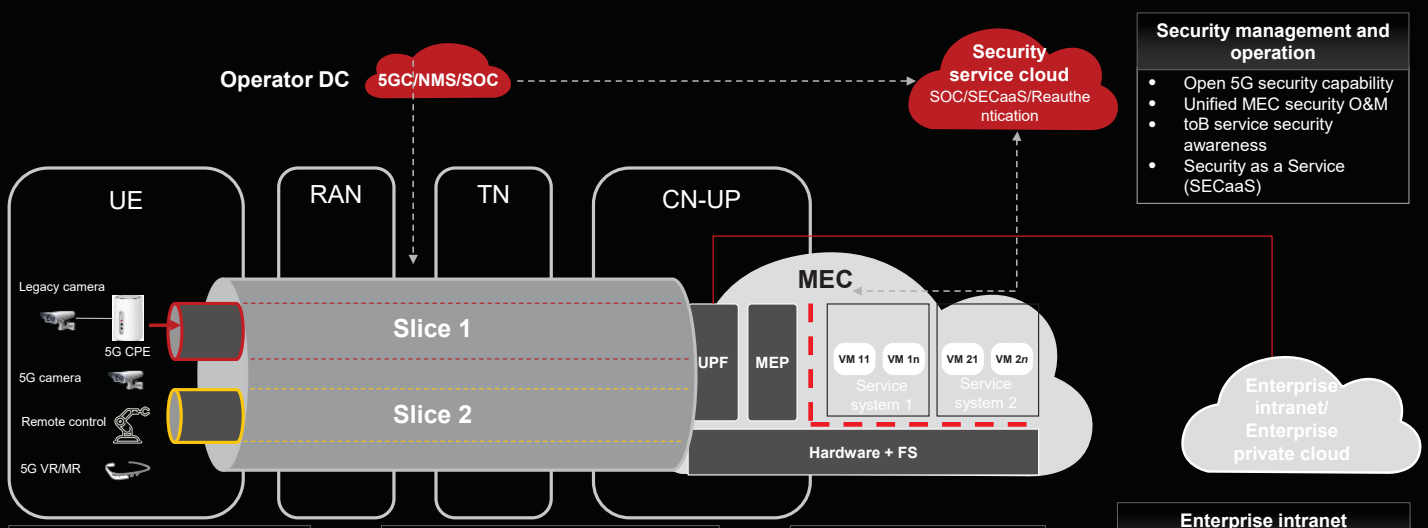


- Matches the collected SRS signals of mobile phones in the fingerprint library to obtain locations
- Assisted method for higher stability

	21A	21B	22AB
Positioning planning	Basic positioning capability 90% of LOS scenarios: 2–3 m	High precision and stability 90% of LOS scenarios: 1 m	Optimized linear scenario 90% of dual base stations: 1 m
Positioning algorithm	UTDOA	UTDOA Field strength triangulation-based fingerprint	Dual base station positioning

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Device-Network-Edge-Cloud Synergy for E2E 5GtoB Security



Device security
- Network access control (identity, **location, and slicing**)
- **Enterprise secondary authentication**

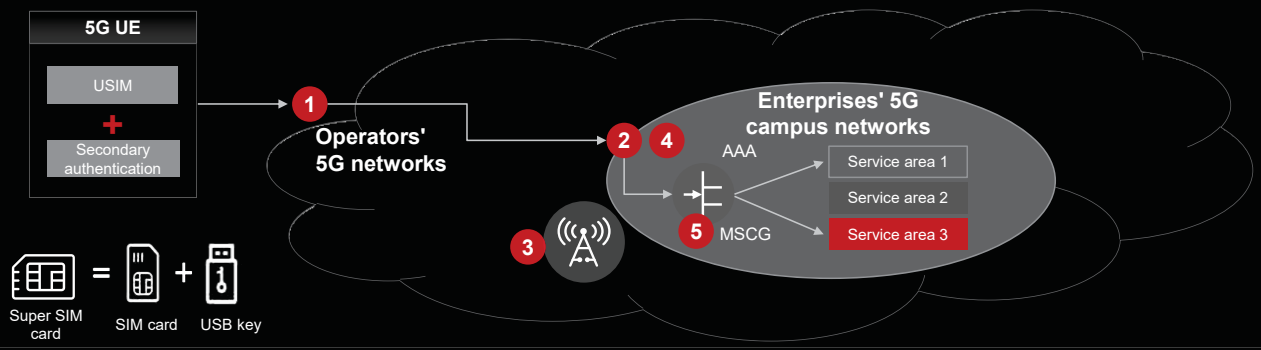
Network security
- **Slice isolation**
- Encrypted transmission
- Anti-DDoS attacks

MEC security
- Platform security
- Border protection
- **Security service**

Enterprise intranet border/private cloud security
- Border firewall/IPsec gateway
- MSCG border gateway control
- AAA server

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

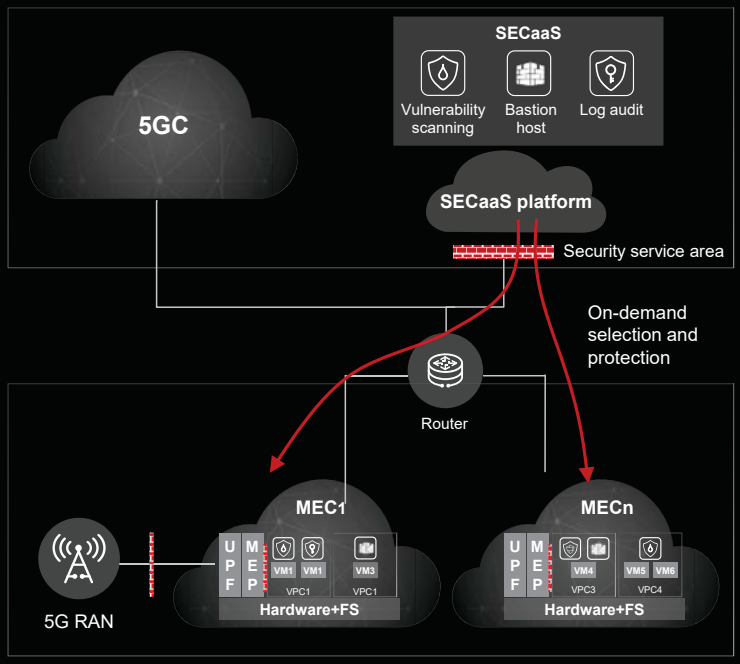
5 Control Points for Refined Device Access Authentication and Management



5 Control Points	Refined Device Authentication, Management, and Control
1 **Primary certification of 5G networks**	5GC: Only devices that pass primary authentication can access the operator's 5G network.
2 **Slice access**	5GC: Devices or apps' access to the enterprise slice is dependent on the mapping between IMSIs, app IDs, and slice IDs.
3 **Location**	5GC/base station: Which base stations are suitable for devices to access the 5G campus private network/slice for toB/toC isolation?
4 **Campus (secondary authentication)**	AAA server: Whether devices can access the enterprise intranet through the 5G network, including device-card binding and high-security SIM cards?
5 **Accessible resource**	MSCG: Which service areas can be accessed by devices (role-based access control, RBAC)?

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

MEC Security Solution for On-Demand Security Capabilities



SECaaS for customized security requirements of MEC apps

- **Edge cloud security capabilities:** provide various security capabilities for toB customers in SECaaS mode to flexibly and efficiently meet the security requirements of different services
- **Edge-cloud collaborated security services:** build more security service capabilities through the center cloud, such as platform vulnerability scanning, O&M audit, and intelligent security incident analysis and management

MEC platform security

- **Trusted computing:** build a trusted chain of infrastructure based on TPM chipsets and remote attestation for integrity protection in dynamic startup and running states
- **Attack defense:** deploy firewalls at the border, especially between MEC platforms and external apps, for intrusion detection and app-level resource and network isolation
- **Intrusion detection:** built-in threat awareness, intrusion detection, and anti-escape capabilities for Hypervisors, VMs, and containers

Slicing | MEC | 5G LAN | Positioning | Security | Industry Device

Industrial Device Development

Customized device

Media	Smart grid	Smart mining	Smart manufacturing	Smart security
5G live broadcast backpack Deviser/Cogent 2020 Q1	Timing CPE Huawei/CSG 2020 Q3	Excavator Shearer Tianma, Chuangli, Huayue, etc. 2021 Q3	Industry camera Microview Image 2020 Q3	Body worn camera TD Tech/Pe 2021 Q2

Smart port | Smart education | Smart healthcare | Smart steel

Basic connection + Universal device

Basic connection

TD Tech | lierda | 中国普业 | M | 宏电

Over 20 CPE, router, gateway, and Dongle models launched in 2020

Universal devices

Camera	AGV	Vehicle-mounted device	UAV
Huawei/Hikvision/ Dahua 2020 Q3	Huaheng 2020 Q4	Kedacom 2020 Q4	Harwar/Tianyujingwei 2020 Q4

Module

QUECTEL | SUNSEA AIOT 日海智能 | Fibocom | SIERRA WIRELESS | 中国移动 China Mobile | SIMCOM | WINGTECH | neoway 有方

- **70+ 5G modules (GSA, 2020–11)**
- **Prices of entry-level modules reduced to less than USD100 by 2021**

Chipset

HiSilicon Balong 5000 2019 Q2	Qualcomm X55 2019 Q4	X60 2020Q1	Unisoc IVY510 2019 Q4	MTK T750 2020 Q3

- **Four platforms, multiple high-end/mid-range 5G chipsets launched in 2020, laying the foundation for the device ecosystem.**

Nesamostojno omrežje 5G
Non-standalone 5G network

Marko Grebenc[1], **Boštjan Batagelj**[2]

[1]Huawei, [2]Univerza v Ljubljani, Fakulteta za elektrotehniko

marko.grebenc@huawei.com

Povzetek

Mobilno brezžično omrežje pete generacije je, za razliko od prejšnjih generacij, možno uvesti v samostojnem ali nesamostojnem načinu. Nesamostojni način omogoča zgolj enega (eMBB) od treh osnovnih primerov uporabe definiranih v zahtevah IMT-2020. Ob začetni uvedbi 5G se večina operaterjev odloča za nesamostojni 5G v dvojni povezljivosti z obstoječim omrežjem 4G. Organizacija 3GPP je pri peti generaciji javnih mobilnih omrežij izjemoma standardizirala nesamostojno delovanje preko sočasne dvojne povezljivosti LTE in NR. Za uvedbo je na voljo več različnih arhitekturnih izbir, ki jih je možno nastavljati preko različnih vrst podatkovnih radijskih nosilnikov. V prispevku so predstavljeni tudi praktični vidiki uvedbe nesamostojnega načina, rezultati testiranj različnih nosilnikov ter možnosti prikazovanja ikone 5G v nesamostojnem načinu.

Abstract

Unlike previous generations, the fifth generation mobile wireless network can be deployed in standalone or non-standalone mode. The non-standalone mode allows only one (eMBB) of the three basic use cases defined in the IMT-2020 requirements. With the initial deployment of 5G, most operators are opting for a non-standalone 5G in dual connectivity with the existing 4G network. In the fifth generation of public mobile networks, organization 3GPP has exceptionally standardized non-standalone mode through simultaneous dual connectivity to LTE and NR. Several different architectural options are available for deployment, which can be configured via different types of data radio bearers. The article also presents the practical aspects of the deployment of a non-standalone mode, the results of testing various bearers and the possibilites of displaying the 5G icon in a non-standalone mode.

Biografija avtorja



Marko Grebenc je prve izkušnje s področja mobilnih komunikacij nekaj let pridobival v oddelku radijskega planiranja, optimizacije in upravljanja omrežja pri mobilnem operaterju, kjer se je ukvarjal predvsem z optimizacijo radijskega omrežja. Poklicno pot je leta 2015 nadaljeval kot Inženir za brezžična omrežja v podjetju Huawei, kjer je skrbel za tehnično vpeljavo produktov in storitev na področju mobilnih omrežij. Trenutno je v podjetju Huawei zaposlen kot Regionalni vodja operative in vzdrževanja, kjer skrbi za vzdrževanje. Poleg tega, na področju radijskih dostopovnih omrežij, pripravlja izvedbene rešitve in vodi tehnično izvedbo tako pilotnih kot tržnih projektov, v zadnjem času predvsem s področja 5G.

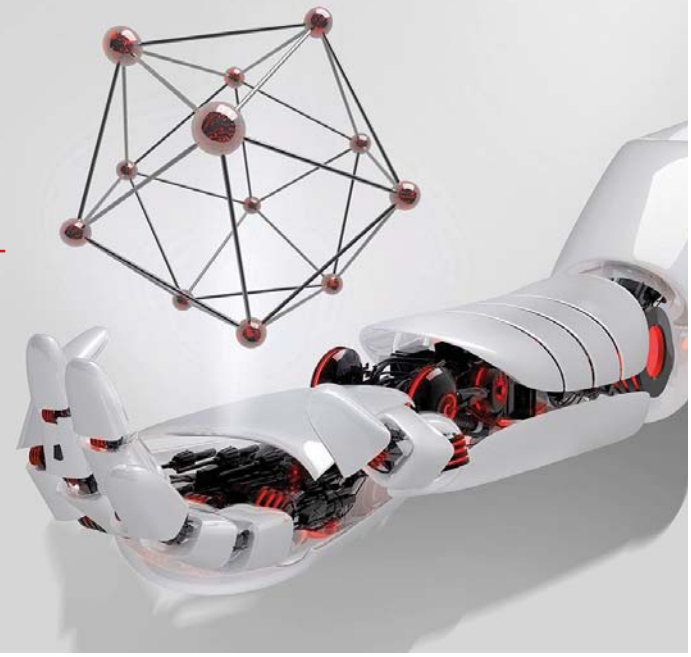
Author's biography

Marko Grebenc *has been gaining his first experience in the field of mobile communications for several years in the department of radio planning, optimization and network management at the mobile operator, where he dealt mostly with radio network optimization. He continued his career in 2015 as a Wireless Engineer at Huawei, where he took care of the technical implementation of products and services in the field of mobile networks. He is currently employed by Huawei as Regional Operations and Maintenance Manager, where he is in charge of maintenance. Besides that he is also preparing implementation solutions in the field of radio access networks and leads the technical implementation of both pilot and commercial projects, recently these are mostly from 5G field.*

Nesamostojno omrežje 5G

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SRK 2022
srk.fe-uni.lj

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Kaj je 5G?

- Termin “generacija” ali oznaka “G” ni standardizirana je pa splošno uveljavljena.
- Zahteve za vsako od t.i. generacij določajo mednarodni standardi IMT, ki jih izdaja ITU-R.

Generacija	Standard IMT	Organizacija	Tehnologija radijskega vmesnika
3G	IMT-2000	3GPP	CDMA Direct Spread
			CDMA TDD
		3GPP2	CDMA Multi-Carrier
		ATIS/TIA	TDMA Single-Carrier
		ETSI	FDMA/TDMA
		IEEE	OFDMA TDD WMAN
4G	IMT-Advanced	3GPP	LTE-Advanced
		IEEE	WirelessMAN-Advanced
5G	IMT-2020	3GPP	NR (novi radio)
			NR+LTE

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Standard IMT-2020 (5G)

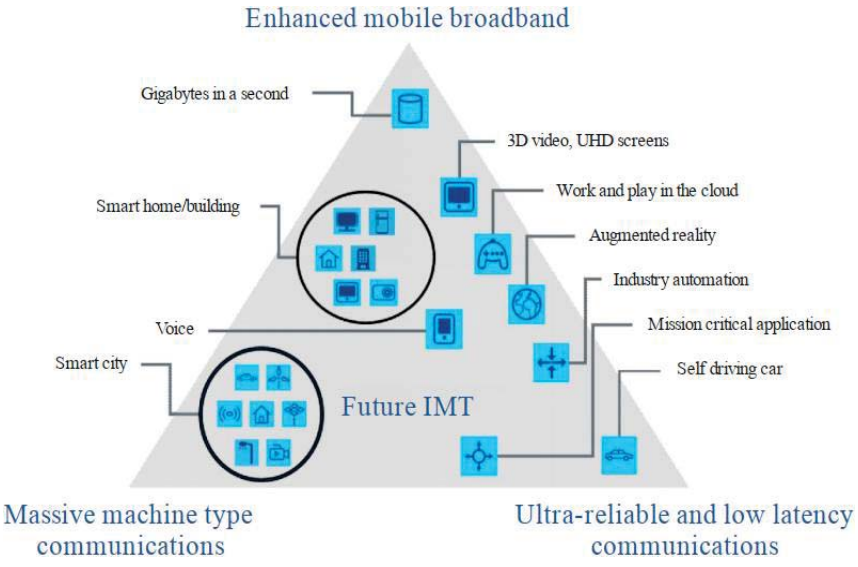
- 2012 – Program IMT za 2020 in naprej
- 2013 – Časovnica proti IMT-2020
- 2015 – Vzpostavljena ciljna skupina za IMT-2020 in izdana vizija IMT-2020
- 2016 – Objava devetih osnutkov priporočil in tehničnih poročil za IMT-2020
- 2017 – Zahteve, evalvacijski kriteriji in oddajne predloge za razvoj IMT-2020
- 2020 – Zaključek evalvacije in potrditev IMT-2020 tehnologij
- 2021 – Podrobne specifikacije radijskih vmesnikov IMT-2020 (3GPP 5G-SRIT, 3GPP 5G-RIT, 5Gi)

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Zahteve radijskega vmesnika v IMT-2020 (5G)

Trije glavni primeri uporabe:

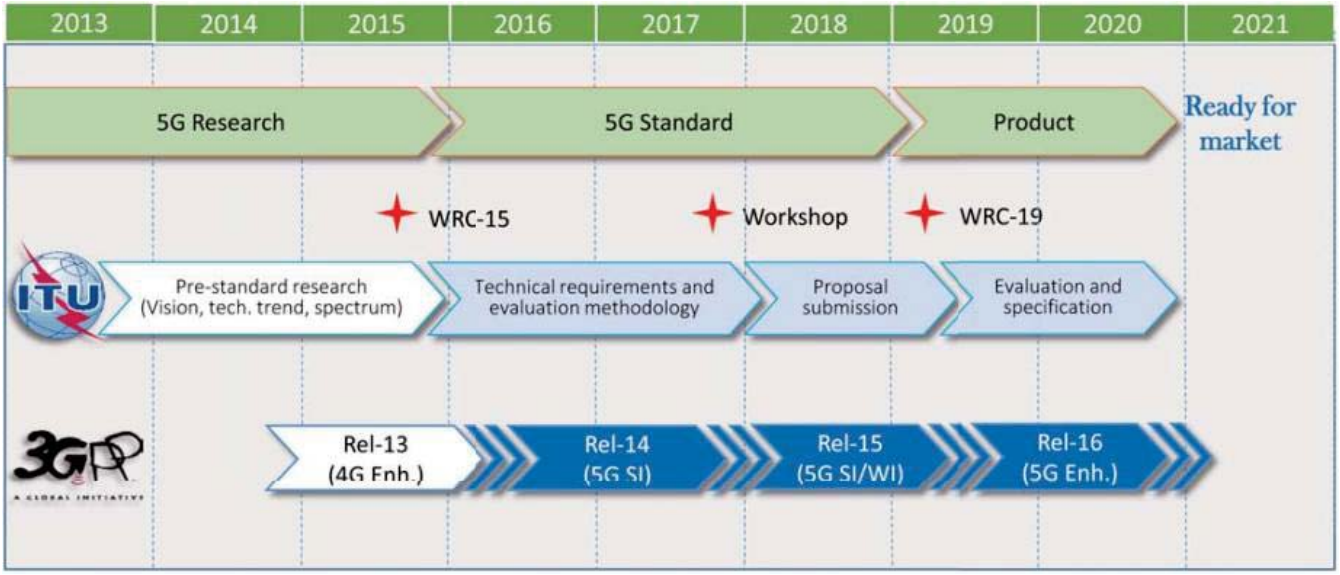
- izboljšan mobilni širokopasovni dostop (eMBB) – **nesamostojni ali samostojni način 5G**
- izjemno zanesljive komunikacije z nizko zakasnitvijo (URLLC) – **samostojni način 5G**
- množična komunikacija naprav (mMTC) – **samostojni način 5G**



Vir: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

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Časovnica razvoja omrežja 5G: mejniki najpomembnejših akterjev



Vir: http://www.imt2020.org.cn/en/documents/download/22

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Način uvedbe 5G v javnih mobilnih omrežjih: Samostojni (Standalone – SA), Nesamostojni (Non-standalone – NSA)

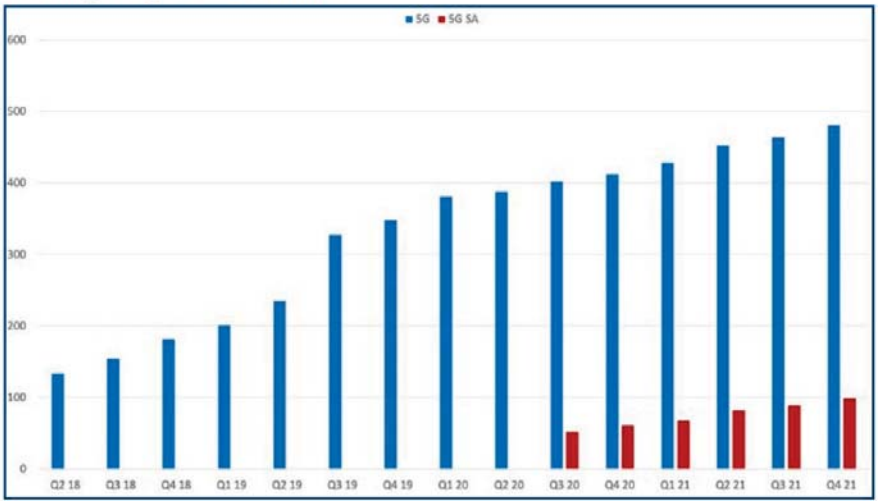
• Okoli 20 operaterjev v 16 državah je že uvedlo 5G SA (januar 2022).

• Okoli 30 operaterjev testira, uvaja ali pa je že uvedlo SA, vendar še ne ponujajo tržnih storitev.

• Še vedno prevladujejo investicije in uvedbe v NSA načinu. Le 20% investicij je trenutno v način SA.

Vir: https://gsacom.com/paper/5g-standalone-january-2022-member-report-with-annex/

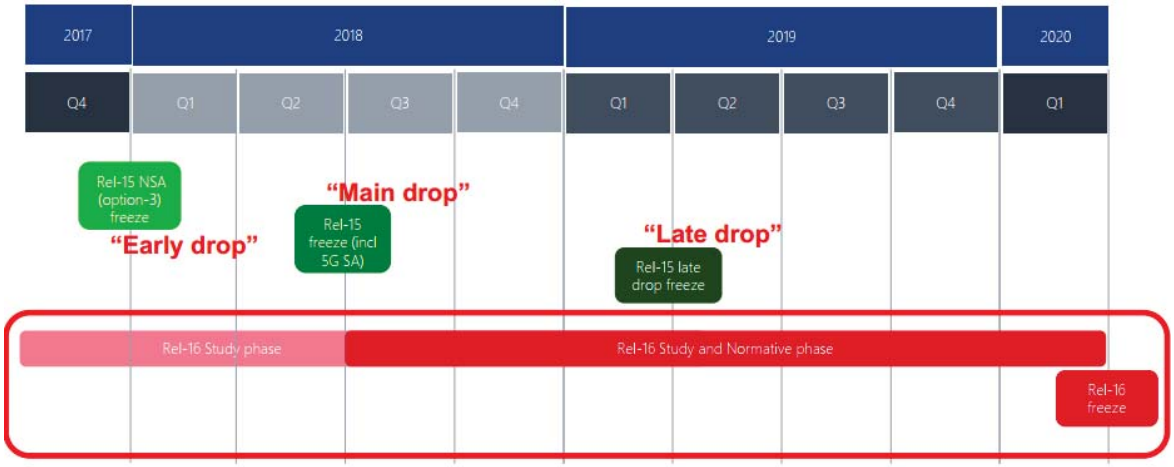
Figure 1: Number of operators investing in 5G SA for public networks versus number investing in any 3GPP 5G network



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Organizacija 3GPP in razvoj standarda 5G NR: Zgodnja (NSA), osrednja (SA) in pozna (LTE na 5GC) objava izdaje 15

• Pri 5G je izjemoma omogočen nesamostojni način delovanja omrežja, izjemoma tudi 3 objave (drop) iste 3GPP izdaje (Release 15).



Vir: https://www.3gpp.org/ftp/Information/presentations/presentations_2019/2019_05_Wireless-Russia-Sasha-Sirotkin.pdf

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Zakaj nesamostojni 5G?

• Pritisk ekosistema 5G po čimprejšnji uvedbi omrežja 5G v praksi, vsaj na radijskem delu.

• Preprečitev razdrobljenosti standardov 5G.

• Kompleksno virtualizirano jedro 5GC.

• Uporaba obstoječega jedra EPC omogoča hitrejšo uvedbo in manjše začetne stroške za operaterje.

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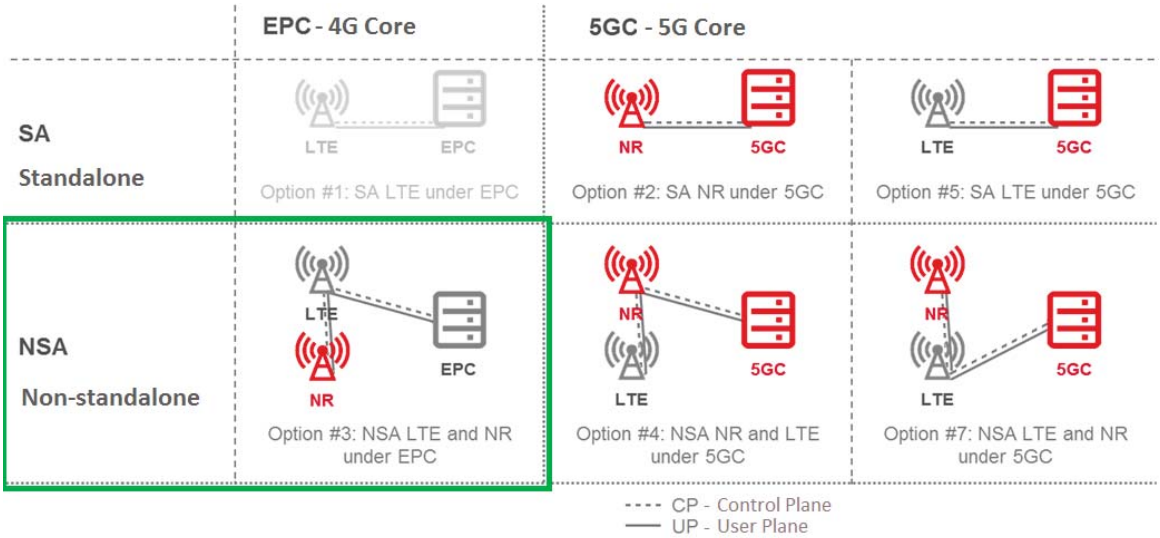
Primerjava med 4G in 5G parametri

Parameter	4G Long Term Evolution	5G New Radio
Full Name	Long Term Evolution	New Radio
3GPP Release	Release 8 – Release 14 (LTE, LTE-A, LTE-Pro)	Release 15 onward
Frequency Range	< 6 GHz	Upto 52.6 GHz
Services	Voice, MBB, IoT	Voice, eMBB, Low Latency Application, Massive IoT
Waveform	DL: CP -OFDM	DL: CP-OFDM;
	UL: DFT -S-OFDM	UL: CP-OFDM, DFT-S-OFDM
Max Carrier Bandwidth	20 MHz	FR1 Below 6 GHz: 100 MHz
		FR2 Above 6 GHz: 400 MHz
Subcarrier Spacing (SCS)	15 kHz	15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz

Vir: https://www.techplayon.com/5g-and-4g-comparison/

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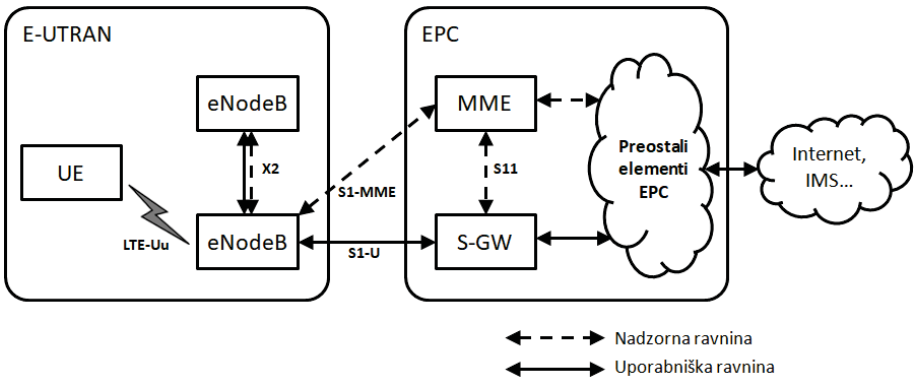
Možnosti uvedbe 5G: Osnovne arhitekturne izbire (options)



Vir: https://www.gsma.com/futurenetworks/wp-content/uploads/2018/04/Road-to-5G-Introduction-and-Migration_FINAL.pdf

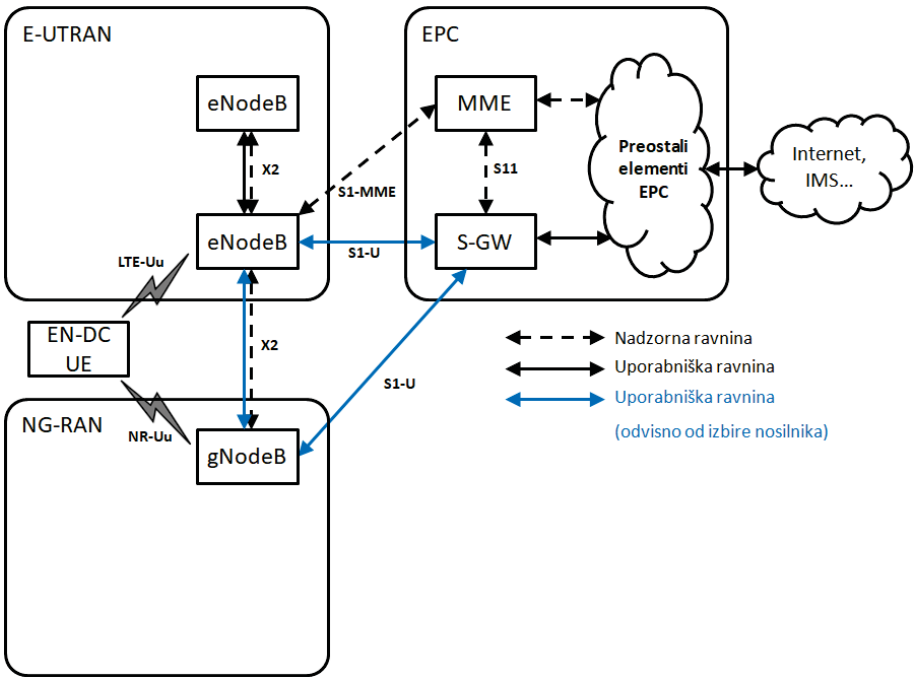
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Arhitektura omrežja 4G



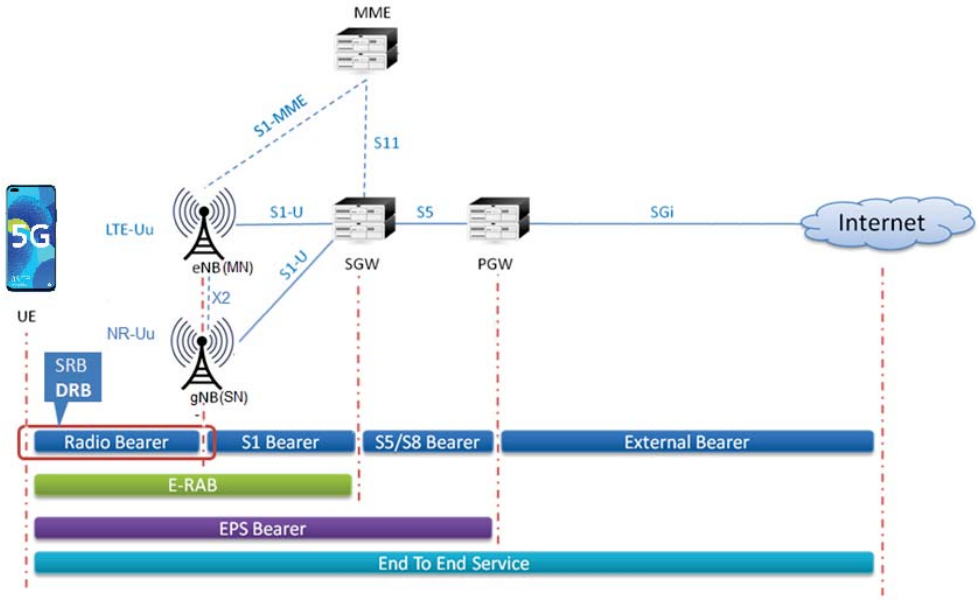
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Nesamostojna arhitektura omrežja 5G v dvojni povezljivosti s 4G



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Nosilniki v mobilnih omrežjih: Arhitekturne izbire 5G NSA odvisne od nastavitve podatkovnega radijskega nosilnika DRB



Vir:
http://140.117.164.12/data/ITRI_OAI/01_ITRI%20LTE%20RRC%20software%20introduction_20160415.ppt

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Dvojna povezljivost (Dual connectivity – DC)

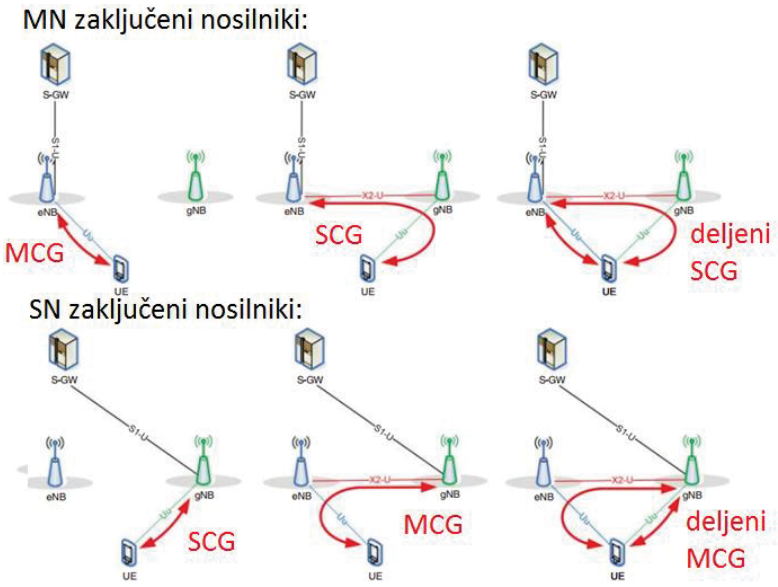
• Organizacija 3GPP je za nesamostojni način delovanja omrežja definirala t. i. večradijsko dvojno povezljivost (multi-radio dual connectivity – MR-DC).

• Arhitektura MR-DC definira v radijskem delu omrežja dva logična radijska dostopovna elementa (bazni postaji). Prek **glavnega elementa** (**master node – MN**) vedno poteka izmenjava podatkov **nadzorne ravnine** z jedrnem omrežjem, odvisno od nastavitev pa lahko tudi izmenjava podatkov uporabniške ravnine. Prek **sekundarnega elementa** (**secondary node – SN**) pa se z jedrnem omrežjem izmenjujejo zgolj podatki **uporabniške ravnine**.

• Arhitekturo MR-DC je možno uporabiti tako v kombinaciji z EPC kot tudi s 5GC. Arhitektura MR-DC v kombinaciji z EPC, je definirana kot **EN-DC (Nesamostojni 5G).**

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Nosilniki v E-UTRAN – NR dvojni povezljivosti (EN-DC)



•Glavni element (master node - MN)
•Sekundarni element (secondary node - SN)
•Skupina glavnih celic (master cell group - MCG)
•Skupina sekundarnih celic (secondary cell group - SCG)

•Podatkovne radijske nosilnike razvrščamo glede na to ali se proti jedru zaključujejo preko MN ali SN elementa in glede na to ali so uporabljeni radijski viri MCG, SCG ali deljeni.

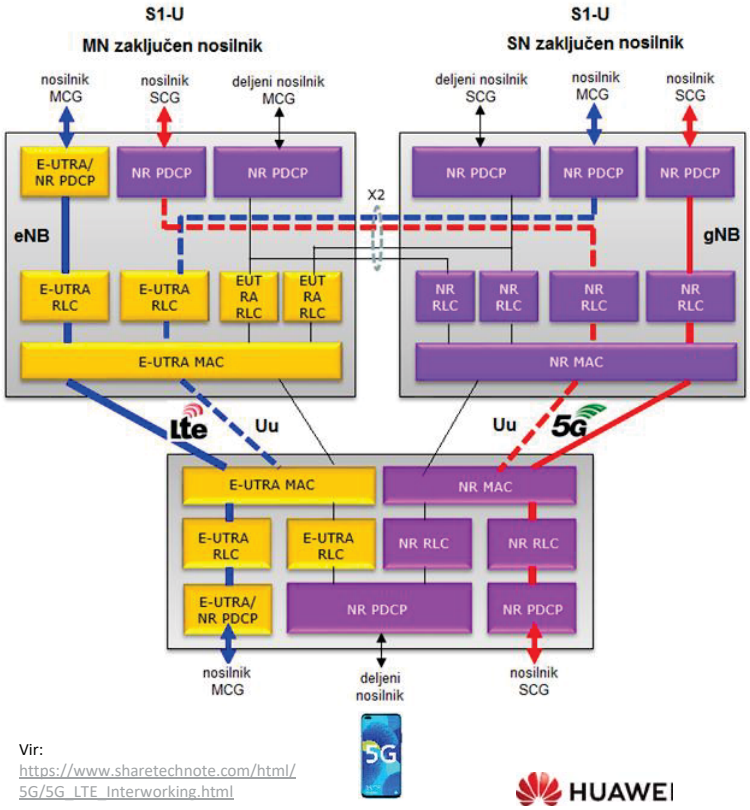
Vir: https://www.wiley.com/en-us/5G+Radio+Access+Network+Architecture:+The+Dark+Side+of+5G-p-9781119550884

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Protokolni sklad EN-DC

• Med bazno postajo LTE (eNB) in NR (gNB) mora biti vzpostavljen logični vmesnik X2, preko katerega bazni postaji izmenjujeta krmilne in uporabniške podatke, ki jih odvisno od izbranega nosilnika ena od baznih postaj združene izmenjuje z jedrom EPC.

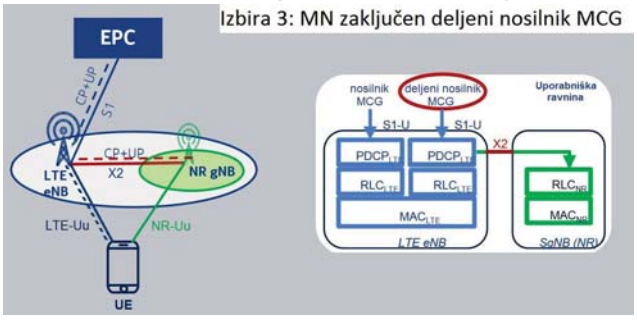
• Podatke poslane sočasno preko LTE in NR nivoja RLC vedno združuje in segmentira protokol zlivanja paketnih podatkov PDCP (NR).

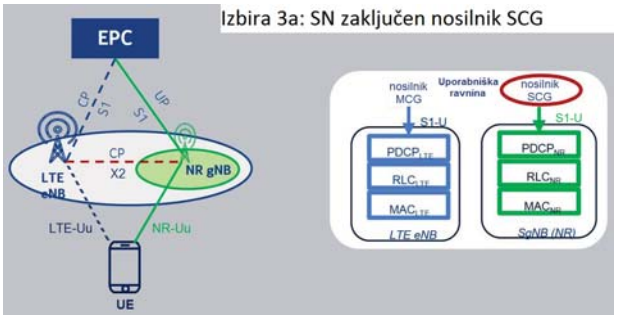


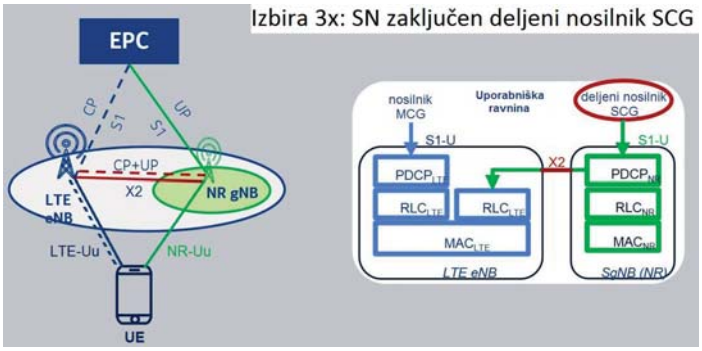
Vir: https://www.sharetechnote.com/html/5G/5G_LTE_Interworking.html

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Arhitekturne podizbire 3 (option 3) v dvojni povezljivosti: EN-DC UE je sočasno povezan z LTE in NR



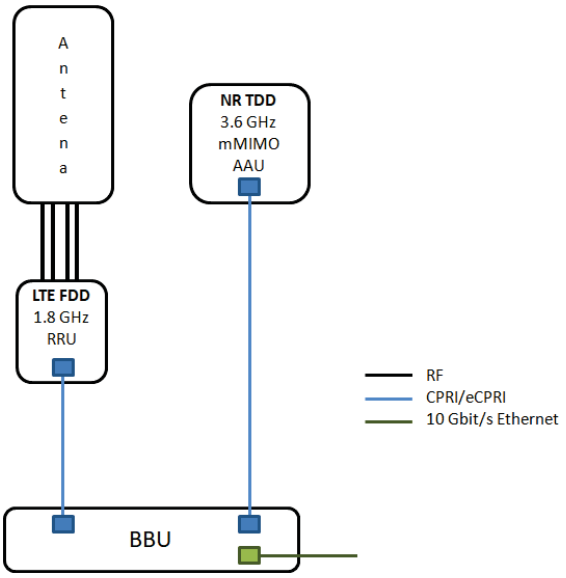


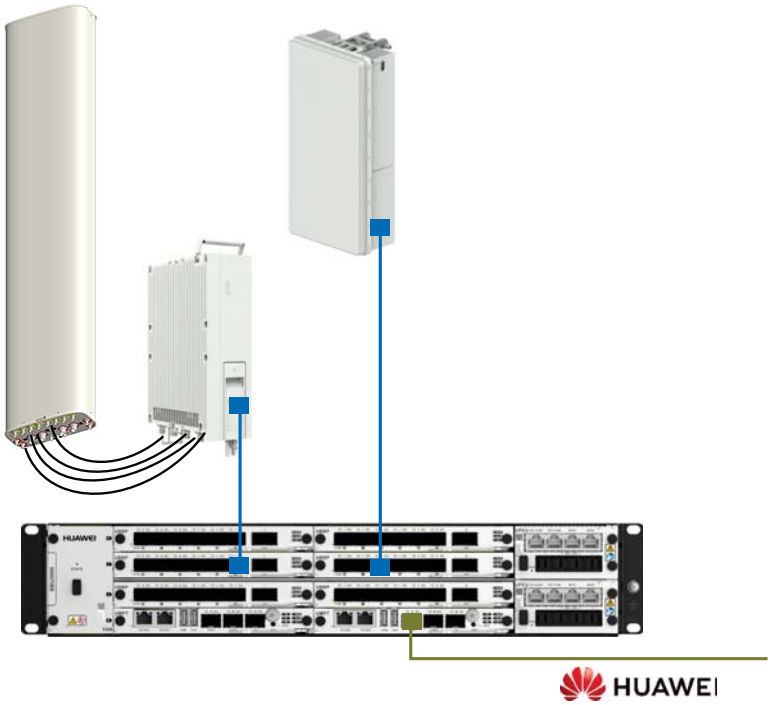


Vir:
https://www.3gpp.org/ftp/Information/presentations/presentations_2018/2018_10_17_tokyo/presentations/2018_1017_3GPP%20Summit_03_TSG-RAN_Bertenyi_Nagata.pdf

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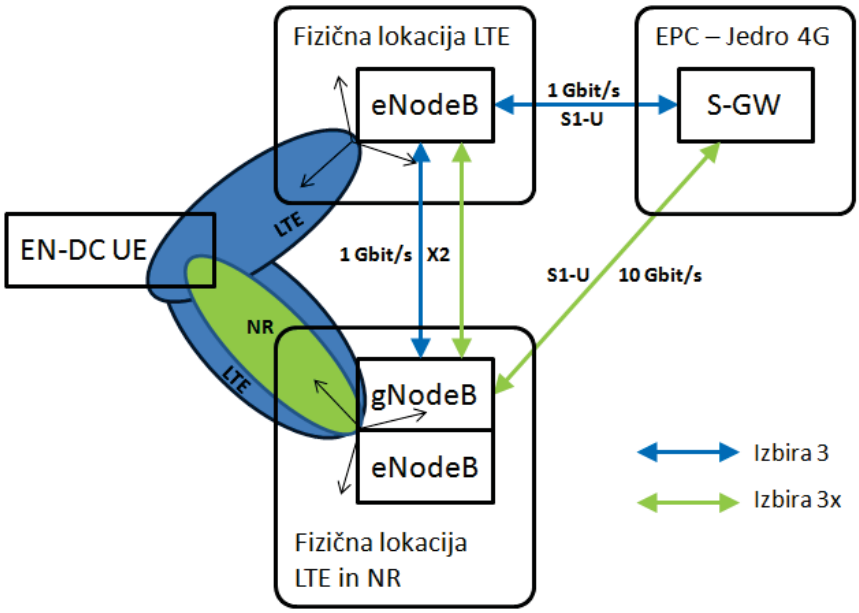
Arhitektura strojne opreme večnačinovne testne bazne postaje LTE in NR





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Praktični vidiki uvedbe nesamostojnega omrežja 5G



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Prikazovanje statusne ikone 5G v načinu NSA

• Ob prehodu aktivne povezave v mirovanje (varčevanje z viri) se ikona iz 5G spremeni v 4G
• Percepcija uporabnika je lahko, da omrežje 5G izginja
• 3GPP je v sodelovanju z GSMA definirala bit »upperLayerIndication«, katerega definicija je: UE je vstopil v področje, ki omogoča zmožnost 5G. Bit se lahko vklopi na katerikoli LTE celici.
•V tabeli je priporočilo za prikazovanje ikone uporabniških naprav na odprtem tržišču (open market devices – OMD), kadar je bit vklopljen. Problem samo enega definiranega bita je, da med stanji 2, 3 in 4 ni mogoče razlikovati. Če je bit vklopljen, to pomeni, da je za stanja 2, 3 in 4 prikazana ikona 5G, če je bit izklopljen pa ikona 4G.

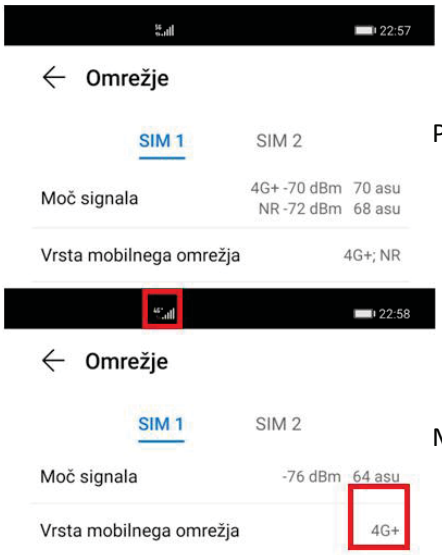
State	UE Indicator
1 (IDLE under or Connected to LTE cell not supporting NSA)	4G
2 (IDLE under or Connected to LTE cell supporting NSA and no detection of NR coverage)	5G
3 (Connected to LTE only under LTE cell supporting NSA and detection of NR coverage)	5G
4 (IDLE under LTE cell supporting NSA and detection of NR coverage)	5G
5 (Connected to LTE + NR under LTE cell supporting NSA)	5G

Vir: https://www.3gpp.org/ftp/tsg_sa/TSG_SA/TSGS_81/Docs/SP-180866.zip

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Prikazovanje statusne ikone 5G z »upperLayerIndication« bitom na LTE celici

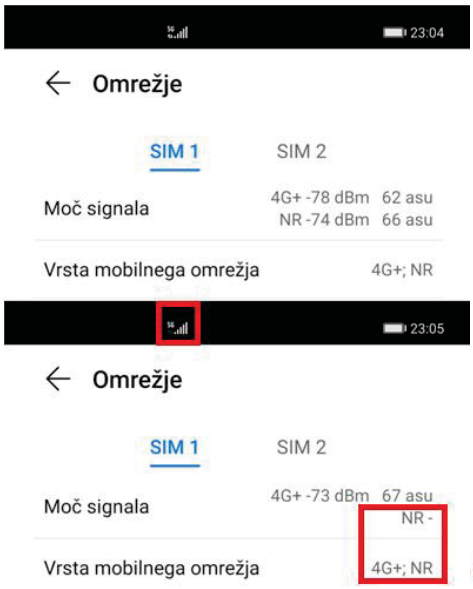
»upperLayerIndication« izklopljen:



Povezava vzpostavljena

Mirovanje povezave

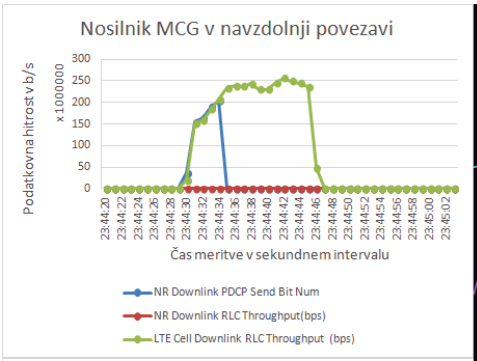
»upperLayerIndication« vklopljen:

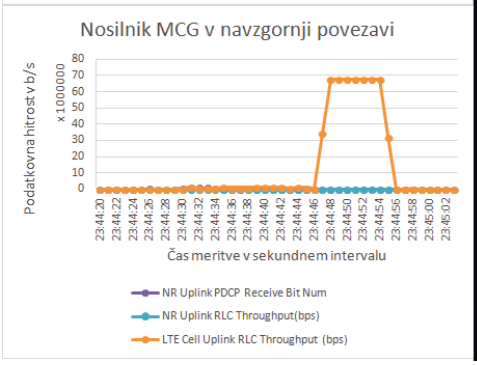


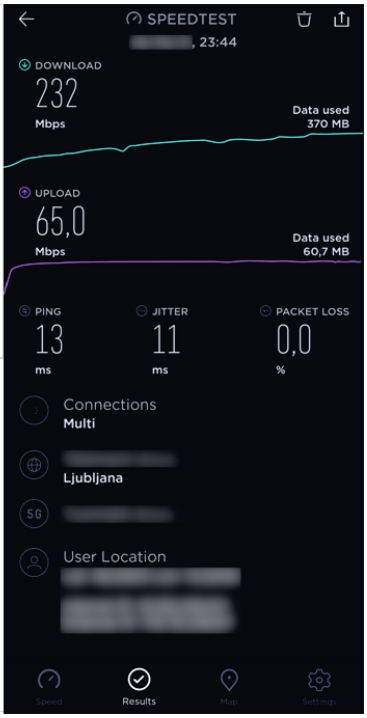
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Rezultati testiranj nosilnikov: SN zaključen nosilnik MCG

• Prenos podatkov poteka zgolj preko radijskega vmesnika LTE (4G).



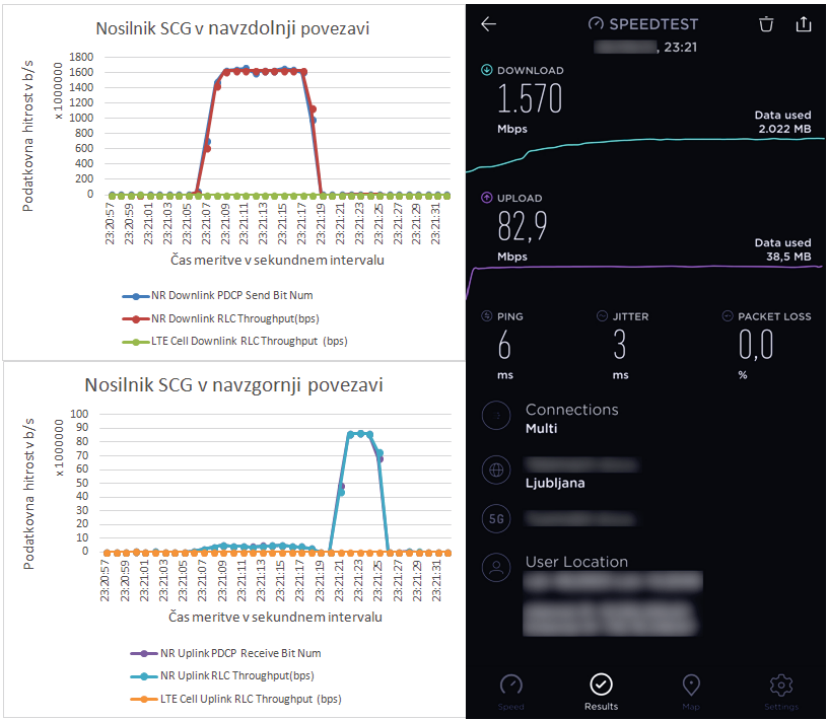




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Rezultati testiranj nosilnikov: SN zaključen nosilnik SCG

• Prenos podatkov poteka zgolj preko radijskega vmesnika NR (5G).



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Rezultati testiranj nosilnikov: SN zaključen deljeni nosilnik SCG

• Prenos podatkov poteka preko radijskih vmesnikov NR (5G) in LTE (4G) sočasno.



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Sklep

• Nesamostojni način 5G je pohitril uvedbo na radijskem delu in preprečil razdrobljenost radijskih tehnologij 5G, vendar omogoča zgolj primer uporabe eMBB. V samostojnem načinu sta omogočena še mMTC in URLLC.

• Najvišje hitrosti v praksi nudita arhitekturni izbiri 3 in 3x, saj bazna postaja 4G in 5G izmenjujeta uporabniške podatke preko obeh radijskih vmesnikov sočasno (LTE + NR). V praksi se bolje izkaže izbira 3x zaradi podatkovnih hitrosti omrežnih vmesnikov.

• Vklop bita za prikaz ikone 5G na celici LTE je smiseln, vendar le na celicah LTE višjih frekvenčnih območjih in le na sektorjih kjer se oddaja tudi NR. S tem se zagotovi, da je prikazovanje bolj omejeno na območje, kjer naprave dejansko vzpostavijo povezavo 5G.

• Dvojna povezljivost je energetsko bolj potratna. Dodajanje NR v povezavo je smiselno zgolj pri večji količini podatkov v čakalni vrsti za prenos proti uporabniški napravi, kar je možno nastaviti na bazni postaji.

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Thank you.

把数字世界带入每个人、每个家庭、
每个组织，构建万物互联的智能世界。

Bring digital to every person, home, and organization for a fully connected, intelligent world.

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Sistemi za avtomatsko detekcijo radijskega signala

Automatic radio signal detection systems

Mirko Ivačič

Think RF

mirko@amiteh.com

Povzetek

ThinkRF Spectrum eXperience Management (SXM) uporablja omrežje zmogljivih RF-senzorjev, povezanih v oblak, za karakterizacijo, optimizacijo in zaščito RF spektra, kot je npr. spekter omrežja 5G. SXM združuje ThinkRF tehnologijo analize RF spektra z napredno analitiko v nastavljivi naročniški storitvi v oblaku. SXM neprekinjeno in avtonomno pregleduje vsa omrežja 4G in 5G v regiji in operaterjem zagotavlja dragocene vpoglede v konkurenco. Posledično lahko operaterji spremljajo konkurenčno zasedenost, pokritost, souporabo spektra in spremembe tehnologije skozi čas.

Abstract

The ThinkRF Spectrum eXperience Management (SXM) solution uses a network of powerful, cloud-connected RF sensors to characterize, optimize, and protect RF spectrum assets such as 5G networks. SXM combines thinkRF's RF spectrum-analysis technology with advanced analytics in a configurable cloud-based subscription service. SXM continuously and autonomously characterizes all 4G and 5G network deployments in a region and provides operators with valuable competitive insights. As a result, operators can track competitive occupancy, coverage, spectrum sharing, and technology changes over time.

Biografija avtorja



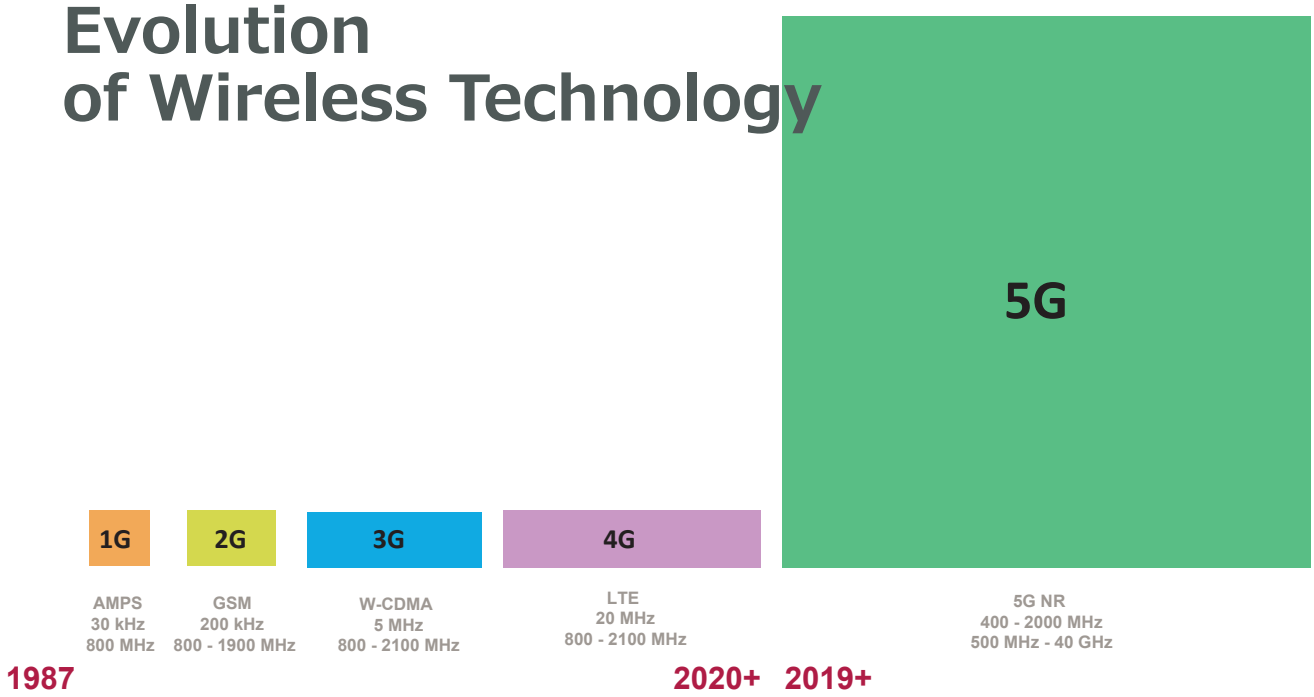
Mirko Ivančič je diplomiral leta 1978 na ljubljanski Fakulteti za elektrotehniko, smer telekomunikacije in se zaposlil v podjetju Iskra Elektrozveze, kjer je vodil oddelek merilne tehnologije. Leta 1984 se je kot inženir za podporo tehničnih računalnikov zaposlil v Hermesu, v sektorju zastopstva za Hewlett-Packard. Od 1986 do 1992 je bil odgovoren za prodajo testno-merilne opreme za področje Hrvaške, nato je postal vodja servisa in leta 1993 član uprave Hermes Plus, d. d. in direktor podpore za vse HP-jeve izdelke za področje Slovenije, Hrvaške, Makedonije in delno Slovaške. Leta 1996 je postal direktor merilne skupine za prodajo in podporo elektronske, medicinske in kemijsko-analitske merilne opreme. Leta 1997 je zapustil Hermes in po letu dni dela v podjetju Spes postal direktor Venture, podjetja za razvoj, proizvodnjo in trženje plovil. Leta 2002 se je pridružil Avektisu, takratnemu slovenskemu zastopniku podjetja Agilent Technologies (bivši HP), kot vodja prodaje elektronske merilne opreme. Od leta 2010, ko je Agilentov partner za Slovenijo postal Amiteh d.o.o., pa dela pod okriljem tega podjetja, specializiranega za trženje visokokakovostne merilne opreme priznanih proizvajalcev Keysight Technologies, Rigol, Itech in ostalih.

Author's biography

Mirko Ivančič *graduated in 1978 from the Faculty of Electrical Engineering in Ljubljana, majoring in telecommunications. After graduation he joined the company Iskra Elektrozveze, where he headed the department of measuring technology. In 1984, he took a job as a technical computer support engineer at Hermes, the Hewlett-Packard agency. From 1986 to 1992 he was responsible for the sale of test and measuring equipment for Croatia, then he became the head of the service and in 1993 a member of the Management Board of Hermes Plus, d. d. and director of support for all HP products in Slovenia, Croatia, Macedonia, and parts of Slovakia. In 1996, he became the director of the measuring group for the sale and support of electronic, medical and chemical-analytical measuring equipment. He left Hermes in 1997 and after a year at Spes company became director of Venture, a vessel development, manufacturing and marketing company. In 2002, he joined Avektis, the then Slovenian representative of Agilent Technologies (formerly HP), as head of electronic measuring equipment sales. Since 2010, when Agilent's partner for Slovenia became Amiteh d.o.o., he has been working for this company, which specializes in marketing high-quality measuring equipment from renowned manufacturers Keysight Technologies, Rigol, Itech and others.*

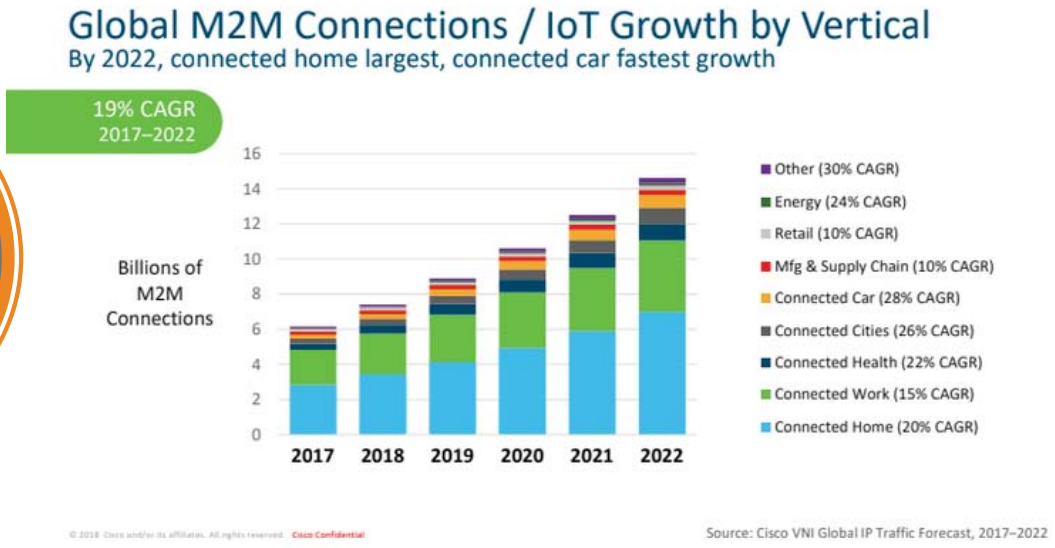


Evolution of Wireless Technology



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Growth of Wireless Technology



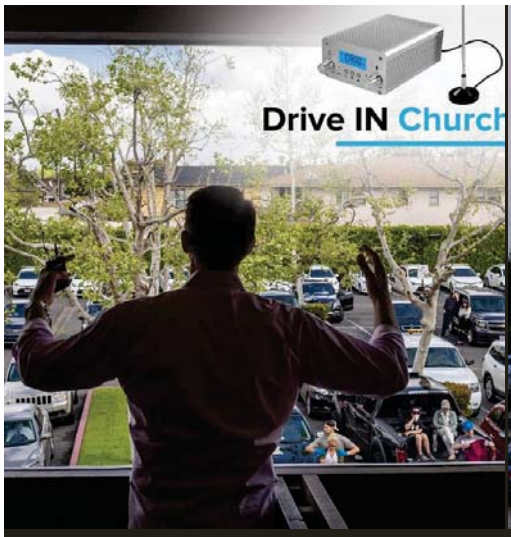
Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

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Illegal use cases are growing rapidly



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New Ways to Inadvertently Disrupt Communications

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thinkRF monitor. detect. analyze.

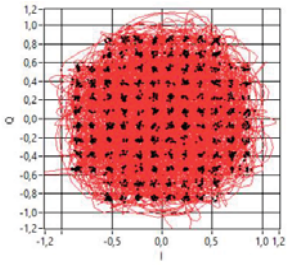
15-Watt FM transmitter



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thinkRF monitor. detect. analyze.

The Wireless Environment Is Very Complex













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thinkRF monitor. detect. analyze.

Why Monitor Spectrum?

Prevent illegal use

Optimize performance

Protect critical infrastructure

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A truck full of monitoring equipment

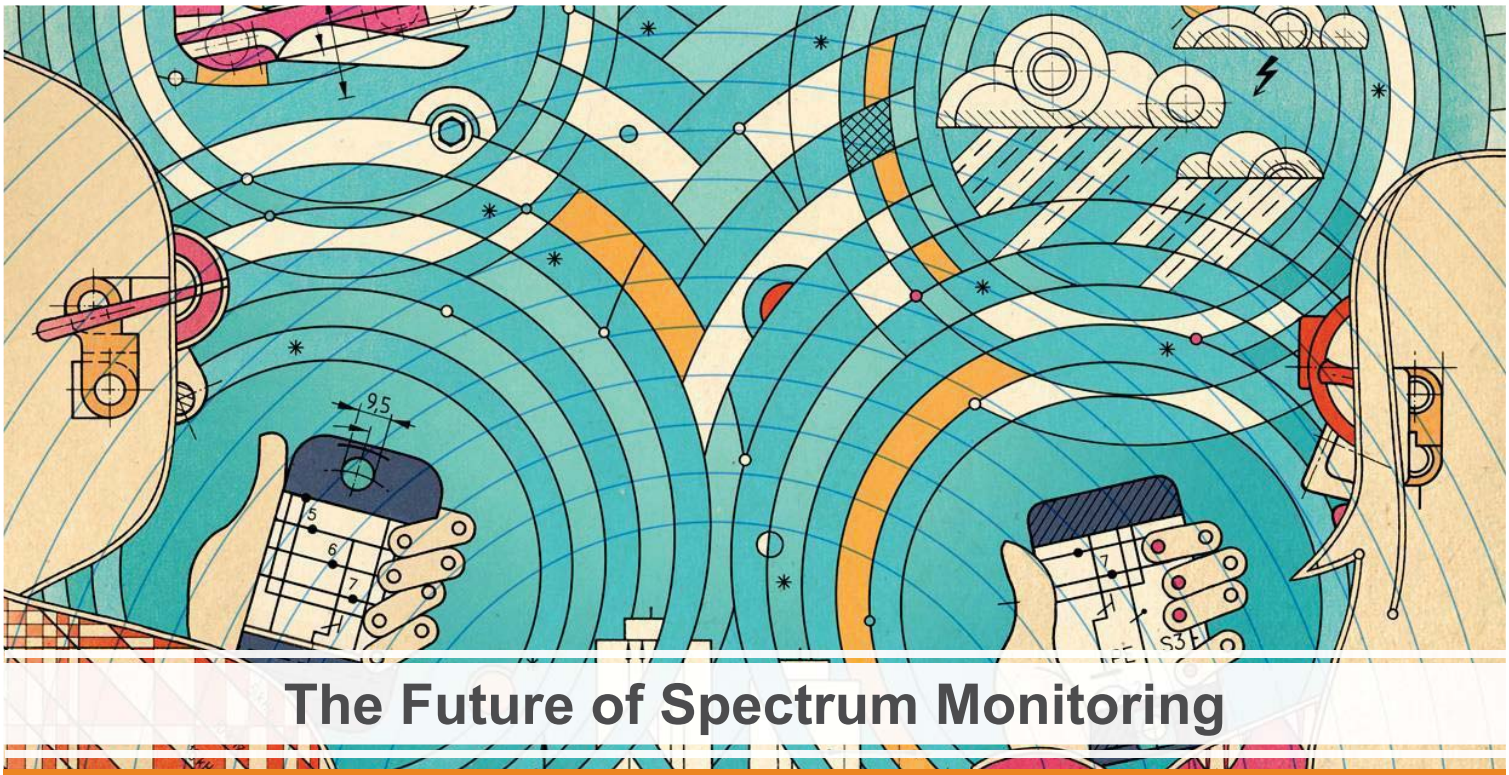








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The Future of Spectrum Monitoring

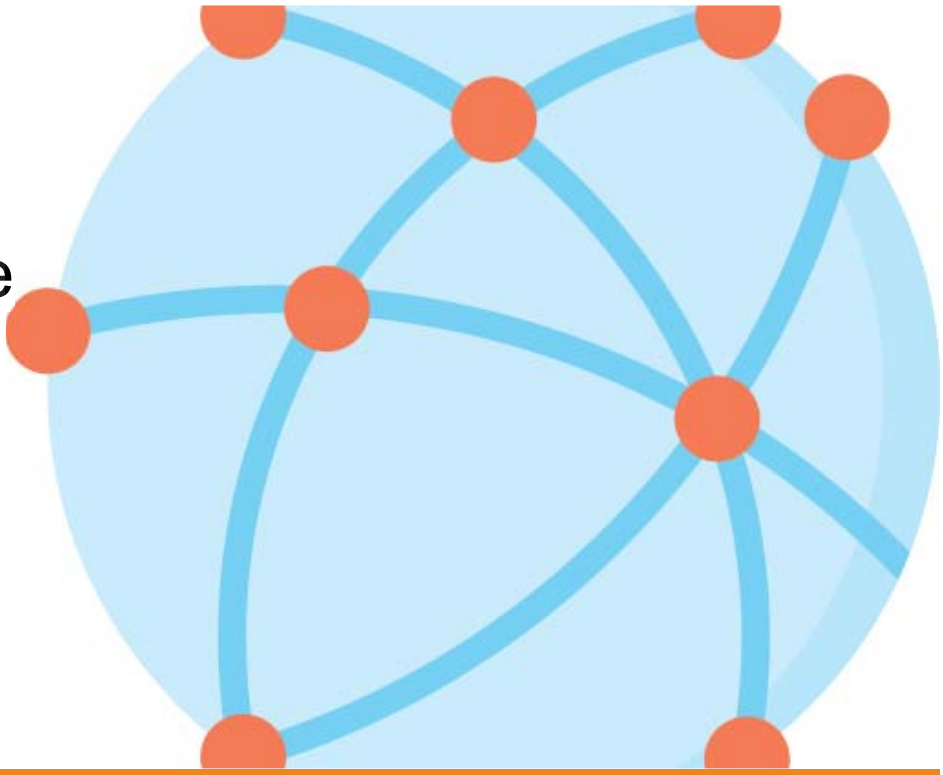
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New use cases



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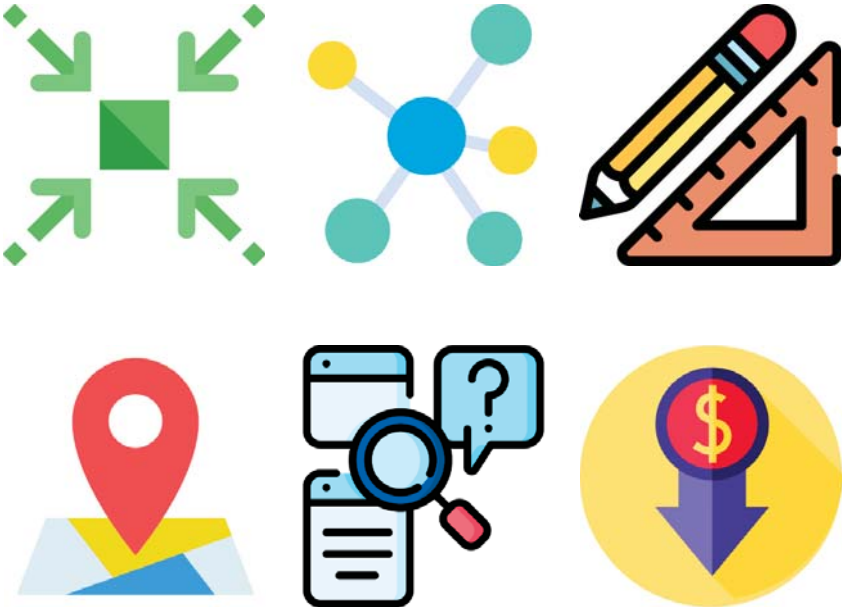
Spectrum monitoring in the not-too-distant future is distributed & persistent



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What are the key requirements?

- Signal measurement
- Signal analysis
- Real-world operation
- Transmitter Location
- Distributed
- Size, Weight, Power
- Cost



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Bench-Top Spectrum Analyzers

- Signal measurement
- Wideband Signal analysis

- Real-world operation
- Transmitter Location
- Distributed
- Size, Weight, Power
- Cost





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Low Cost Software-Defined Radios

- Size, Weight, Power
- Cost

- Signal measurement
- Wideband Signal analysis
- Real-world operation
- Transmitter Location
- Distributed






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thinkRF R5xxx Real-Time Spectrum Analyzer

- Signal measurement
- Signal analysis
- Real-world operation
- Transmitter Location
- Distributed
- Size, Weight, Power
- Cost





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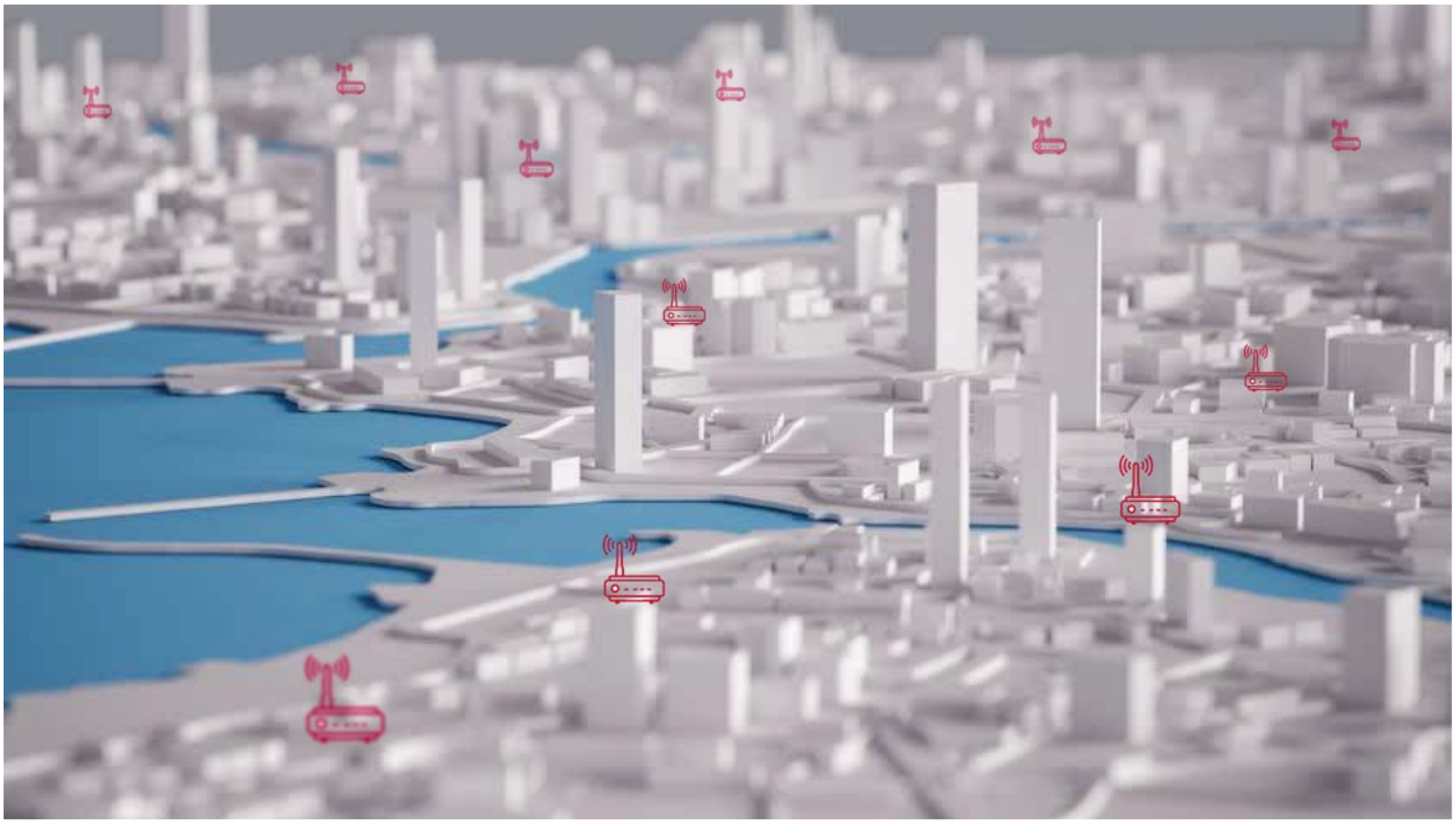
Persistent RF Monitoring

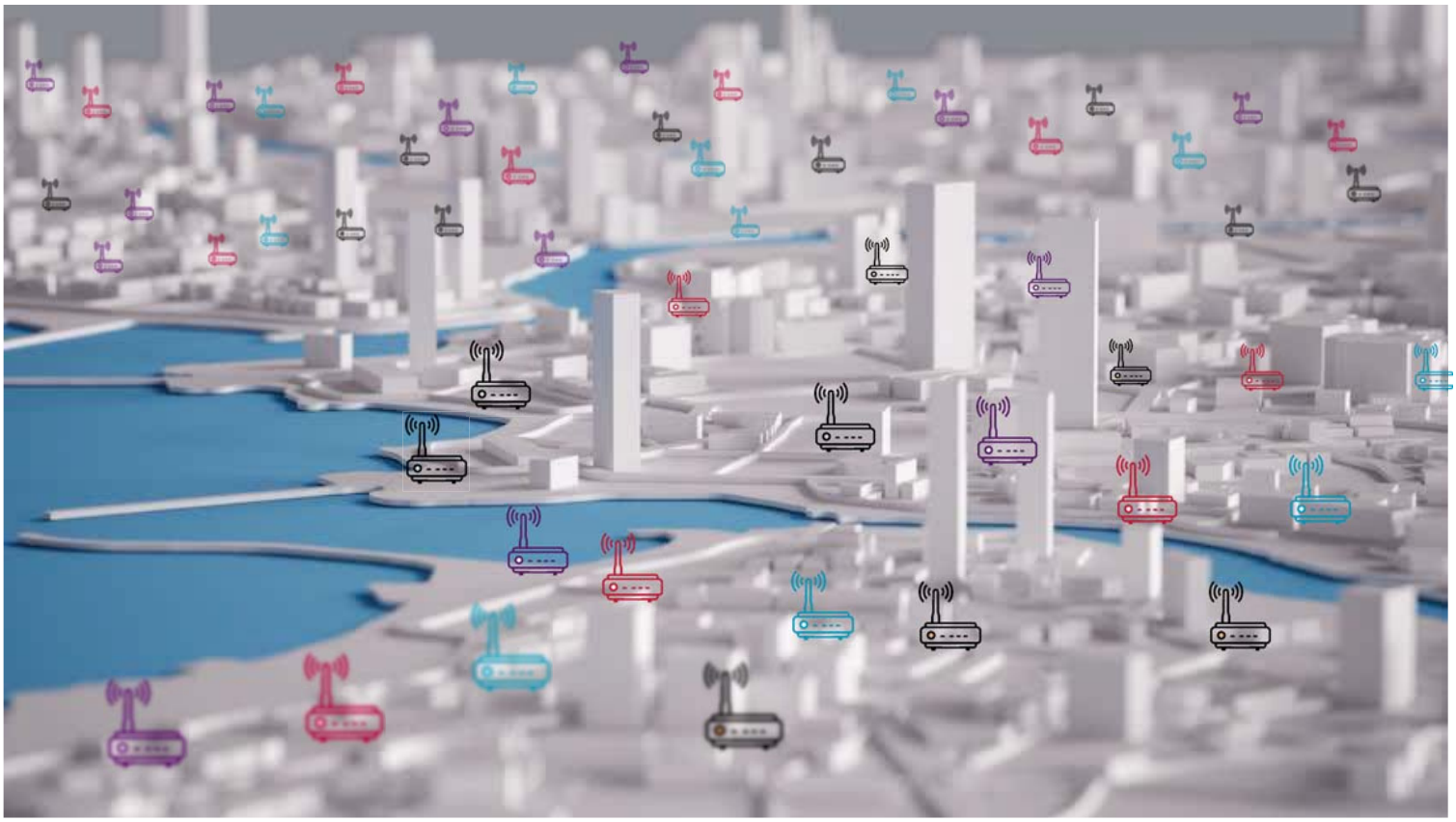
Distributed, Networked Architecture for 24x7 Real-time RF monitoring

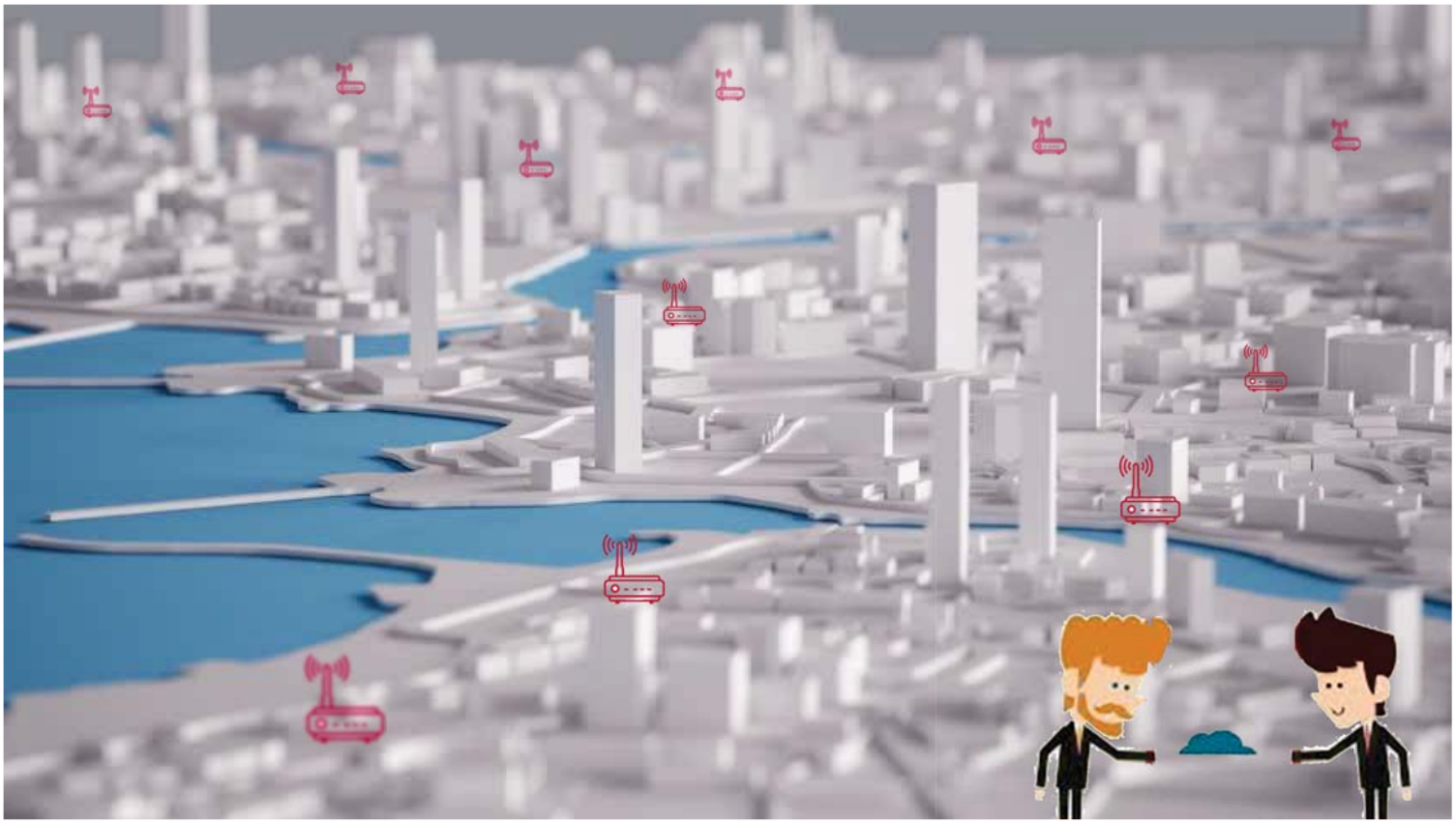
Applications:
- Interference Detection & Location
- Performance Monitoring
- Competitive Analysis
- License Enforcement

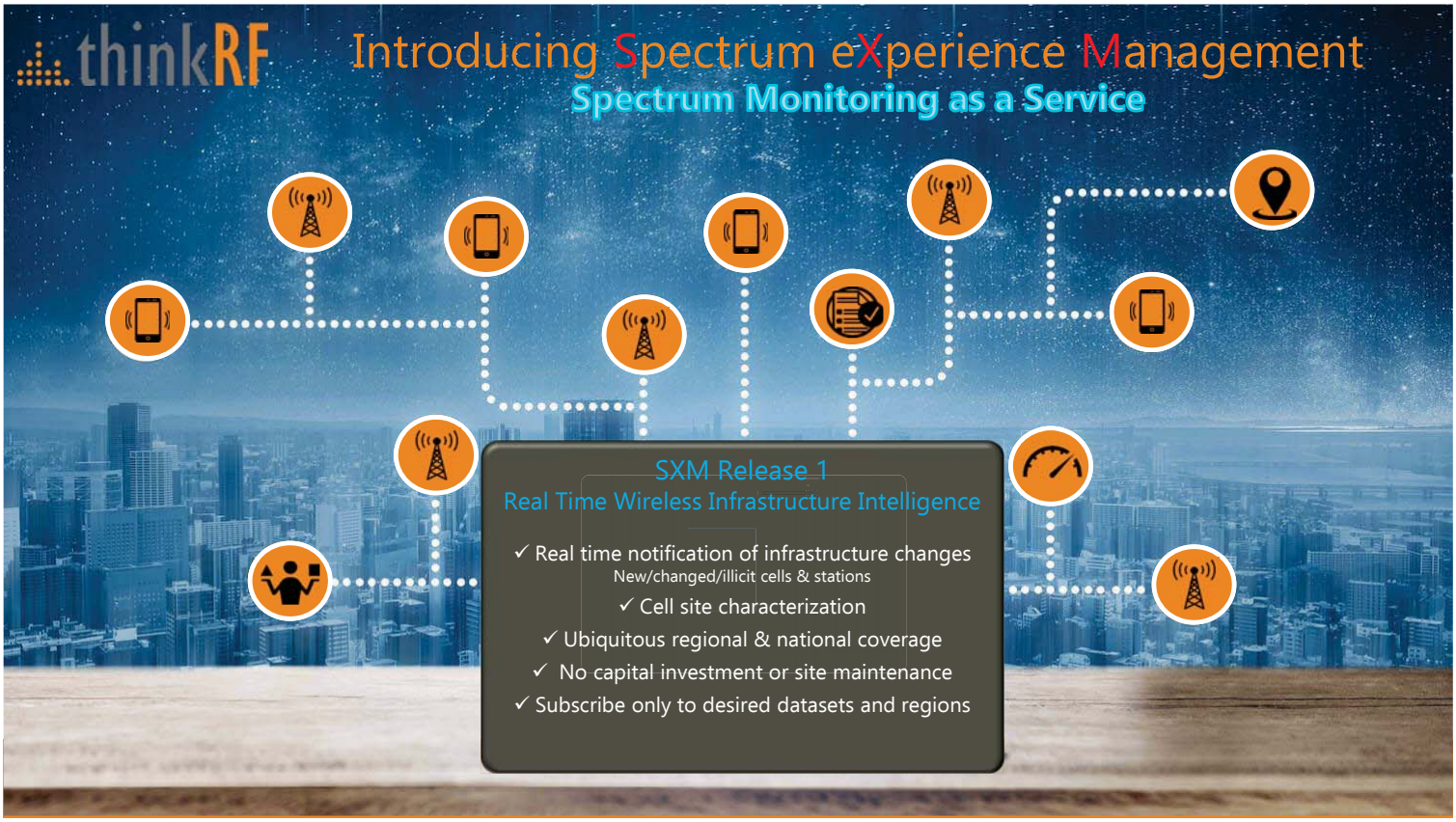


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thinkRF
Introducing Spectrum eXperience Management
Spectrum Monitoring as a Service
SXM Release 1
Real Time Wireless Infrastructure Intelligence
✓ Real time notification of infrastructure changes
New/changed/illicit cells & stations
✓ Cell site characterization
✓ Ubiquitous regional & national coverage
✓ No capital investment or site maintenance
✓ Subscribe only to desired datasets and regions



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SXM Monitoring Node

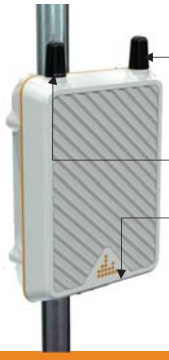
Hi fidelity RTSA
600 to 8GHz
100MHz bandwidth

Integrated signal analysis
Edge processing
IOT connectivity





Thermal management
-40 to +50 C
IP67 rated
Wall & pole mount options



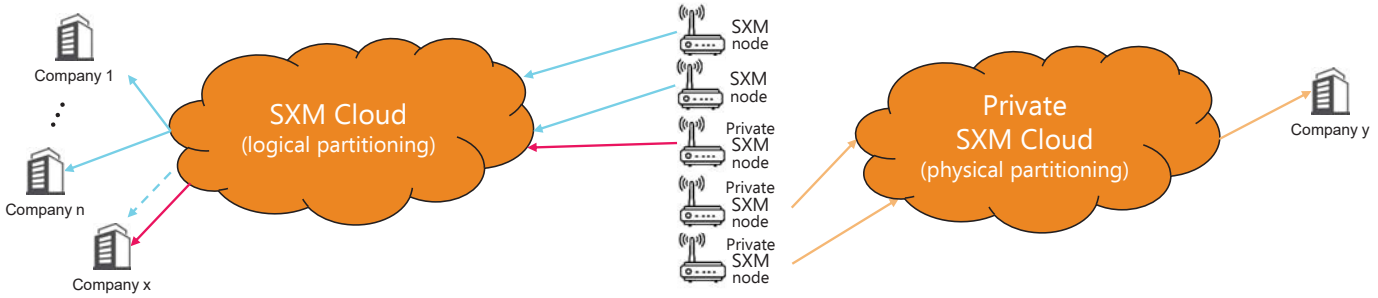
LTE IOT & GPS antenna

Rx Antenna

Optional external Rx Antenna

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SXM Network Deployment Options



Shared Nodes | Private Node(s) | Private Network

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Dashboard – Typical Data from Node

Device Id	Capture Timestamp	RAT	EARFCN	Fc	PCI	BW	MCC	MNC	NB ID	Cell ID	Antenna	RSSI(dBm)	RSRQ(dB)
210414-002	2021-11-25 21:14:31	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-10.9	-15.8
210414-003	2021-11-25 21:14:21	eLTE	2,585	887.5M	454	5	302	220	219037	33	2x2	-32.8	-29.3
210414-003	2021-11-25 21:13:26	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-30.5	-14.4
210414-002	2021-11-25 21:12:30	eLTE	5,255	753.5M	63	5	302	220	219037	21	2x2	-17.6	-23.4
210414-002	2021-11-25 21:12:19	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	8.0	-28.5
210414-003	2021-11-25 21:11:37	eLTE	5,255	753.5M	454	5	302	220	219037	21	2x2	-26.1	-33.6
210414-003	2021-11-25 21:11:25	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	-13.2	-28.0
210414-002	2021-11-25 21:11:17	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-11.1	-15.2
210414-003	2021-11-25 21:10:21	eLTE	375	2,147.5M	325	5	302	490	112674	64	4x2	-50.4	-16.9
210414-003	2021-11-25 21:10:01	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-31.3	-15.1
210414-002	2021-11-25 21:09:34	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-10.9	-14.2
210414-003	2021-11-25 21:09:32	eLTE	9,720	723.0M	454	10	302	220	219037	11	2x2	-40.4	-16.0
210414-003	2021-11-25 21:07:08	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	-15.8	-34.6
210414-002	2021-11-25 21:06:52	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	4.4	-33.0
210414-003	2021-11-25 21:05:41	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-30.4	-17.2
210414-002	2021-11-25 21:05:11	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	7.0	-31.8
210414-003	2021-11-25 21:04:00	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-30.3	-15.7
210414-003	2021-11-25 21:03:22	eLTE	9,720	723.0M	454	10	302	220	219037	11	2x2	-40.7	-17.8
210414-002	2021-11-25 21:02:49	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-11.5	-17.1
210414-003	2021-11-25 21:01:38	eLTE	5,060	734.0M	133	10	302	720	36123	9	2x2	-35.1	-30.4
210414-002	2021-11-25 21:01:30	eLTE	2,435	872.5M	485	5	302	720	36123	52	2x2	-11.3	-50.9
210414-002	2021-11-25 21:01:17	eLTE	375	2,147.5M	116	5	302	490	112674	64	4x2	-20.8	-32.9
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210414-003	2021-11-25 21:00:20	eLTE	225	2,132.5M	73	5	302	490	112674	21	4x2	-30.8	-15.2
210414-003	2021-11-25 20:59:44	eLTE	2,585	887.5M	454	5	302	220	219037	33	2x2	-39.4	-16.6

• • •

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Spectrum Monitoring Simplified

Spectrum eXperience Management (SXM)

Reduce Subscriber Churn
Identify transient interference. Attain / maintain performance leadership by dynamically adjusting deployment in lockstep with competitors.

Eliminate RF Drive Tests
24/7 regional coverage provides the data you used to get from RF drive tests, plus much more.

Critical Competitive Insights
Real-time insights about competitive network deployments and configurations.

Protect Critical Infrastructure
Identify and mitigate interference that can degrade or bring down your network.

Improve Spectrum Efficiency
Continuously characterize opportunities in shared and unlicensed spectrum bands.

No CapEx
Subscription based services. No maintenance. Just pure data as you need it.

thinkRF™
monitor. detect. analyze.

Uporaba mobilnega telefona za oceno odtisa radijskega okolja

Use of a mobile phone for radio environment fingerprint assessment

Aleš Švigelj, Tomaž Javornik

Institut Jožef Stefan

ales.svigalj@ijs.si, tomaz.javornik@ijs.si

Povzetek

Brezžične naprave, kot so mobilni telefoni, brezžične zapestnice ali pametne ure danes praviloma uporablja ena sama oseba, zato jih lahko uporabimo za modeliranje človeških stikov, medsebojne bližine in mreženja. Sodobne komunikacijske sisteme sestavlja vrsta različnih brezžičnih tehnologij in omrežij, ki jih lahko zaznajo uporabniki. Skupna značilnost večine brezžičnih dostopovnih točk je, da jih brezžične naprave zaznajo brez kakršnega koli posega v samo telekomunikacijsko infrastrukturo. Tako uporabnik radijsko okolje spremlja s svojo napravo pri čemer izkorišča ocenjene parametre radijskega kanala, da ustvari odtis radijskega okolja. Uporabniki/radijske naprave, ki se nahajajo blizu drug drugi, zaznajo podoben prstni odtis radijskega okolja. V raziskavi se ukvarjamo z opredelitvijo "intenzivnosti stika" med osebami/napravami in raziskujemo inovativne metode za oceno "intenzivnosti stika" na podlagi odtisa radijskega okolja, ki jo je posnela uporabnikova naprava. Osredotočamo se na tehnologije, ki jih je možno spremljati z mobilnim telefonom, predvsem WiFi in BLE. Novost in prednost predlaganega uporabniško usmerjenega pristopa je, da je uporabnik tisti, ki spremlja »radijsko okolje« in ne, da uporabniku »sledi« infrastruktura (npr. omrežni operater, ponudnik interneta, Google, ...). Metoda direktno ne izda lokacije uporabnika ampak oceni koliko je uporabnik oddaljen od sosednjih sprejemnikov. V okviru raziskav smo razvili mobilno aplikacijo za spremljanje radijskega okolja in pripadajoče zaledne storitve.

Abstract

Wireless devices such as mobile phones, wireless bracelets or smartwatches are now commonly used by a single person. Thus, they can be used to model human contact, proximity to each other or social networking. Modern communication systems consist of a number of different communication technologies that can be detect by users. A common feature of most wireless base stations/access points is that they can be detected by wireless devices without the need for any intervention from the infrastructure. Thus, the users monitor the radio environment with their device, using the estimated parameters of the radio channel to create a fingerprint of the radio environment. Users/ radio devices located close to each other perceive a similar fingerprint of the radio environment. In this research, we address the "contact intensity" between people/devices and investigate innovative methods for estimating the "contact intensity" based on the footprint of the radio environment recorded by the user device. We focus on technology that can be monitored with mobile phone, especially WiFi and BLE. The

novelty of our approach is that it is the user who is monitoring the "radio environment" and it is not the infrastructure "tracing" the user (e.g. telcos, internet service providers, Google, ...). The method does not directly output the user's location, but estimates how far the user is from neighboring receivers. As part of our research, we have developed a mobile application to monitor the radio environment and related backend services.

Biografija avtorja



prof. dr. **Aleš Švigelj** je doktoriral leta 2003 na Fakulteti za elektrotehniko Univerze v Ljubljani. Je višji znanstveni sodelavec na Odseku za komunikacijske sisteme na Institutu Jožef Stefan in redni profesor na Mednarodni podiplomski šoli Jožefa Stefana. Njegovo raziskovalno področje obsega modeliranja, simulacije in načrtovanje naprednih telekomunikacijskih elementov, sistemov in storitev. Njegovo trenutno delo pa se osredinja na napredne omrežne tehnologije za brezžične sisteme in pametna omrežja. Sodeloval je pri več domačih in mednarodnih projektih, vključno s projekti COST. Bil je tehnični/znanstveni koordinator projekta SUNSEED FP7. Je soavtor več knjig ter poglavij knjig, soavtor enega ameriškega patenta in več kot 80 recenziranih člankov in konferenčnih prispevkov. Je član IEEE.

Author's biography

*Prof. dr. **Aleš Švigelj** was awarded his Ph.D. from the Faculty of Electrical Engineering, University of Ljubljana, in 2003. He is a research fellow in the Department of Communication Systems at the Jozef Stefan Institute and full professor at the Jožef Stefan Postgraduate School. He has extensive research in modelling, simulation, and design of advanced telecommunications elements, systems, and services. His current work focuses on the advanced networking technologies for wireless systems and smart grids. He has participated in several national and international projects including COST projects. Recently, he was a technical/scientific coordinator of the FP7 SUNSEED project. He co-authored several books/book chapters and more than 80 peer-reviewed journal and conference papers. He is member of IEEE.*



Uporaba mobilnega telefona za oceno odtisa radijskega okolja

prof. dr. Aleš Švigelj, dr. Tomaž Javornik

ales.svigelj@ijs.si

Odsek za komunikacijske sisteme

Institut „Jožef Stefan“

Ljubljana, 2. do 4. februar 2022

Oris predstavitve

- Motivacija
- „Disclaimer“
- Radijsko okolje
  - Prstni odtis radijskega okolja oz. Radijski odtis
- Razvoj sistema za oceno intenzivnosti stika
  - Mobilna aplikacija
  - Zaledni sistem
- Zasnova algoritma
- Preliminarni rezultati
- Zaključek

Motivacija

- Epidemija COVID-19
  - Vsi smo se hitro priučili osnov epidemiologije
  - **Zmanjševanje stikov**, higiena rok in kašlja, maske, ...
- V okviru raziskovalnega programa se ukvarjamo tudi z lokalizacijo v notranjih prostorih (predznanje)
- Brezžične naprave (mobilni telefoni, pametne ure, zapestnice itd.)
  - **uporablja ena sama oseba**
  - uporaba za modeliranje človeških stikov, medsebojne bližine in mreženja
  - za nadgradnjo matematičnega modeliranja človeških stikov z empiričnimi podatki.

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„Disclaimer“

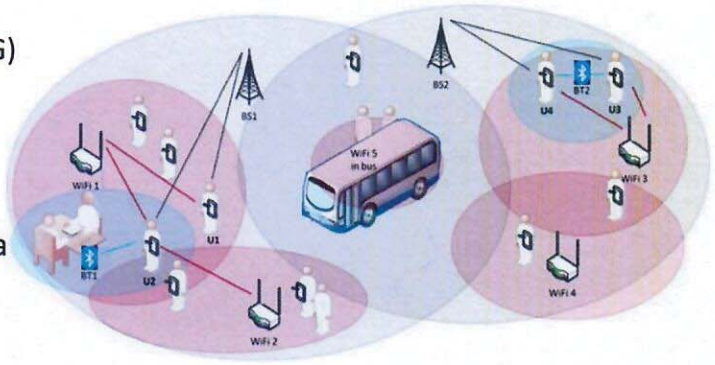
- Nismo virologi
- Nismo mikrobiologi
- Nismo epidemiologi
- Smo strokovnjaki za komunikacijska omrežja in storitve

„Proučujemo možnosti uporabe IKT za oceno intenzivnosti stika“

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Brezžični komunikacijski sistemi

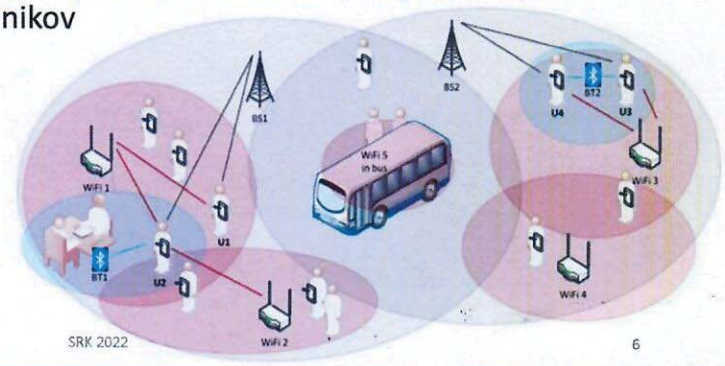
- Različne brezžične tehnologije
  - Mobilne (GSM, UMTS, LTE, 5G)
  - WiFi
  - BLE (Bluetooth Low Energy)
  - ...
- Javna ali zasebna infrastruktura
  - Ustvarja radijsko okolje



- Brezžične naprave lahko zaznajo omrežja brez kakršnega koli posega v samo telekomunikacijsko infrastrukturo

Prstni odtis radijskega okolja oz. Radijski odtis

- Množica ocenjenih parametrov radijskega kanala na sprejemniku.
- Vsak oddajnik naredi svoj radijski odtis na sprejemniku.
- Sprejemnika, ki sta blizu skupaj imata podoben radijski odtis oddajnika.
- Če imamo več oddajnikov lahko na podlagi odtisa radijskega omrežja ocenimo bližino dveh sprejemnikov



Izhodišča inovativnega pristopa

- Uporaba mobilnega telefona
- **Uporabnik** je tisti, ki spremlja radijsko okolje,
  - brez posega v infrastrukturo.
  - uporabniku NE »sledi« infrastruktura (npr. omrežni operater, ponudnik interneta, Google, ...).
- **Ne izda lokacije uporabnika/terminala** ampak oceni koliko je uporabnik/naprava oddaljena od sosednjih sprejemnikov
- Primerno tudi za časovno „zaporedno“ določitev stika (npr. uporabo kavomata, dvigala)

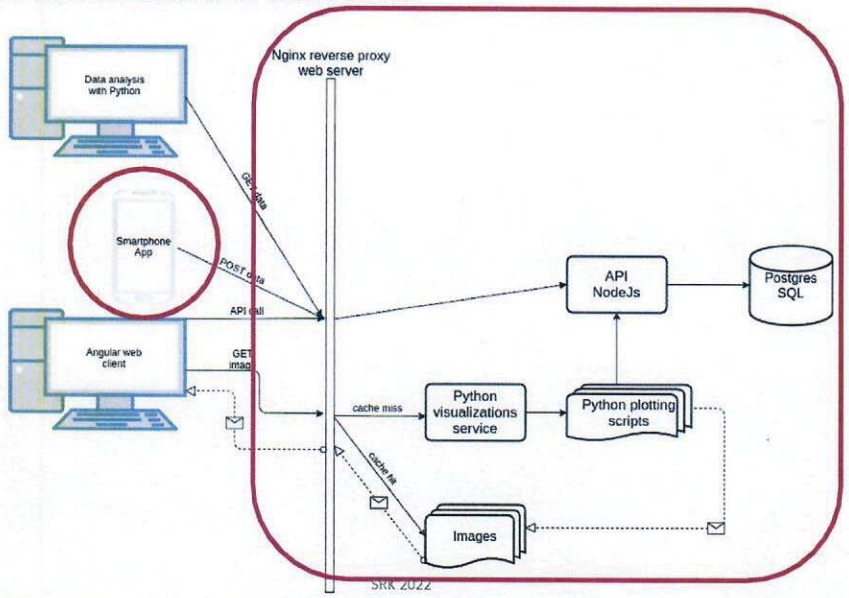
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Zaznavanje odtisa radijskega omrežja s telefonom

- Zelo primerni tehnologiji:
  - **BLE** (zelo kratek doseg, lahko del kakšne opreme (npr. kavomat)
    - Tudi aplikacija OstaniZdrav deluje na tej tehnologiji
  - **WiFi** (kratek doseg, ponavadi več oddajnikov)
- Manj primerno:
  - Mobilna omrežja (GSM, UMTS, LTE, 5G) (dolg doseg, primerno le za grobo pozicioniranje)

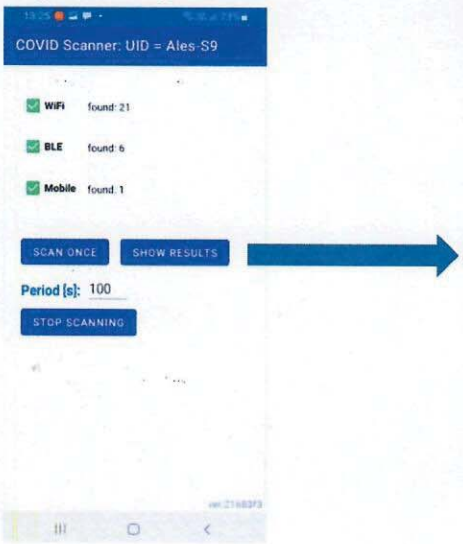
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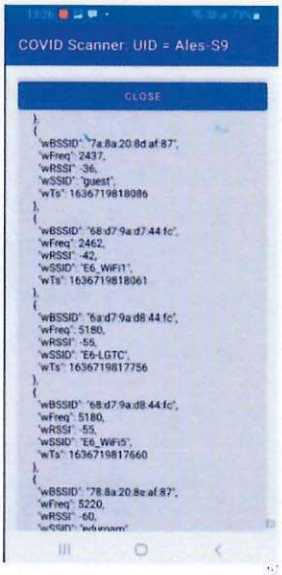
Zasnova arhitekture sistema



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Mobilna aplikacija





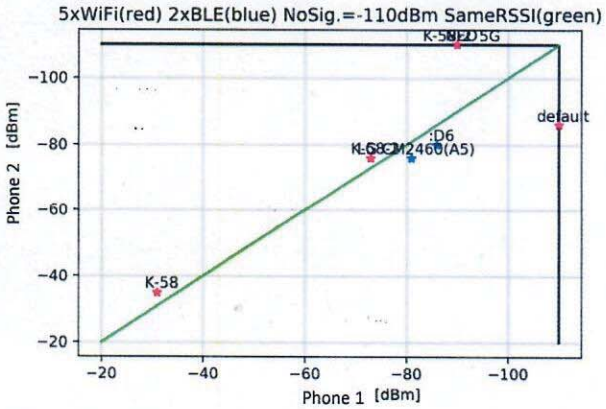
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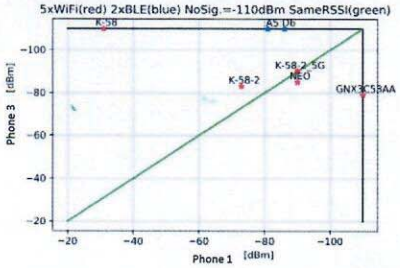
Primer radijskega odtisa WiFi in BLE

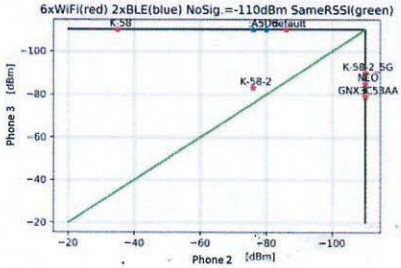
WiFi	Phone 1	Phone 2	Phone 3
SSID: 'K-58' Freq: 2417 kHz RSSI:	-31 dBm	-35 dBm	N/A
SSID: 'K-58-2'; Freq: 2417 kHz; RSSI:	-73 dBm	-76 dBm	-83 dBm
SSID: 'K-58-2_5G'; Freq: 5180 kHz; RSSI:	-90 dBm	N/A	-90 dBm
SSID: 'NEO'; Freq: 5180 kHz; RSSI:	-90 dBm	N/A	-85 dBm
SSID: 'def'; Freq: 2437 kHz; RSSI:	N/A	-86 dBm	N/A
SSID: 'GNX'; Freq: 2437 kHz; RSSI:	N/A	-86 dBm	- 79 dBm
BLE			
MAC: '09:28:2C:3A:D3:D6', RSSI:	-86 dBm	-80 dBm	N/A
MAC: '08:EF:3B:63:44:A5'; RSSI:	-81 dBm	-76dBm	N/A
MAC: '7B:DF:2C:4A:8B:CF'; RSSI:	N/A	N/A	-92 dBm

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Grafična ponazoritev radijskega odtisa

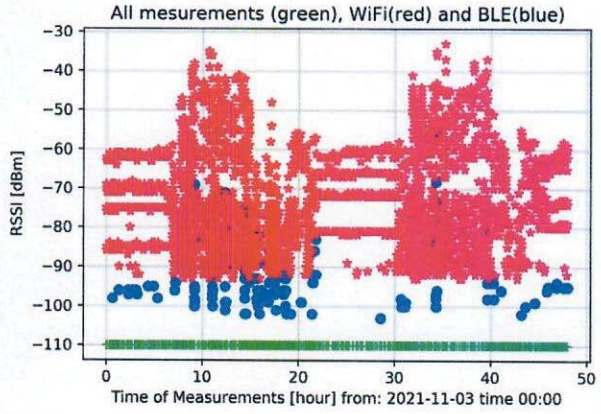


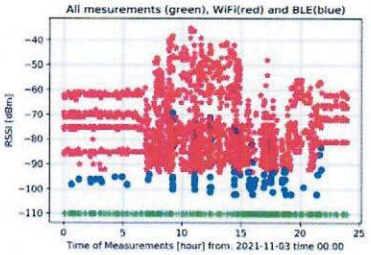


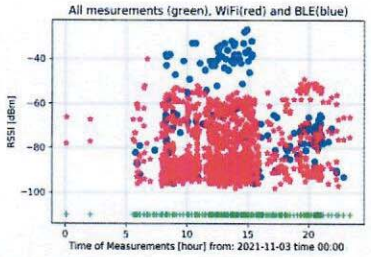


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Primeri radijskih odtisov







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Izzivi pri zasnovi algoritma za oceno intenzivnosti stika

- Položaji oddajnikov niso znani (triangulacija ni mogoča)
- Moč sevanja oddajnikov ni znana
- Geometrija in materiali okolja (tj. stene, tla, strop) niso znani

Posledice:

- Ni mogoče izračunati oddaljenost sprejemnika od oddajnikov
- Majhna sprememba v sprejeti moči naredi veliko spremembo v oddaljenosti

$$d_{\max}[m] = \frac{c[m/s]}{4\pi f[Hz]} 10^{\frac{P_t[dBm]}{20}} \left(10^{-\frac{P_{r2}[dBm]}{20}} + 10^{-\frac{P_{r1}[dBm]}{20}}\right) \qquad d_{\min}[m] = \frac{c[m/s]}{4\pi f[Hz]} 10^{\frac{P_t[dBm]}{20}} \left(10^{-\frac{P_{r2}[dBm]}{20}} - 10^{-\frac{P_{r1}[dBm]}{20}}\right)$$

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Zasnova

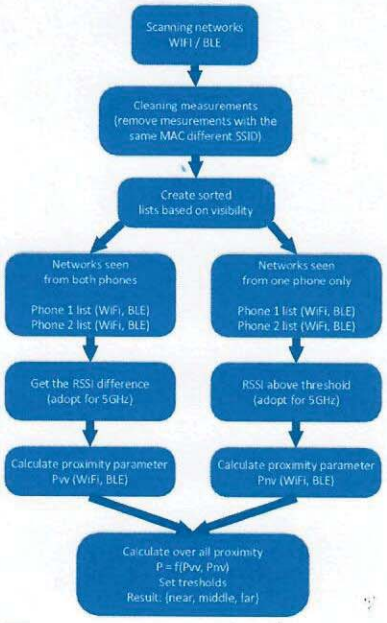
- Upoštevali:
  - Lastnosti radijskega širjenja
  - Meritve
  - Eksperimentiranje
  - Hevristiko

- Tri kategorije:
  - **blizu**: telefoni so blizu drug drugega (tj. nekaj metrov, ista soba)
  - **srednje**: telefoni so še vedno v istem okolju (tj. iste pisarne sosednje sobe)
  - **daleč**: telefoni niso v istem okolju

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Algoritem za oceno stika

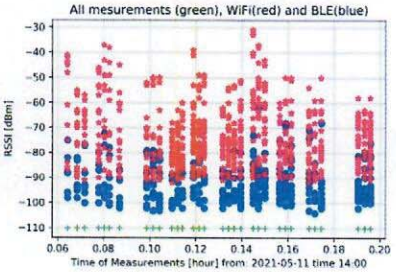
- Periodično skeniranje omrežja
- Čiščenje podatkov
  - Več SSID za isti oddajnik
- Kreiranje seznamov
  - Zaznata oba
  - Zazna samo eden
- Izračun „proximity“ parametra
- Upoštevanje pragov (hevristični)
- Določitev (blizu, srednje, daleč)

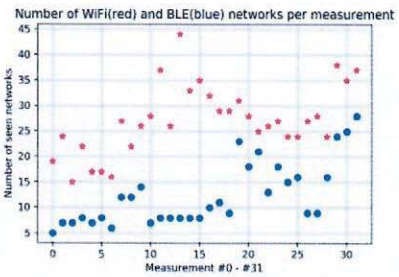


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Kalibracija / nastavitve algoritma

- Izvedba meritev (označenih) v različnih okoljih

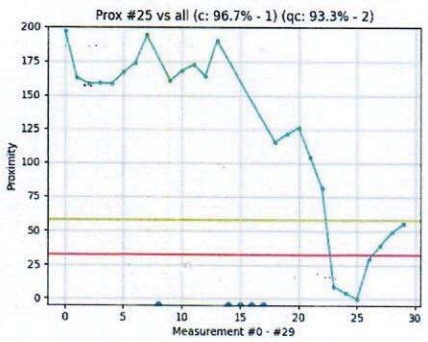


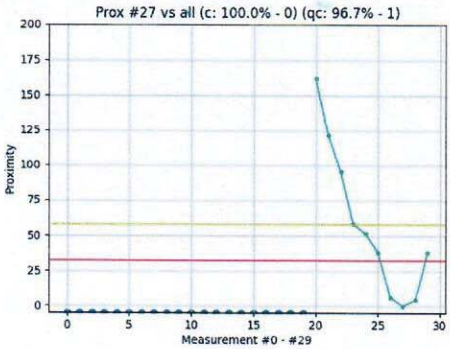


- Nastavitev parametrov in pragov

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Rezultati – posamezni primeri

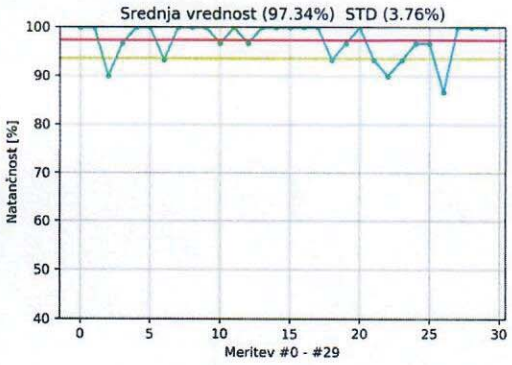




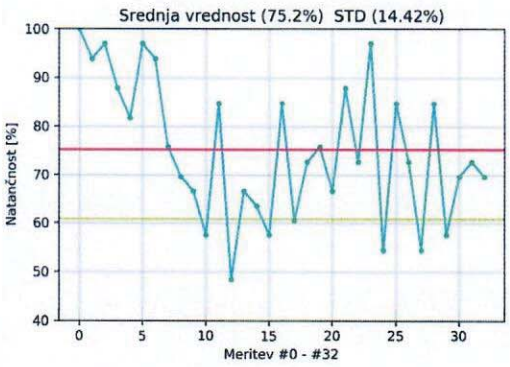
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Rezultati

Znotraj (IJS)



Zunaj (Pot na Debeli hrib)



- Uspešnost odvisno od okolja (tudi telefona)

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Zaključek

- Z uporabo prstnega odtisa radijskega okolja mobilnega telefona je možno oceniti intenzivnost stika.
- Uspešnost močno odvisna od števila in razporeditve radijskih oddajnikov.
- Primerno za oceno „zaporednega“ stika dveh uporabnikov preko skupne naprave (npr. kavomat, tiskalnik)

Trenutne / nadaljnje raziskave:

- Modeliranje človeških stikov, bližine in mreženja (npr. v poslovnem okolju).
- Nadgradnja matematičnega modeliranja človeških stikov z empiričnimi podatki.

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Development of 24 GHz SAR platform for autonomous object detection

Filip Turčinović, Marko Bosiljevac

University of Zagreb, Faculty of Electrical Engineeering and Computing, Croatia

filip.turcinovic@fer.hr, marko.bosiljevac@fer.hr

Abstract

Remote sensing today plays an important role in ensuring sustainability and protection of natural resources, in saving time and energy in industry and agriculture, and in many other applications. These applications were previously reserved for large industries, however, with recent developments in electromagnetic millimeter-wave (mm-wave) technology it is possible to build multi-spectral and radar sensors with reasonable resources. Our aim is to develop and demonstrate a Synthetic Aperture Radar (SAR) platform based on 24 GHz FMCW (Frequency Modulated Continuous Wave) radar module. For SAR processing we will use a modified Range Migration algorithm implemented on an embedded computer platform along with all the control signalling and processing. Processed SAR images will be passed through a developed object detection algorithm which will allow the system to work as a standalone platform for autonomous detection of various objects or intrusions. The paper will present the details of the development process and the developed algorithms along with the obtained results.

Authors' biograpies



Filip Turčinović *was born in Rijeka in 1994. He received B.Sc. in 2016, and M.Eng. degree in 2018 in computer engineering from the University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Zagreb, Croatia. From 2018 he works at the Department of Communication and Space Technologies at FER as research assistant. He participated in the organization of several international conferences.journal and conference papers. He is member of IEEE.*

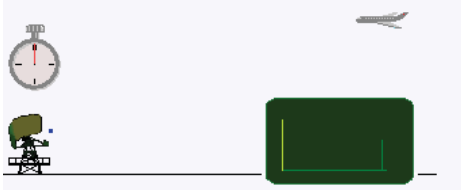


Marko Bosiljevac *was born in Zagreb in 1980. He received B.Sc., and Ph.D. degrees in electrical engineering from the University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Zagreb, Croatia, in 2005 and 2012, respectively. From March 2006 he was working at the Department of Wireless Communications at FER. He was a visiting researcher at the University of Siena, Italy in 2010 and 2011. As of March 2016 he is Assistant Professor at the Department of Wireless Communications at FER. He published more than 50 papers in journals and conference proceedings in the area of analytical and numerical modelling and development of various electromagnetic and optical structures and systems.*



Radar

- **Ra**dio **D**etection **a**nd **R**anging
- Transmits and receives signal





Door (motion sensor)



Police (radar speed gun)



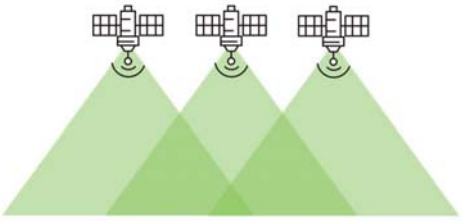
Medicine (MRI imaging)

Radar

- Sentinel-1 SAR
- Synthetic Aperture Radar
  - Radar is moving in orbit to synthesize a virtual 10 km long antenna from the physical 10 m antenna

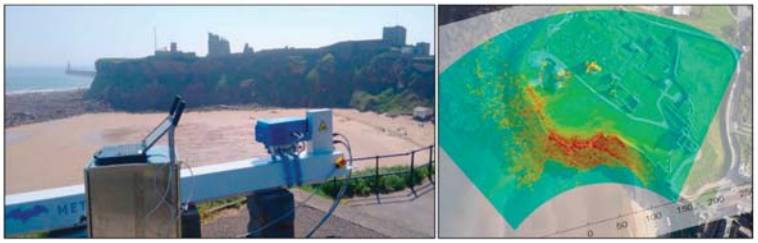


Source:ESA



Radar

- Sentinel-1 SAR
- Synthetic Aperture Radar
  - Radar is moving in orbit to synthesize a virtual 10 km long antenna from the physical 10 m antenna
- GB-SAR
  - Radar moves along a rail track to synthesize a virtual 2 m long antenna from the physical 2 cm antenna



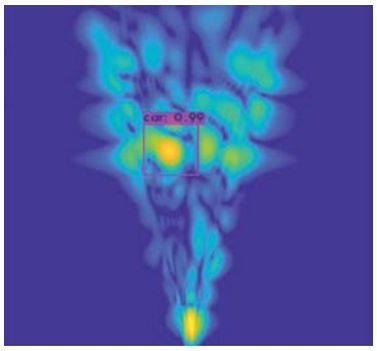
Wang, Z.; Li, Z.; Liu, Y.; Peng, J.; Long, S.; Mills, J. A New Processing Chain for Real-Time Ground-Based SAR (RT-GBSAR) Deformation Monitoring. Remote Sens. 2019, 11, 2437. https://doi.org/10.3390/rs11202437

Goal

- Development of GB-SAR
- Object recognition on SAR images



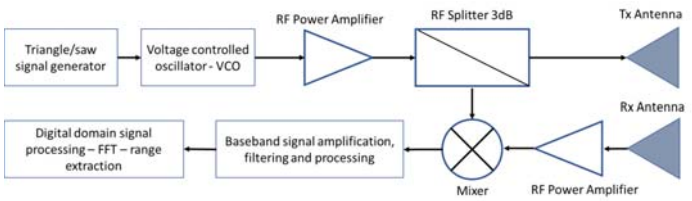
Camera photo

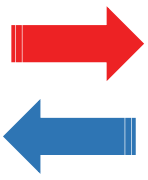


SAR image

FMCW radar

- Frequency Modulated Continuous Wave (FMCW) radar
- Transmits the **frequency modulated signal** and captures the signal reflection from the objects
  - Frequency is changed according to sawtooth law
- Delayed reflected signal and VCO signal are mixed in the receiver







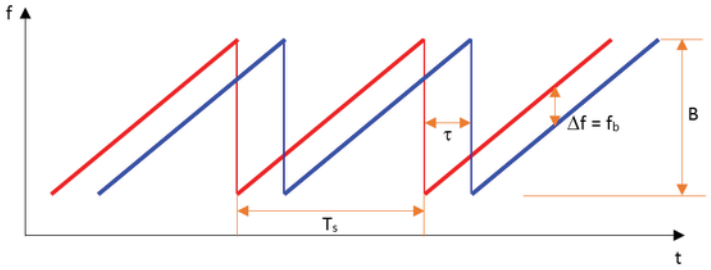
FMCW radar

- Time delay in nanoseconds
  - Frequency obtained after mixing is proportional to the time delay

$$\Delta f = \frac{\tau B}{T_s}$$

- The distance to the target :

$$R = \frac{cT_s\Delta f}{2B}$$

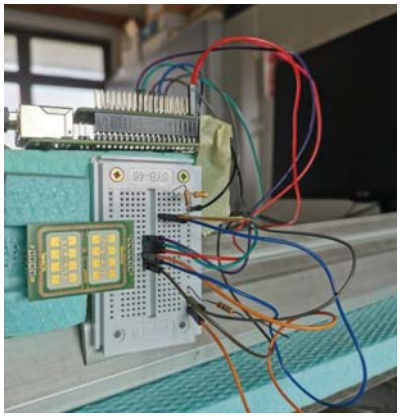


FMCW radar development

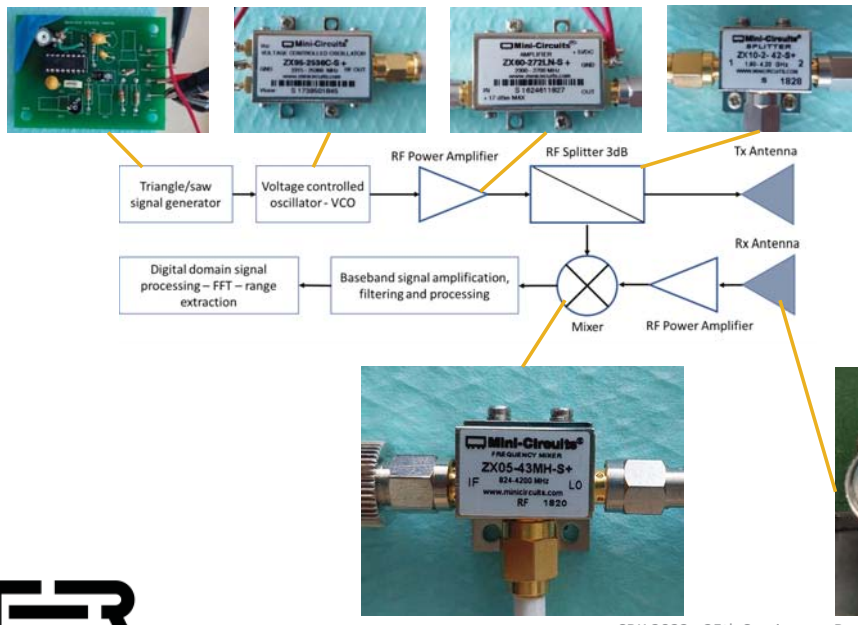
2,4 GHz



24 GHz

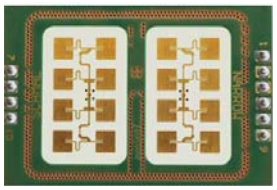


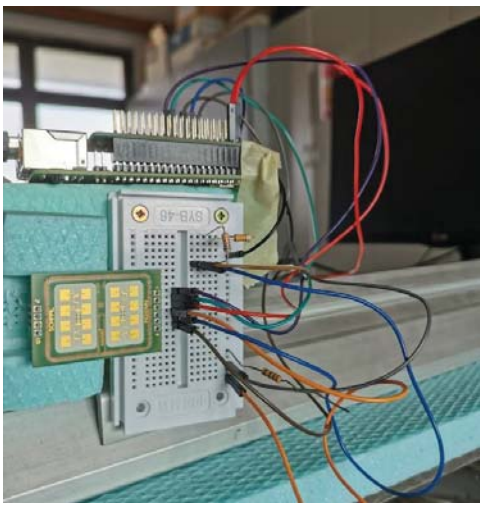
FMCW radar [2,4 GHz]



FMCW radar [24 GHz]

- Raspberry Pi (RPi)
  - Controls VCO and records mixed signal
- ADC/DAC
- Innosent IVS-362 FMCW module
  - Integrated VCO, antennas and mixer





SAR (Synthetic-aperture radar)

- FMCW -> 1D (distance)
- SAR -> 2D (distance, shape and position)
- Uses the motion of the FMCW over a target to synthesize virtually longer antenna

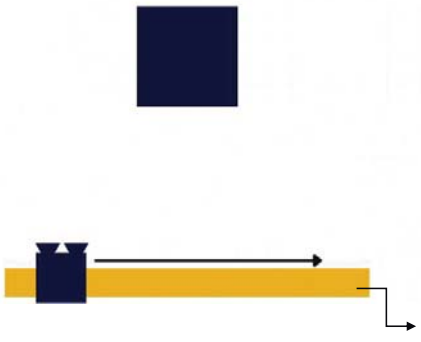
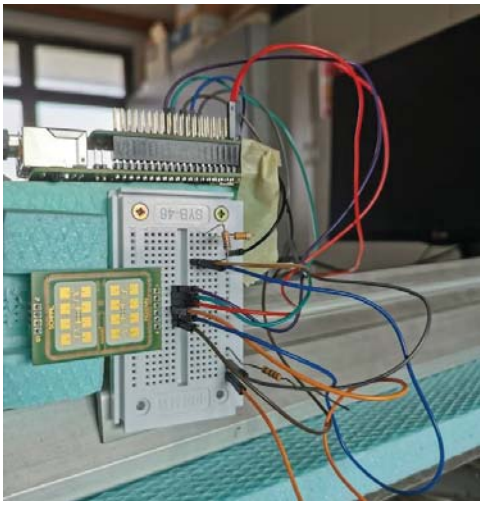


Image resolution
- Number of steps
  - step length, aperture length
- FMCW radar properties
  - Frequency, bandwidth
- Environment
  - Interference, distance to the observed object

24 GHz SAR radar development

RPi generates sawtooth signal
↓
DA converter
↓
FMCW module
- Mix transmitted and received signal

↓
AD converter
↓
RPi stores the signal
↓
Move the platform for one step



24 GHz SAR radar development

RPi generates sawtooth signal

↓

DA converter

↓

FMCW module

- Mix transmitted and received signal

↓

AD converter

↓

RPi stores the signal

↓

Image reconstruction

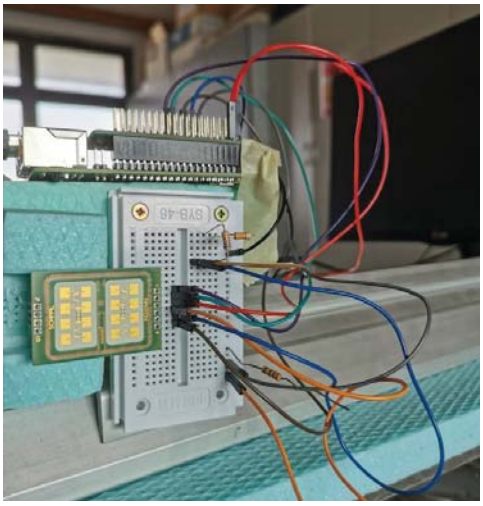
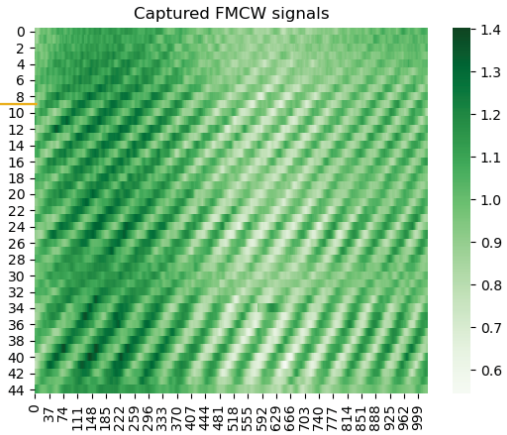


Image reconstruction

Omega-k algorithm

- Hilbert transform
- Removing Residual Video Phase (RVP)
- Azimuth Fourier transform
- Matched filtering
- Stolt interpolation
- 2D Inverse Fourier transform

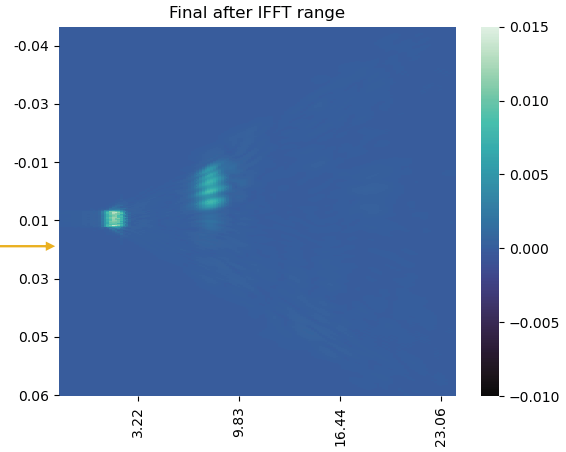


45 steps
1024 samples per chirp

Image reconstruction

Omega-k algorithm

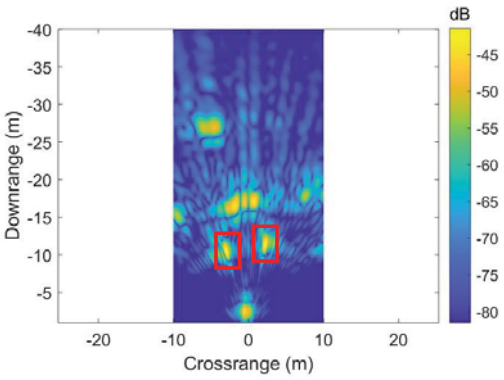
- Hilbert transform
- Removing Residual Video Phase (RVP)
- Azimuth Fourier transform
- Matched filtering
- Stolt interpolation
- 2D Inverse Fourier transform



Object recognition

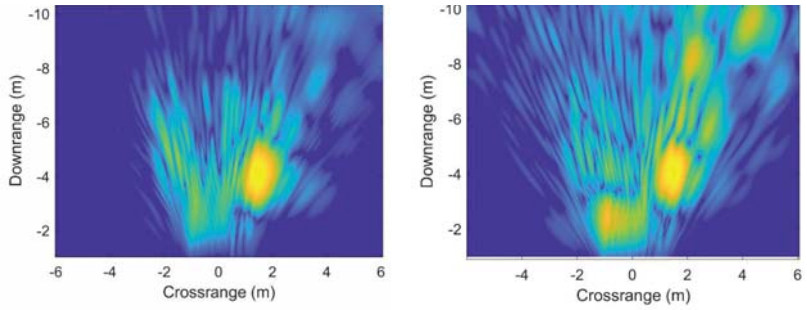
- Requests
  - Big dataset
  - High resolution
    - FMCW radar frequency
    - Number of steps
    - Aperture length
  - Labeled images





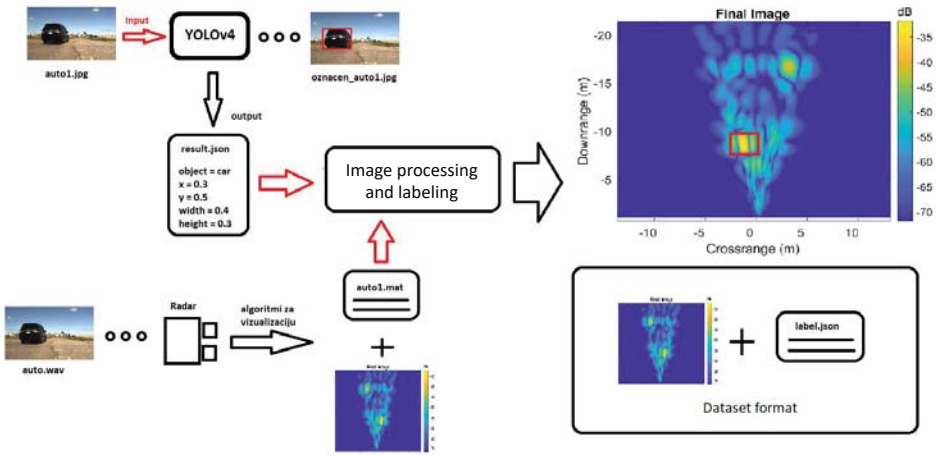
Object recognition

- Requests
  - Big dataset
  - High resolution
    - FMCW radar frequency
    - Number of steps
    - Aperture length
  - Labeled images
- Object recognition on SAR images
  - Polarization diversity can be utilized



vertical horizontal

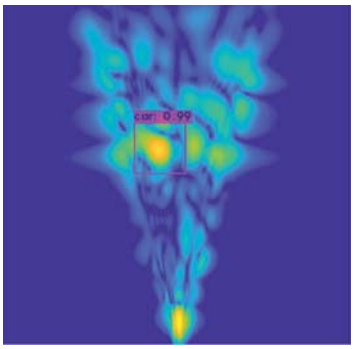
Automatic labeling



Conclusion

- GB-SAR images provide new perspective
  - Various applications
- Optimize object recognition
  - Adjusting SAR radar properties
  - Polarization diversity





Acknowledgment

This work was supported in part by Croatian Science Foundation (HRZZ) under the project number IP-2019-04-1064.

EMF exposure and synchronization challenges in 5G

Sanja Marković, Darko Lekić

IBIS Instruments

sanja.markovic@ibis-instruments.com, darko.lekic@ibis-instruments.com

Abstract

Planned use of millimeter waves by future wireless telecommunications, particularly the 5th generation (5G) of mobile networks, has given rise to public concern about any possible adverse effects to human health. Given limited reach, 5G will require cell antennas every 100 to 200 meters, exposing many people to millimeter wave radiation. 5G also employs new technologies which pose unique challenges for measuring exposures.

New generation of radio networks in 5G produce new demands for quality of synchronization. High throughput and low latency are hard to achieve without well synchronized mobile devices and radio heads. That is why we need to set up proper synchronization network architecture and tune all network locations to fulfill high requirements and deliver high quality services to end customers.

Authors' biograpies

Sanja Marković *is a Master of Science in Electrical Engineering and since 2016 is a member of IBIS Instruments' Test and Measurement Division. During this time, she has been working closely with Regulatory Agencies, Science and Defence sector offering together with the experienced technical team high local support for market-proven solutions in RF domain.*

Darko Lekić *is engineer with more than 18 years of experience. He is experienced in sales, technical support and management of technical resources, people and processes. Keeping in touch with newest and most advanced telecommunication technologies and equipment. Mr. Lekić has strong experience in synchronization of telecommunication networks with more than 15 implemented systems in Balkans region.*

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EMF exposure and synchronization challenges in 5G

About Us

Since its founding in 1996, Ibis Instruments has grown to be one of the largest test and measurement equipment providers in the SEE.

Ibis Instruments is a partner for cutting edge technology companies.

founded	HQ	presence
1996	Belgrade	SEE

100+ Employees

30+ national CSPs and **300+** customers in over **10** countries

Key facts

- Market proven solutions
- Skilled team
- Financial stability
- ITIL certified
- ISO 9001 & 27000

Markets: Serbia, Montenegro, Bosnia & Herzegovina, Macedonia, Kosovo, Albania, Slovenia

VIAVI, KEYSIGHT TECHNOLOGIES, Fujikura, MICROCHIP, WAVECONTROL, TEOCO, ATDI, ixia, narda Safety Test Solutions, ETS-LINDGREN, alladin, utimaco, TCI, telestream, BRIDGE TECHNOLOGIES, TRILOGIC, NeoSoft, Panasonic, Fotech, FREMCO, Calnex

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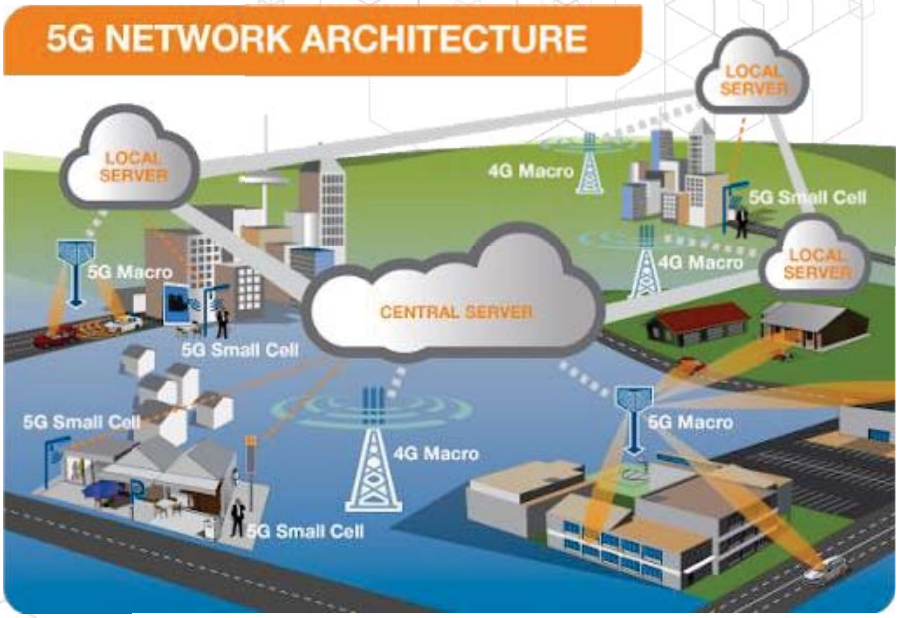
5G NR – Health concerns

WAVECONTROL
Safety, Quality, Service

With the 5G deployment plans, numerous concerns have arisen regarding RF safety.

Main reasons are:

- Higher frequency bands usage
- Higher number of antennas
- higher maximum power



Source: www.emfexplained.info

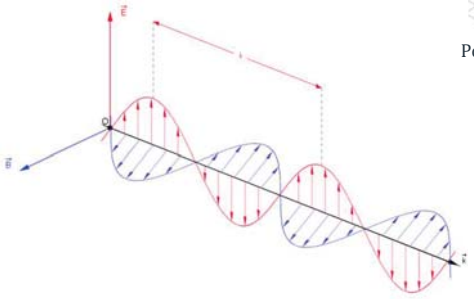
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EMF interaction with the human body

WAVECONTROL
Safety, Quality, Service

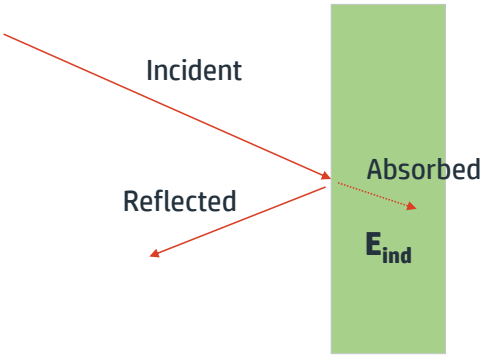
$$\text{Power} = \frac{\text{Energy (Joules, J)}}{\text{Unit time } (s)} = \text{W}$$

Radiofrequency EMFs transfer power from its source



Some of the power is reflected and some is absorbed.

The main component of the RF EMF that affects the body is the induced electric field inside the body, E_{ind} (V/m)



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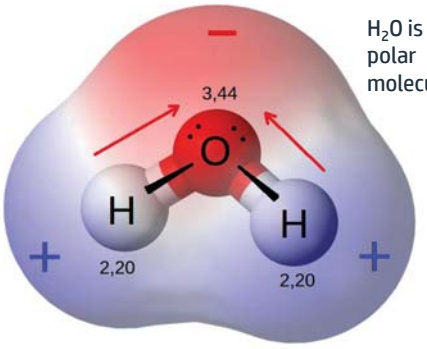
EMF Relevant biological Interaction mechanisms

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Interaction mechanism 1: **Nerve stimulation and dielectric breakdown**

If the E_{ind} is below about 10 MHz and strong enough, it can exert electrical forces that are sufficient to **stimulate nerves**, and

If the E_{ind} is strong and brief enough (pulsed low frequency EMFs), it can cause **dielectric breakdown** of biological membranes.



H_2O is a polar molecule

Source: Riccardo Rovinetti (creative commons)

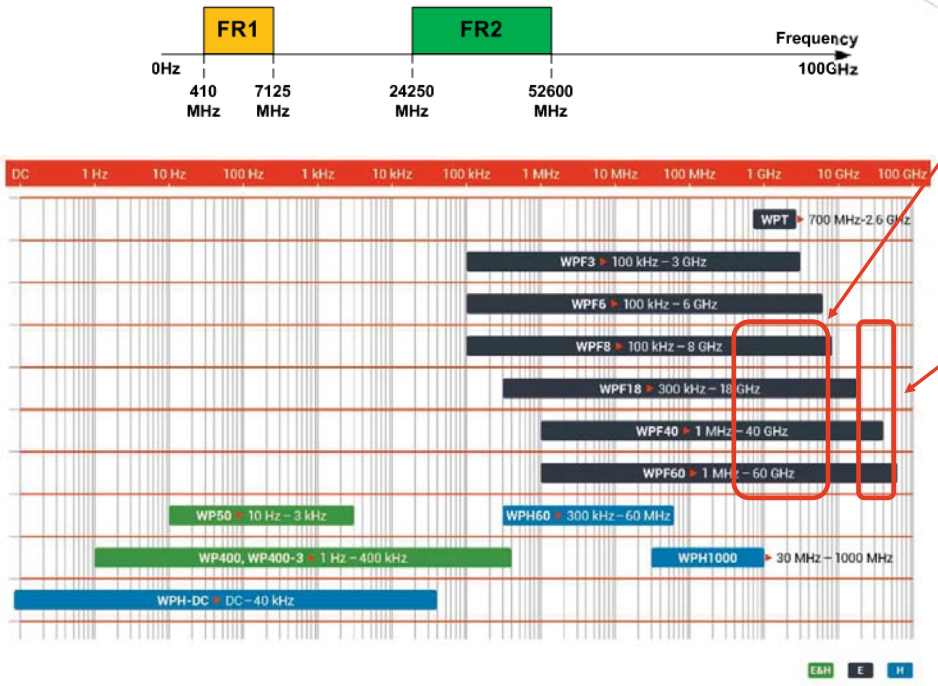
Interaction mechanism 2: **Heat**

E_{ind} exerts a force on both polar molecules (mainly water molecules) and free moving charged particles such as electrons and ions, forcing them to move, and converting the energy to **heat**.

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5G Frequency ranges

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Frequency Range 1 (FR1) (Sub 6 GHz)
- From 410 MHz to 7 125 MHz.
- Maximum bandwidth: 100 MHz.

Frequency Range 2 (FR2) (mmWave)
- From 24 GHz to 52.6 GHz.
- Maximum bandwidth: 400 MHz.

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EMF penetration depth

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Frequency range

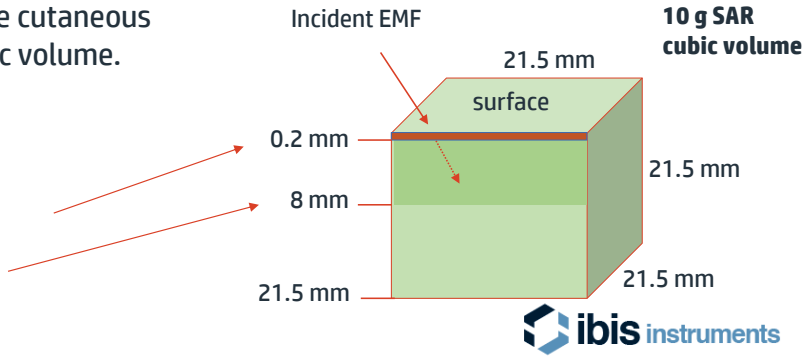
FR1 → EMF energy skin penetration is same as currently used frequencies

FR2 → EMF energy is deposited mainly in superficial tissues

At 6 GHz, most of the absorbed power is within the cutaneous tissue, so within the upper half of a 10-g SAR cubic volume.

For example, 86% of the power:

- at 300 GHz is absorbed within 0.2 mm
- at 6 GHz is absorbed within 8 mm



Source: ICNIRP 2020

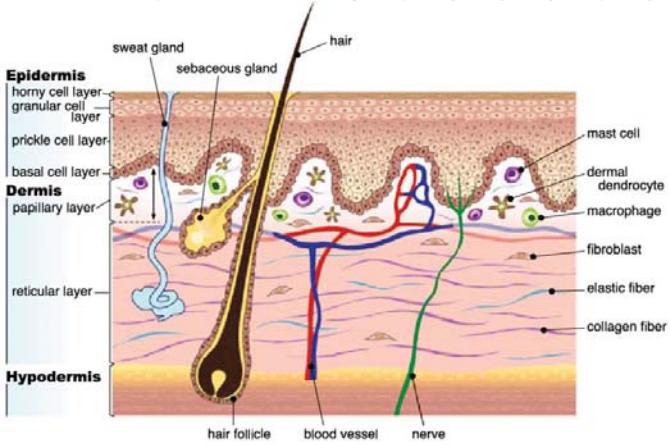
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EMF penetration depth

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As EMF frequency increases, exposure of the body and the resultant heating becomes more superficial, and above about 6 GHz this heating occurs predominantly within the skin.

However, research has shown that high EMF frequencies cause heating within the dermis, and the vascular network can transport this heat deep within the body, which can increase body core temperature beyond the 1°C.



So, it is ICNIRP's opinion that it is still appropriate to also protect against body core temperature rise above 6 GHz.

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5G EMF Assessment

- ✓ **Beam Forming**
- ✓ **Beam steering**
- ✓ **Coexisting Technologies: 3G, 4G, FM, TV, etc.**

EMF exposure challenges:

- **To force 5G beams**
- **To assess the total exposure**
- **Exposure vs Traffic**



Source: www.emfexplained.info



Methods for EMF Measurements in 5G NR Bands

International EMF organizations are currently writing the standards for EMF measurement procedures in 5G applications. There are three main methods, which all have their various advantages and disadvantages.

- **Broadband Measurement:**
  Fast, not expensive, no advanced technical knowledge needed.
  No complete extrapolation possible (was already true in 4G)

- **Frequency-selective Measurement:**
  Detailed frequency information and extrapolation possible (not perfect and not easy due to beam forming)
  Not fast, expensive and advanced technical knowledge needed. No isotropic solution for FR2.

- **Code-selective Measurement:**
  Detailed information and extrapolation possible
  Not fast, expensive and advanced technical knowledge needed. No isotropic solution for FR2.

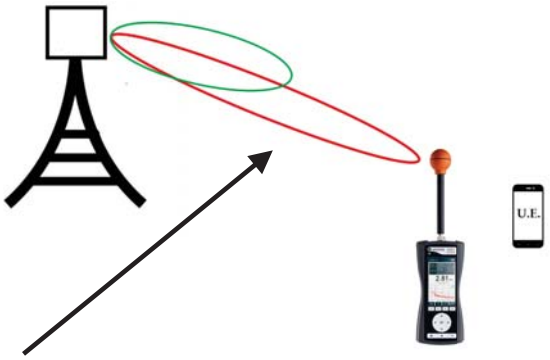
EMF total exposure assessment

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To consider all EMF environment, including FM, TV, 3G, 4G and 5G's FR1 and FR2. → Broadband field probe. Example: Wavecontrol WPF60 (1 MHz – 60 GHz)

To consider all EMF environment, including FM, TV, 3G, 4G and 5G's FR1. → Broadband field probe. Example: Wavecontrol WPF8 (100 kHz – 8 GHz)

You may want to consider all present cellular energy, forcing a 5G connection.



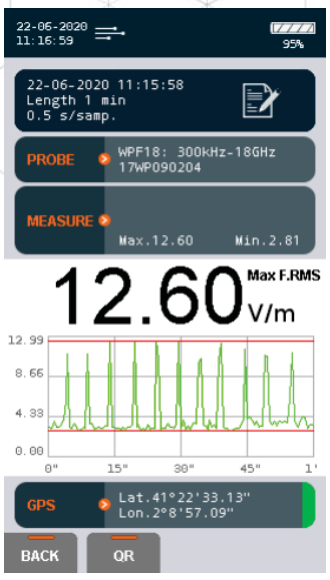
Traffic beam forced towards a Wavecontrol SMP2 field meter by means of the user equipment (U.E.).

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EMF total exposure assessment

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Conclusion

— Using broadband solution, you can also assess maximum exposure by forcing traffic.

— Wavecontrol probes are 5G ready, with the aid of WPF40 and WPF60 (allowing up to 40 and 60 GHz), the new bands in FR2 can be covered.

— Area monitors are excellent solutions for continuous assessment of RF exposure, including the 5G NR bands.



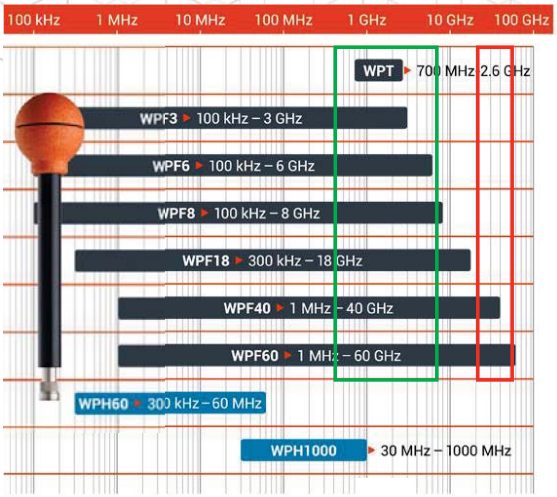
RF Assessment Solutions for 5G and previous gen.:









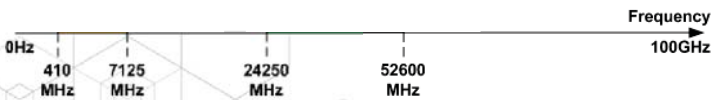


Telecoms frequency ranges

Group 1 (410 MHz – 7 GHz): 2G, 3G, LTE, 5G FR1 band (WPF probes)

Group 2 (24.25 – 52.6 GHz): 5G FR2 band (WPF40 and WPF60 probes)

E&H E H



Modern network synchronization

Every Major Market We Address Is Developing New Services These Services Need More Precise Timing In More Places

Power Utilities



Financial Services



Data Center / Cloud Services





Communications



Transportation



Smart Cities



Position Navigation & Time Services
Connected Vehicles
Drones
etc

5G promises Ubiquitous High Speed Real Time Low Latency connectivity for Humans & Machines
Precise Time services are increasingly required by Communications, Power Control Systems, Financial Services, Vehicles, & Smart City / IoT applications.

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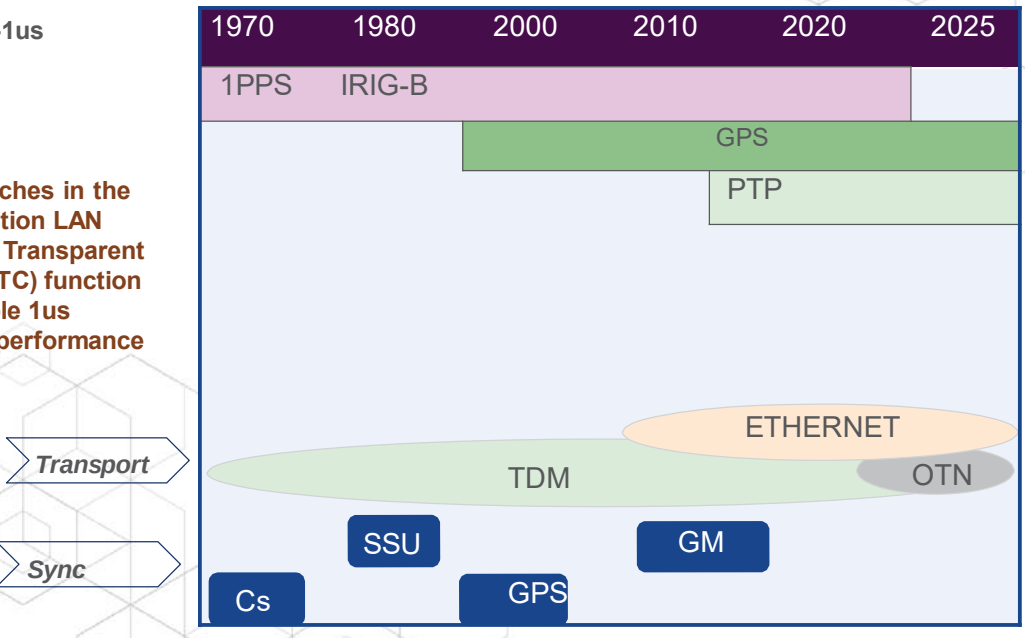
Evolution of Power, Cable, Data Centers, & Telecom Networks

From a Sync and Timing Perspective

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Evolution of Power Network Requirements & Transport Drives Changes In Synchronization In The Power Industry

+/-1us



All switches in the sub-station LAN require Transparent Clock (TC) function to enable 1us timing performance

Power Utility



Sub-station and synchro-phaser services **require & rely on** precise timing.

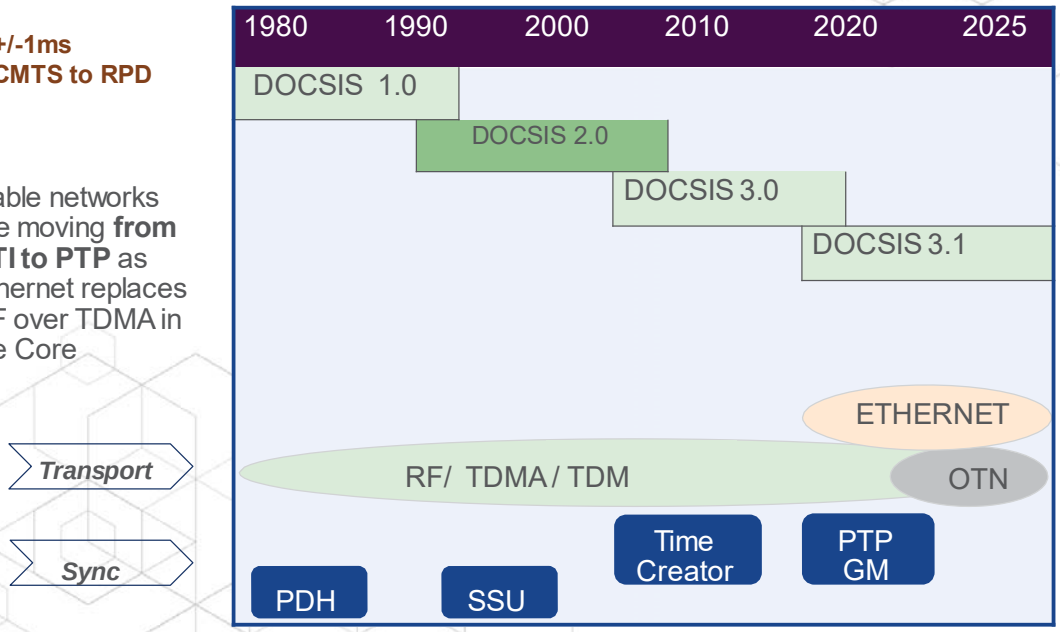
IRIG-B with GPS today moving to PTP as Ethernet replaces SDH & IRIG RF / TDM

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Evolution of Cable Network Requirements & Transport Drives Changes In Synchronization In Next Gen Cable Networks

+/-1ms CMTS to RPD

Cable networks are moving **from DTI to PTP** as Ethernet replaces RF over TDMA in the Core



Cable **requires** precise timing between the **Cable Head End and the Cable Modem**

These requirements drive the cable network sync engineering.

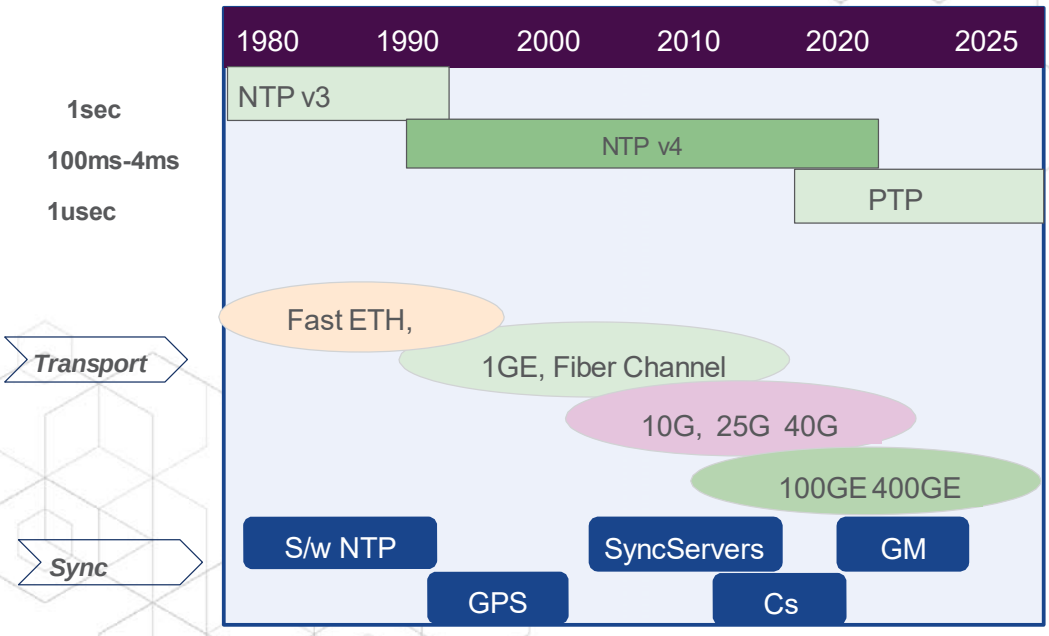
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Evolution of Service Requirements (Financial Services, Search Response Times, SDN/NFV…) is Driving Changes In Synchronization In Data Centers

1sec

100ms-4ms

1usec



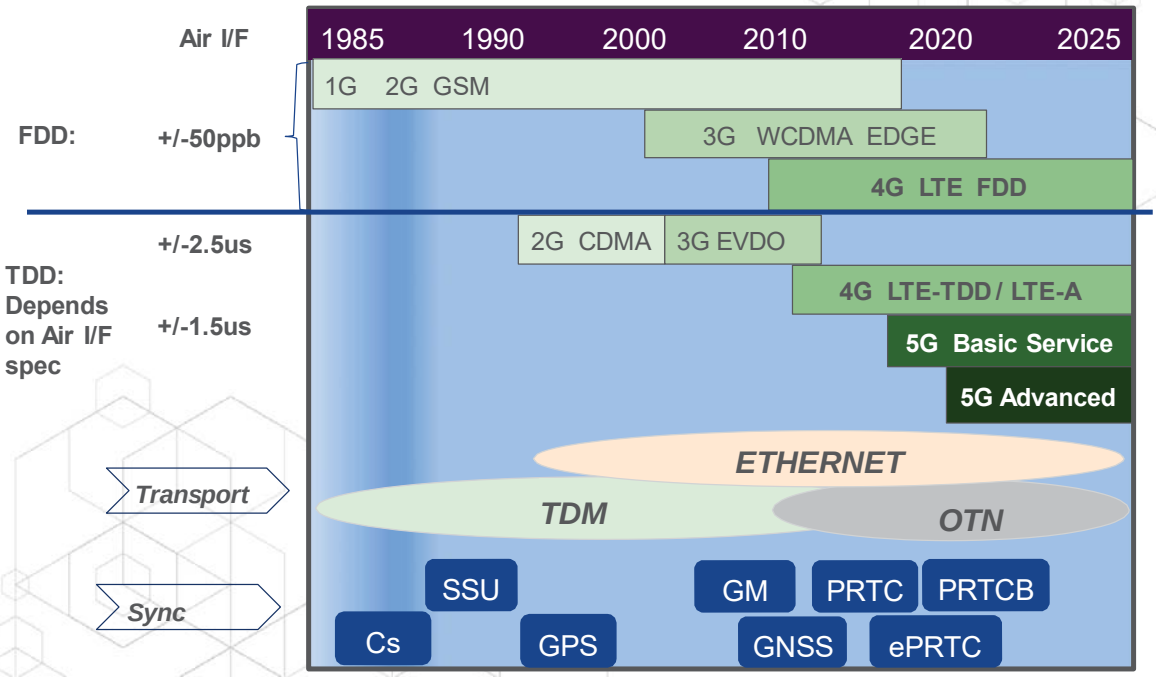
Data Centers are rapidly evolving to require more precise timing.

Today NTP with 4ms to 100's ms of accuracy

Financial trading accuracy target <100 usec (wrt UTC)

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Evolution of Mobile Services & Network Transport Drives Changes In Telecom Synchronization Requirements & Architectures





Faster Wireless connections **require & rely on** changes in network transport and in synchronization architectures in the Core and at the Mobile Edge

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Forums, Standards, & Requirements

Focusing on Telecom Architectures & System Sales

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First: The 5G Initiatives: A Huge Global Effort by Mobile Operators, RAN OEM, Component Suppliers, etc

Organization	Members	Main Focus
ORA		terfaces,
(ope		lavenir,
Time Netw (IEEE		ive nsport“
Tele Pro		om
Sma		n

Why is this important?

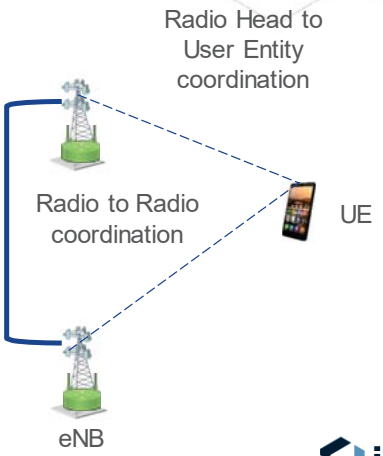
Standards Drive Sync Architectures and Specifications
5G Forums rely on 3GPP/5GPP for Sync Requirements at the Base station and ITU-T to State the Transport Requirements
We build clocks to meet or exceed those specifications

Microchip participates in all of the above

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3GPP: Performance of the Radio Air Interface

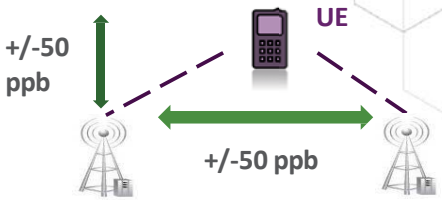
- The 3GPP specifies maximum **Frequency** or **Time Error** between the Radio Antenna and the Mobile device
- This is **Radio Application Specific**
  - *i.e. GSM, CDMA, LTE-FDD, LTE-TDD, LTE-A, 5GNR, etc)*



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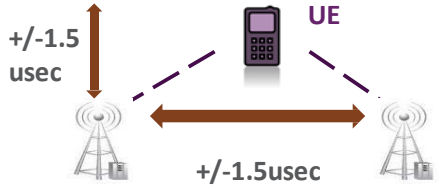
Mobile Network Frequency/Phase Specifications are Based on Specific Radio Service Inter Cell / UE Alignment Requirements (3GPP)

FDD: *frequency* alignment
2G:GSM, 3G:WCDMA, 4G:LTE



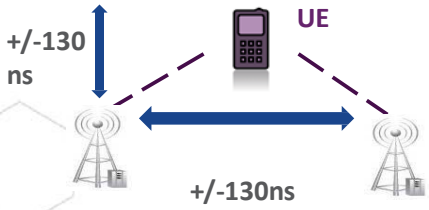
SyncE was designed for this application (replicating E1/T1). (syncE may not be stable enough for 5G NR Frequency recovery)

TDD: *Absolute phase* alignment
4G: LTE-TDD, 4.5G LTE-A
5G NR Basic Service :
+/-1.5usec Time Error from UTC



Requires Distributed PRTC based Timing Architectures

5G NR *Relative phase* alignment
+/-130 nsec between eNB connected to the same DU (Radio Aggregation device)



Advanced 5G services at the network edge will be mostly PTP based, especially for small 5G Radio Units

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Time Error Limits for LTE & 5G Services:

LTE-TDD / LTE-A & Basic 5G Services

Absolute TE Limits

Application	eNB Phase	Problems if Non Compliant
LTE (TDD)	±1.5us	Spectrum inefficiency, Packet collision
LTE-A function		
eICIC	±1.5us	Interference and crosstalk
CoMP	±1.5us	Poor signal quality
MBSFN	±1.5us	Broadcast degradation

5G Advanced Services

Intra-site & Relative Limits

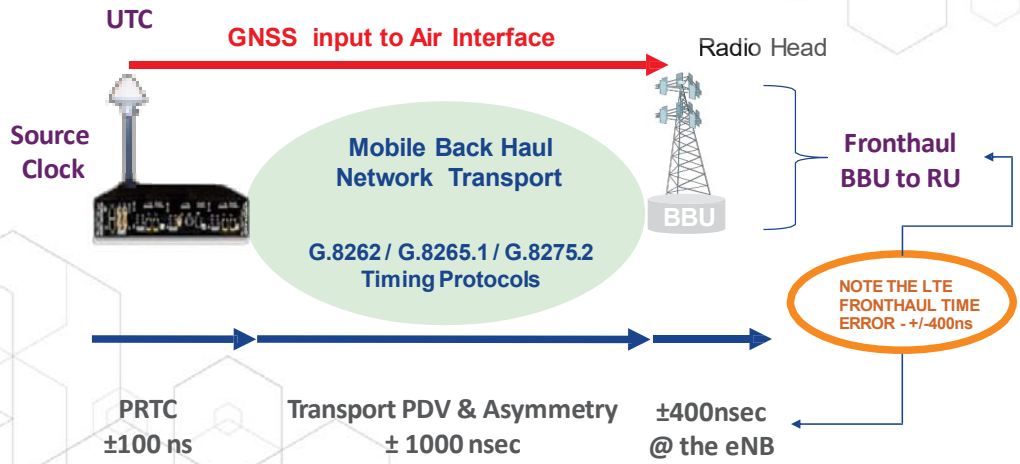
Typical applications (for information)	Time error requirements (Note 1)	Specification
Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity	±260 ns	3GPP 36.104 V13.1.0 section 6.5.3.1
Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	±130 ns	3GPP 36.104 V13.1.0 section 6.5.3.1
MIMO or TX diversity transmissions, at each carrier frequency	±65 ns	3GPP 36.104 V13.1.0 section 6.5.3.1

3GPP TS 36.101/104

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ITU Specifies All Network Attributes from GNSS to Radio Head

- Functions, Protocols, Clock Types, Distribution Methods, Timing Architectures, Timing Performance for **every element in the Network**



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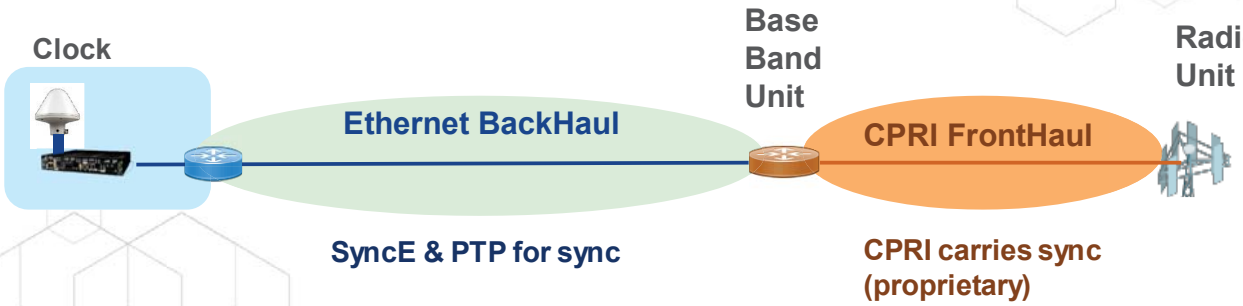
4G: Focused on Mobile Backhaul

5GNR: Focuses on Mobile Fronthaul

From Frequency to Phase based Radio Services

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4G Terminology:Backhaul, CPRI, BBU, RU

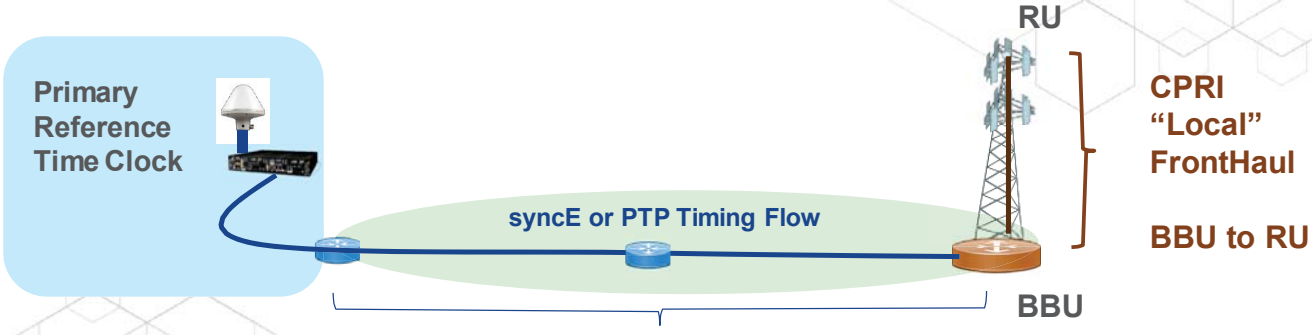


The BBU terminates the Radio I/Q and sends user data to the network
The BBU also terminates the CPRI physical interface (dedicated fiber)

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4G Time Error: Mobile Backhaul/Local Fronthaul

SyncE & PTP for timing on the Mobile Backhaul
BBU to RU Timing is CPRI over Fiber @ the Tower



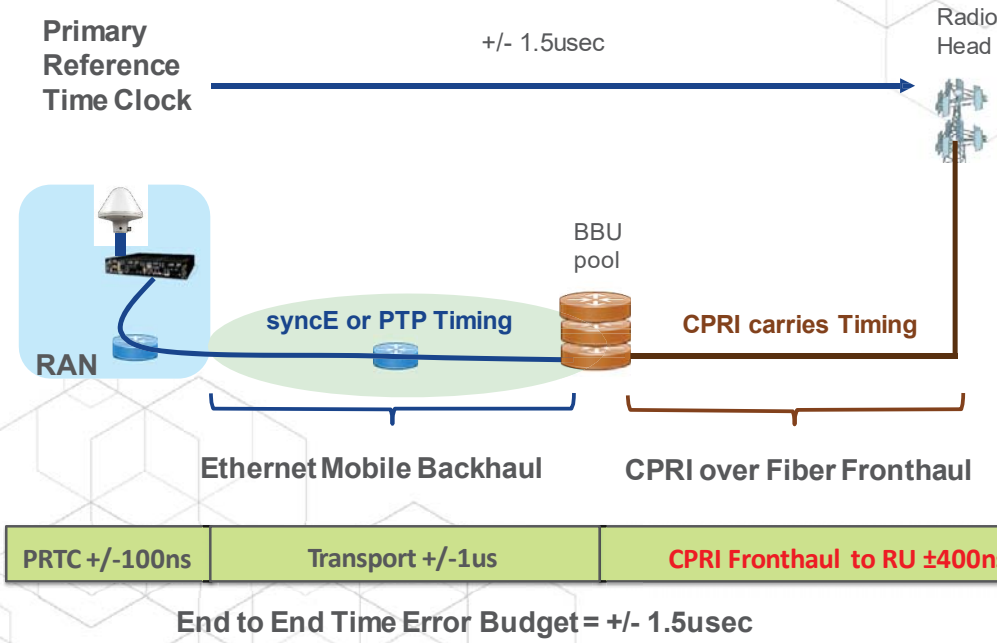
Mobile Backhaul Network
Timing over Ethernet between PRTC & BBU

PRTC +/-100ns	Transport +/-1us	BBU to RU ±400ns

End to End Time Error Budget = +/- 1.5usec

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4G cRAN:CPRI over Fiber Fronthaul/ BBU Aggregation



Issues with CPRI

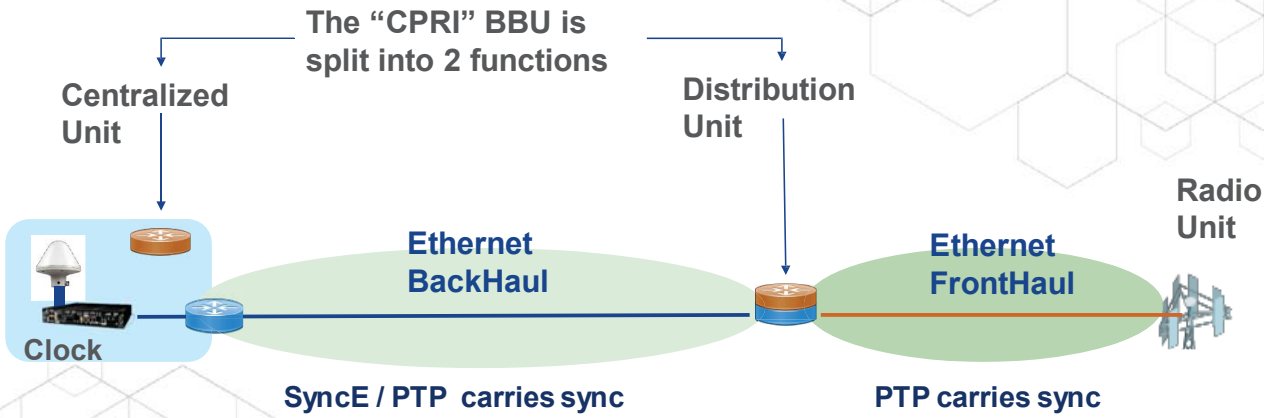
Power hungry
Proprietary
Expensive Requires many BBU

Fronthaul TE budget still +/-400 nsec

CPRI cannot deliver 5G bandwidth to the UE

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5G Terminology:Backhaul, Fronthaul over Ethernet, CU, DU, RU

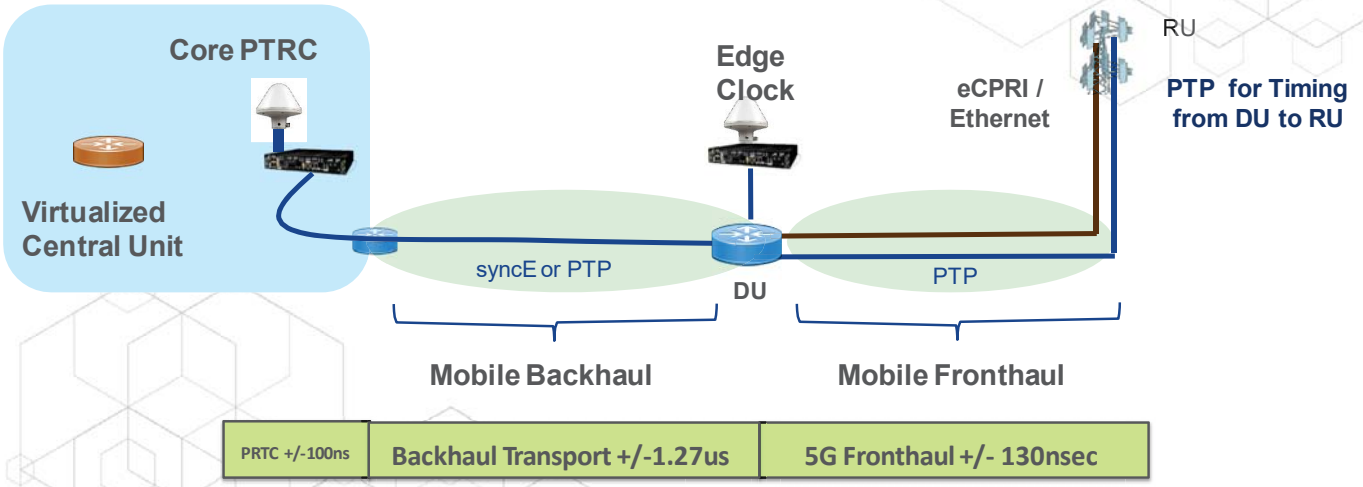


- The DU terminates the Physical Radio I/Q and sends user data to the CU in the network.
- The DU to RU is Ethernet. CPRI only carries user data to the RU
- PTP is used for sync, with GNSS possible

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5G Advanced Services: PTP Replaces CPRI for Timing

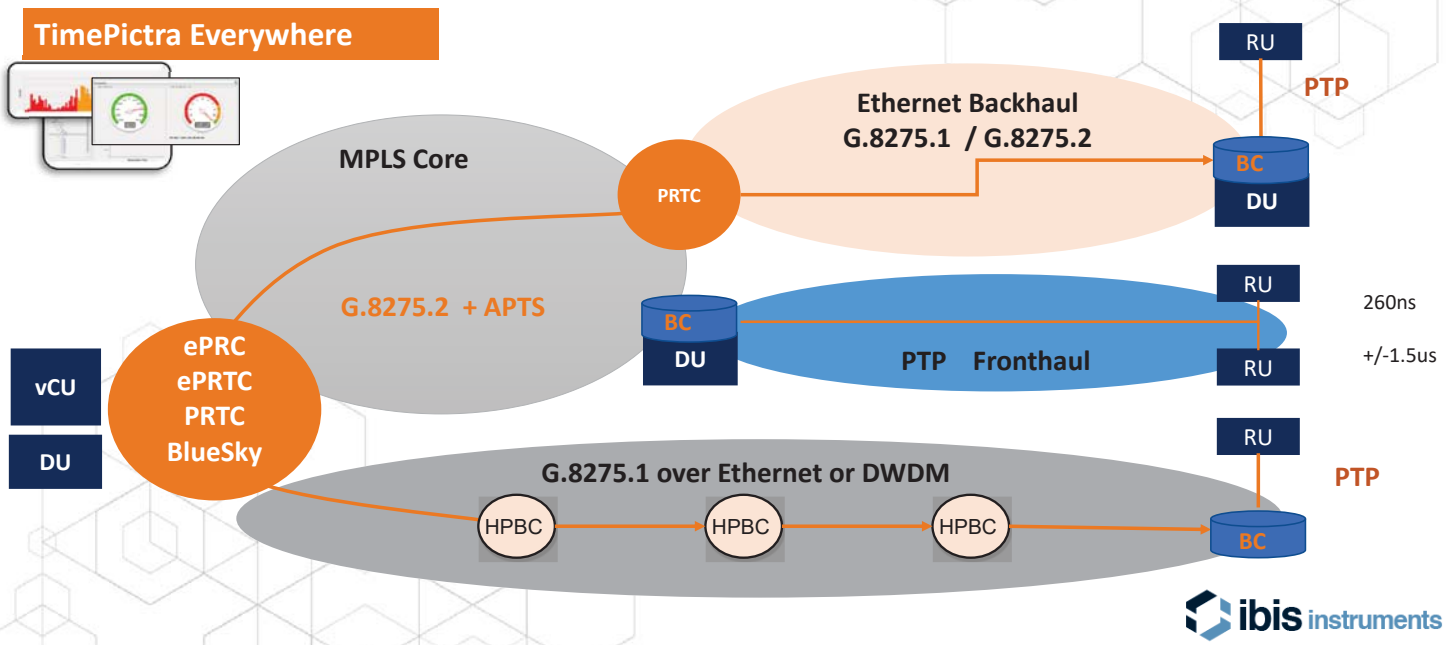
Centralized Unit (CU) and Distributed Unit (DU)
Fronthaul TE Budget reduced from +/-400 to +/- 130 nsec to enable Advanced Services



End to End Time Error Budget +/-1.5usec

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5GNR Generic Network Architecture

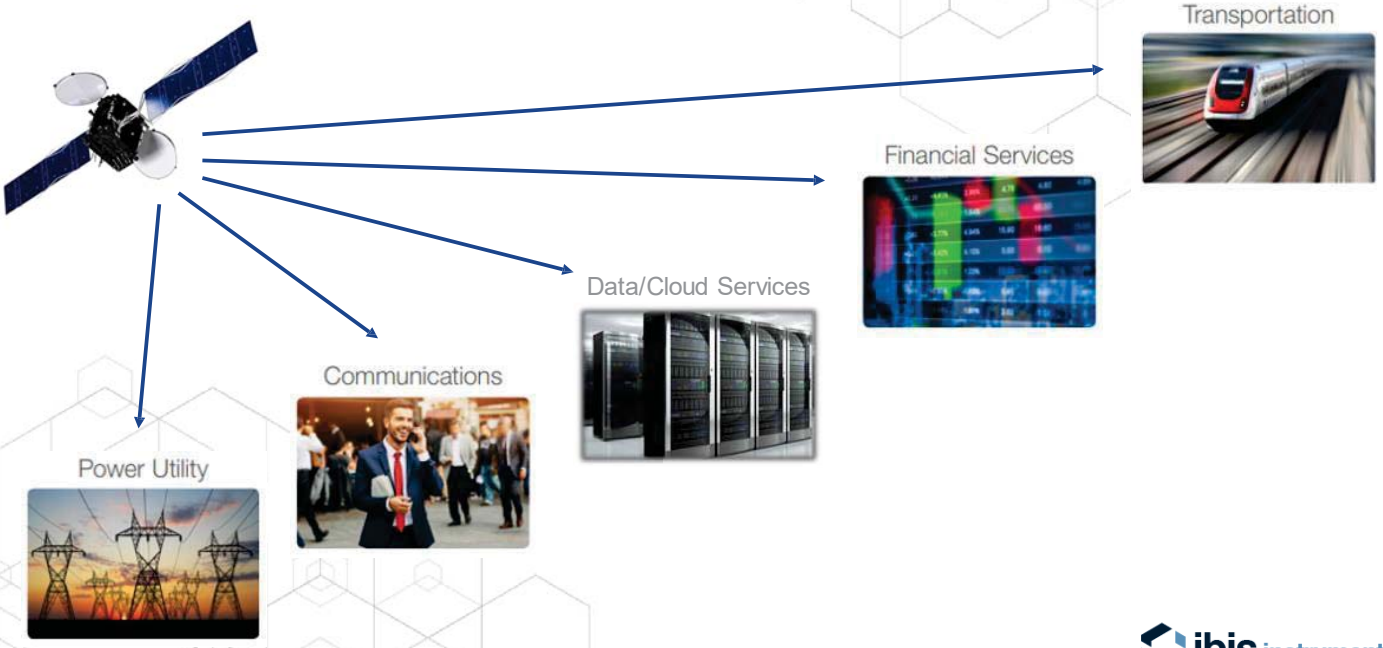


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GPS Threat Protection and Security

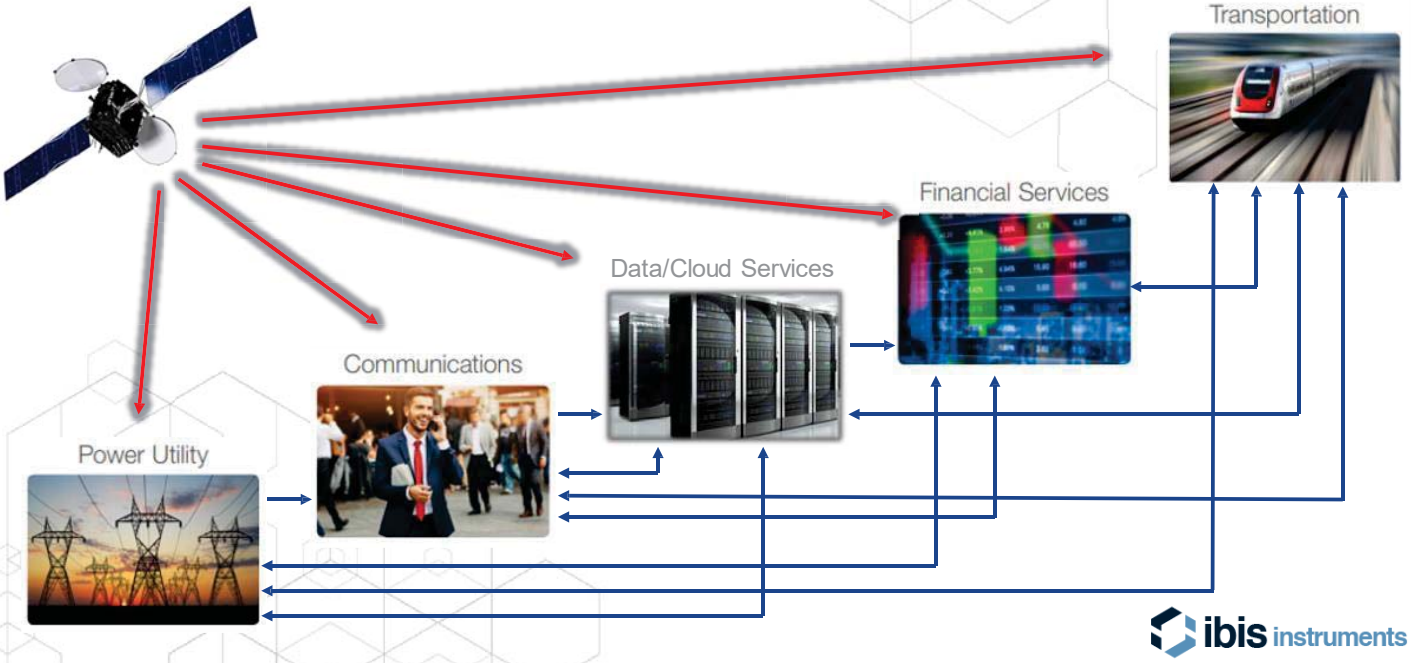
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GNSS has become the "utility of utilities"



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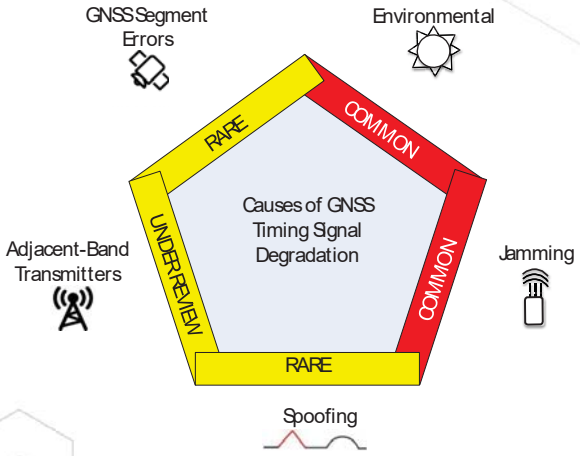
GNSS is a single point of failure for Critical Infrastructure



Growing concern of GNSS Vulnerability impact on timing

WSTS WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

ITSF International Timing & Synchronisation Forum



CISA CYBER+INFRASTRUCTURE

atis

NIST

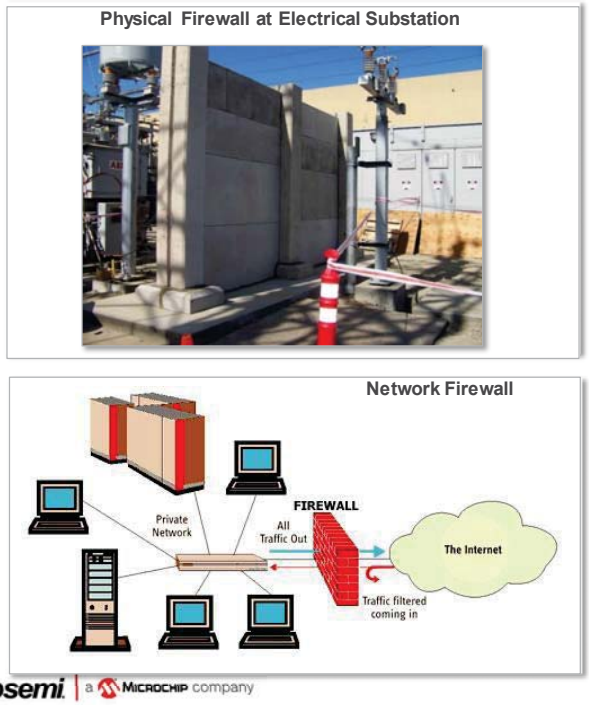
This, as well as solutions for mitigating these vulnerabilities, is discussed in the ATIS technical report on GPS vulnerability ATIS-0900005, which can be downloaded here: http://www.atis.org/01_resources/whitepapers.asp

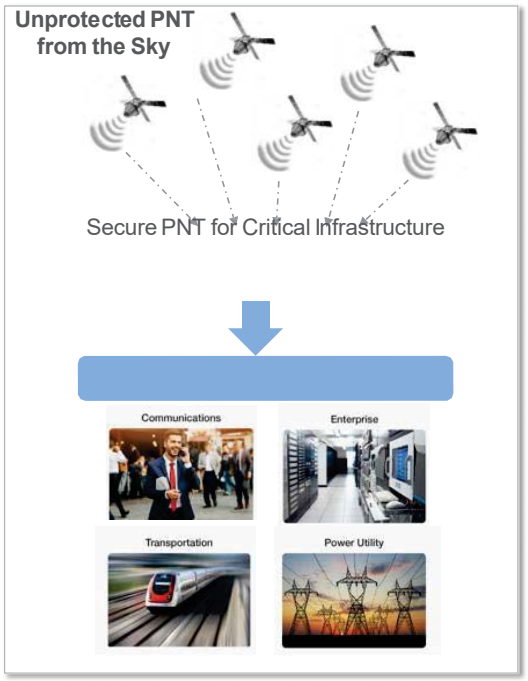
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BlueSky GNSS Firewall

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Firewall concept



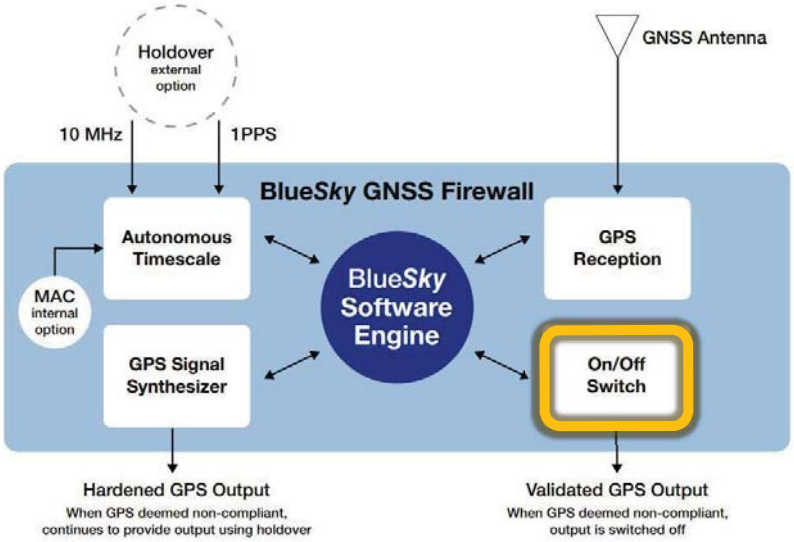


Microsemi | a Microchip company

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Validated GPS Output

- Validated GPS output provides a copy of the actual GPS signal being analyzed
- When anomalous conditions are detected, firewall turns Validated output off
- Validated output includes L1, L2, and L5 signals, Galileo and GLONASS
- Enables downstream system that use multiple frequencies (such as SAASM or M-code) to use Blue*Sky* GPS Firewall to provide additional layer of protection



Microsemi | a Microchip company

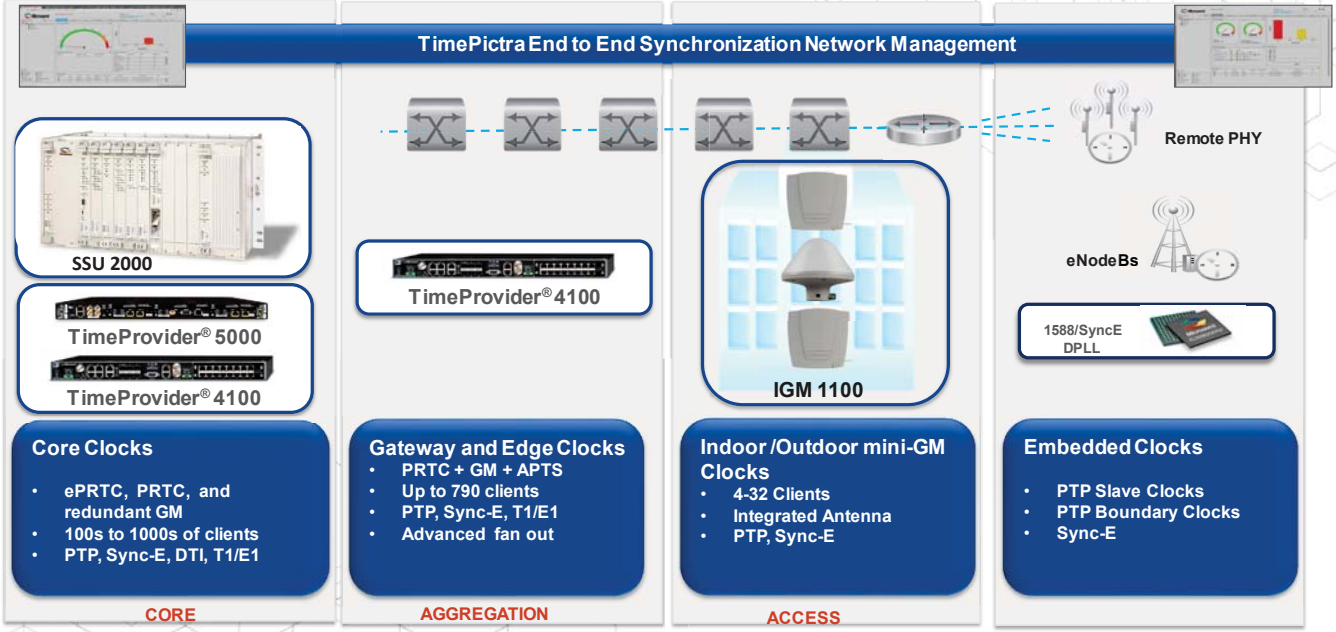
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Monitoring and management of sync network

Monitor sync signals to understand and act proactive

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End to End Portfolio



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TimePictra unifies "Frequency and Phase Platforms"

TimePictra Management & Monitoring

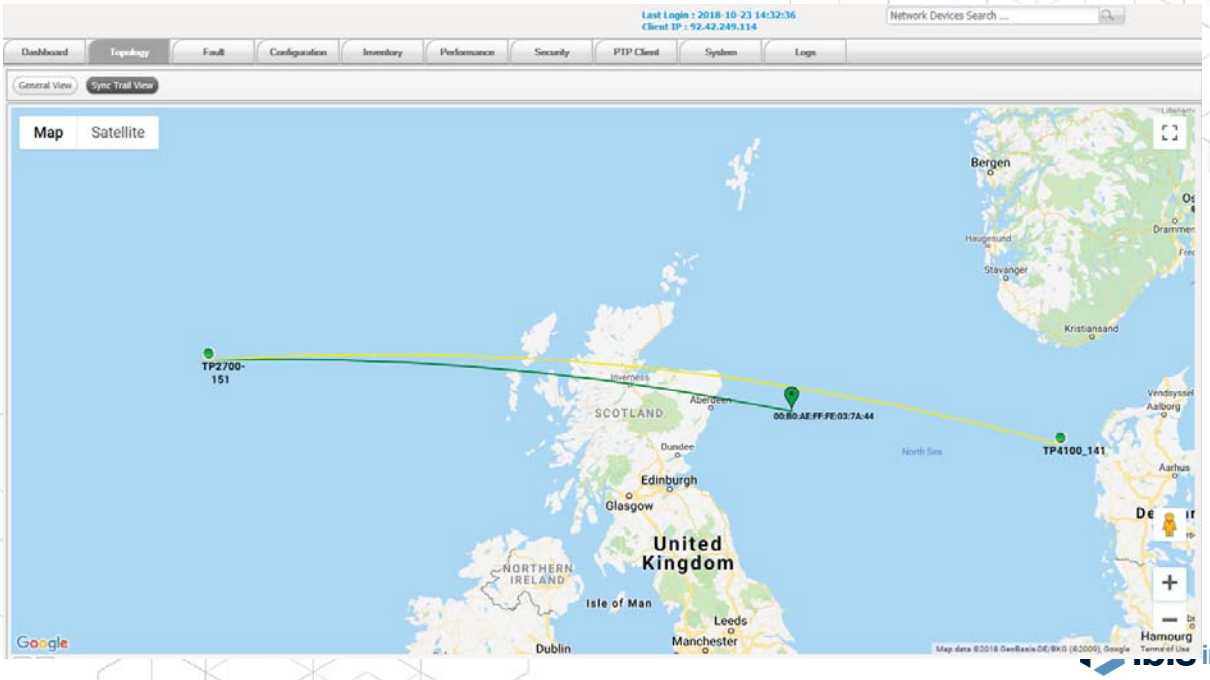


TimePictra unifies management & visibility for complete portfolio of Microsemi products



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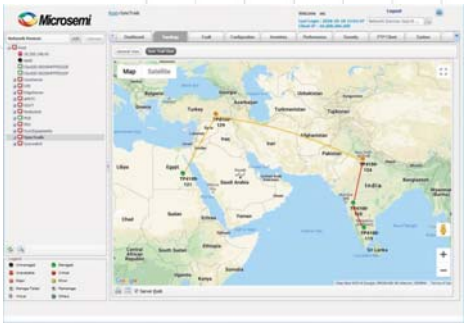
Dynamic maps of PTP Clients

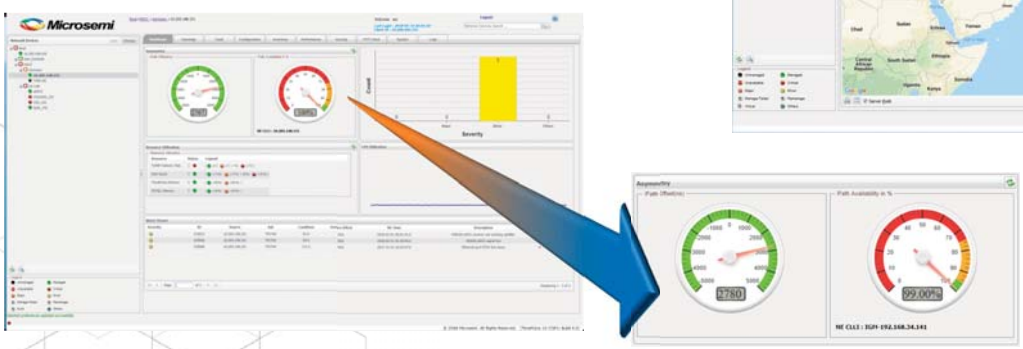


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TimePictra – Realtime network indication

- Shows you the Asymmetry, in real time
- Shows you the Backup Path Go / No-Go
- Keeps the History for up to a year





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ibis instruments

Thank you

Gbit radios for the mobile anyhaul

Attila Hilt

NOKIA
&
Budapest University of Technology and Economics, Faculty of Electrical Engineering and Informatics

attila.hilt@nokia.com

Abstract

Traditionally, the microwave and millimeter-wave (μ/mmW) links have been limited by thermal noise. Long microwave hops had to connect distant sites of several kilometers. The antennas were mounted on high altitude towers. Unwanted interference was eliminated with proper link design and frequency re-use plans. The link design focused on Free Space Loss, rain and atmospheric attenuation. Fading events (e.g., attenuation due to rain or multipath) can significantly reduce the received signal level and degrade the link performance. In worst case, the microwave connection is cut resulting in outage. In the last two decades we observed a rapid breakthrough in direct fiber-optical access. The very long microwave backbone links have been systematically replaced by fiber-optics wherever it was possible by terrain conditions. Consequently, the majority of μ/mmW links became shorter and shorter. In urban environments, the wireless hops are typically shorter than five-six kilometers. On the other hand, there is a huge demand for a flexible LTE, 5G and 6G front- and backhaul (commonly called anyhaul). In mobile systems the μ/mmW anyhaul became extremely dense. 5G and 6G mandate challenging user bit rate and latency requirements. To avoid radio interference and support high link throughputs, higher and higher carrier frequencies are introduced. State-of-theart radios offer excellent possibilities in the millimetric (E, V and W) bands. In the paper the long road to nowadays Gigabit radios is presented. Starting from the very early microwave experiments, the evolution of mobile networks and anyhaul is shown. Finally, some design examples are presented for the recent use of the E-band.

Author's biography



Attila Hilt *graduated in Electrical Engineering from the Technical University of Budapest (BME) in 1990. In 1989 he joined the Research Institute for Telecommunications (TKI), Budapest, Hungary. Until 1999, he led the Telecommunication Test Laboratory of TKI. In 1999, he received the doctorate degree in Optics, Optoelectronics and Microwaves from INPG, the 'Institute National Polytechnique de Grenoble', in France. In 2000, he received the PhD degree at the Budapest University of Technology and Economics. Attila Hilt joined Nokia in 2000, where he is currently working as a lead architect. He has been involved in the dimensioning and planning of several mobile and cloud networks. He participated in the testing, piloting, deployment and optimization of mobile and backhaul networks, including nationwide*

modernization projects in Europe. He worked for two years in Slovenia too, for the mobile network roll-out and modernization of two Slovenian Operators. His research interests include: measurement techniques, fixed, mobile, wireless, cloud-based networks, and microwave, millimeter-wave, photonic systems. He is an author and co-author of over 80 scientific papers and 120 research, project and test reports, including guidelines and specifications in the field of telecommunications. He is a member of the Scientific Association of Infocommunications (HTE) and the Hungarian Chamber of Engineers (MMK). Since 2016, he is a member of the Telecommunications Public Body of the Hungarian Academy of Sciences (MTA). Since 2018, Attila Hilt is a member of the Telecommunications Scientific Committee (TTB). He is one of the editors of HTE's Infocommunications Journal. Attila Hilt is associated professor at the Faculty of Electrical Engineering and Informatics of Budapest University of Technology and Economics (BME-VIK) since 2019. He gives lectures on optical telecommunications and lightwave system applications.

Gbit Radios for the Mobile Anyhaul

(invited paper)

Attila Hilt*#

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#BME-VIK, Budapest University of Technology and Economics, Faculty of Electronic Engineering and Informatics, HVT, Department of Broadband Infocommunications and Electromagnetic Theory, Hungary
e-mail: attila.hilt@nokia.com

Abstract* – Traditionally, the microwave and millimeter-wave (μ/mmW) links have been limited by thermal noise. Long microwave hops had to connect distant sites of several kilometers. The antennas were mounted on high altitude towers. Unwanted interference was eliminated with proper link design and frequency re-use plans. The link design focused on Free Space Loss, rain and atmospheric attenuation. Fading events (e.g., attenuation due to rain or multi-path) can significantly reduce the received signal level and degrade the link performance. In worst case, the microwave connection is cut resulting in outage. In the last two decades we observed a rapid breakthrough in direct fiber-optical access. The very long microwave backbone links have been systematically replaced by fiber-optics wherever it was possible by terrain conditions. Consequently, the majority of μ/mmW links became shorter and shorter. In urban environments, the wireless hops are typically shorter than five-six kilometers. On the other hand, there is a huge demand for a flexible LTE, 5G and 6G front- and backhaul (commonly called anyhaul). In mobile systems the μ/mmW anyhaul became extremely dense. 5G and 6G mandate challenging user bit rate and latency requirements. To avoid radio interference and support high link throughputs, higher and higher carrier frequencies are introduced. State-of-the-art radios offer excellent possibilities in the millimetric (E, V and W) bands. In the paper the long road to nowadays Gigabit radios is presented. Starting from the very early microwave experiments, the evolution of mobile networks and anyhaul is shown. Finally, some design examples are presented for the recent use of the E-band.

***Keywords* – 5G, 4G, mobile anyhaul, digital radio, PDH, SDH, GbE, System Gain, hop-length, optimization, rainfall, availability.**

I. A Brief History of Microwave Radios from First Experiments to Mobile Anyhaul

A. Pioneer Works at Microwave Frequencies

The history of microwave (μW) and millimeter wave (mmW) radios is older than 90 years. One of the very first transmission experiments was successfully performed between Dover, England and Calais, France over the English Channel in 1931 [1] Fig.1 shows the three meters diameter antenna of the link. The duplex μW link transmitted voice, telegraph and facsimile images at 1.7 GHz frequency. The transmit (Tx) and receive (Rx) directions used separate antennas. The receiving antenna is seen behind the transmitting antenna in the right side.

During World War II the application of microwave frequencies focused on military applications, namely the development of RADAR (Radio Detection and Ranging).

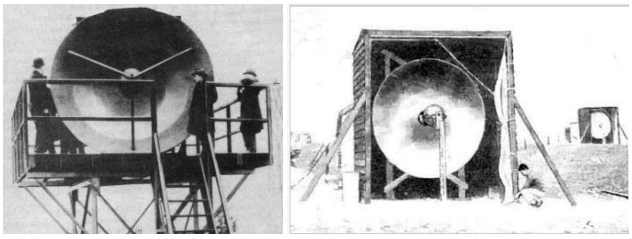


Fig. 1. 1931: the first successful μW link between Calais and Dover [1]

However, there were a few experiments focusing peaceful applications too. One of the most interesting experiments was the Moon-RADAR [2][3]. The original idea was to use the Moon as a passive repeater for microwave communications. In 1945-47 a team of Hungarian researchers –led by professor Zoltán Bay– measured the Moon-Earth distance using an array of microwave dipole antennas (Fig.2).

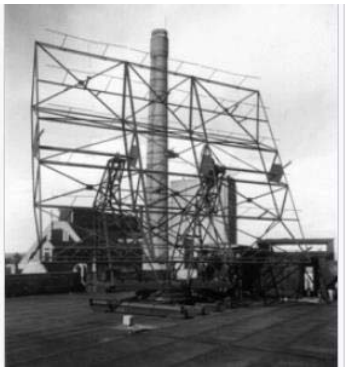


Fig. 2. 1945-47: The antenna of the Moon-radar experiment [2]

B. Analog and Digital Radio-Relay Links

The breakthrough for commercial telecommunication application of microwave technology has been started by AT&T with the famous 'Long-Lines' [4][5]. The first microwave radio-relay chain called 'Long-Lines' was built between New York and Boston. As seen in Fig.3, eight links formed together a 354 km (220 miles) long chain. Officially AT&T started its operation in 1947 [6]. The multi-channel systems operated in the 4 GHz band and transmitted both telephony and analog television (TV) signals. Soon the first 'Long-Lines' were followed with the 5000 km long New York - San Francisco chain having 107 relay stations, in 1951. In several countries,

such analog microwave radio-relay links operated for decades as trunk lines for traditional PSTN (Public Switched Telephone Networks) and analog TV signals.

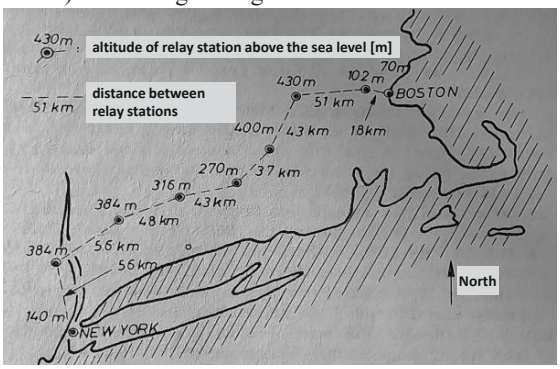


Fig. 3. 1947: The first µW radio relay chain: the AT&T 'Long Lines' [4]

During the 80's the old analog radio links were step-by-step replaced by digital, mainly PDH (Plesiochronous Digital Hierarchy) links in most of the countries [7]-[13]. The PDH radio links were soon followed by SDH Microwave Digital Radios (MDR) to serve as high-capacity backbone (BB) connections [14]. As an example, Fig.4 shows 'Radio Bridge', an early developed 26 GHz radio-relay utilizing 2-FSK (two-state Frequency Shift Keying) modulation [12]. The 2 Mbit/s (2 Mbps) digital radio was designed and built in Hungary in 1989. In fact, 'Radio Bridge' was the first 26 GHz digital microwave radio link installed in Hungary.



Fig. 4. 1989: The first 26 GHz radio link in Hungary [12][13].

When a µW or mmW signal is digitally modulated, its power is spread over the bandwidth of the radio channel (Fig 5.).

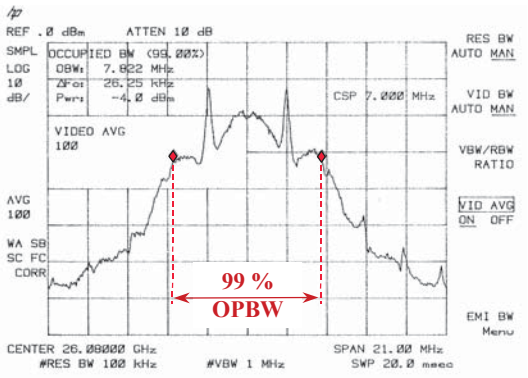


Fig. 5. Spectrum plot the 2-FSK modulated 26.080 GHz radio signal.

To determine the occupied power bandwidth (OPBW), we need to measure the spectrum of the transmitted signal. The goal is to maximize the transmission capacity inside the radio's own channel, meanwhile unwanted emissions to any neighboring channels must be reduced to the minimum. In the early years of digital radio-relay links, the spectral efficiency was weak. Spectral efficiency is calculated as the bit rate R transmitted over the occupied RF bandwidth B [13]:

$$\eta = \frac{R\,[\mathrm{bit/s}]}{B\,[\mathrm{Hz}]}. \qquad (1.)$$

As seen in the 2-FSK example of Fig.5, for the transmission of the 2 Mbps digital bit rate, a 7 MHz radio frequency (RF) channel was occupied. Due to the increasing number of microwave links, more efficient modulation modes, such as QAM (Quadrature Amplitude Modulation) are required [13]-[15]. The technology of µ/mmW semiconductors and integrated circuits evolved rapidly together with the adaptation of digital signal processing and coding techniques [14]-[20]. The tele-communications industry has been prepared to deliver reliable electronics for the next step: the huge demand for digital radios to build mobile networks.

II. Microwave Radio Links in Mobile Networks

The real 'big boom' for µW and mmW digital radio links started in the 90's. In July 1991, the Finnish prime minister Harri Holkeri made the first GSM (Global System for Mobile Communications) call using the 900 MHz network of the Finnish operator 'Radiolinja', built by Nokia and Siemens. In 1992 the first commercial GSM mobile phone, the Nokia 1011 became available. In most of the countries, earlier analog mobile networks have been completely replaced by GSM networks very quickly. During a couple of years, hundreds and thousands of GSM base stations (BTS) were built serving the quickly growing second generation (2G) mobile systems. As seen in Fig.6, in the access transmission part, the majority of these base stations were connected to the Base Station Controllers (BSCs) by digital µW and mmW radios or by Leased Lines (LL).

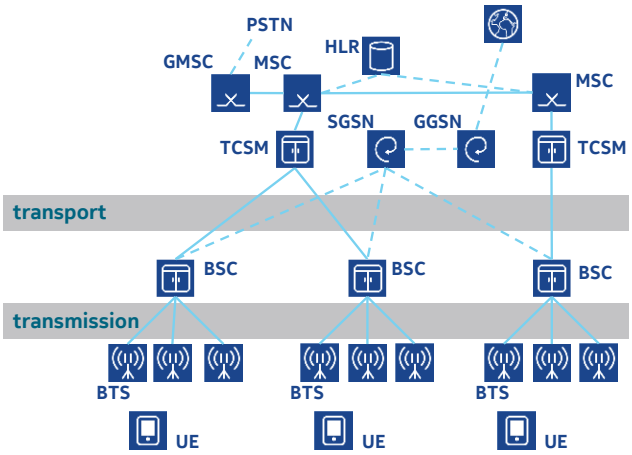


Fig. 6. 2G mobile network with µ/mmW transmission and transport.

In these years (1991-2001), fiber-optical techniques were used mainly in the transport and core parts of the early GSM networks. Direct fiber-access or satellite BTS connection was relatively rare in in European GSM systems. As a result, very soon µ/mmW access links have been deployed with such a great density, that was unexpected in the earlier years (Fig.7).



Fig. 7. A transmission node with extra amount of MDR units.

A. *Evolution of Mobile Networks*

Starting with the big 'GSM boom', in roughly every 10 years a new Radio Access Technology (RAT) is launched. The simple 2G landscape got more and more complicated. The meshed 3G/2G network (years 2001-20…) is shown in Fig.8.

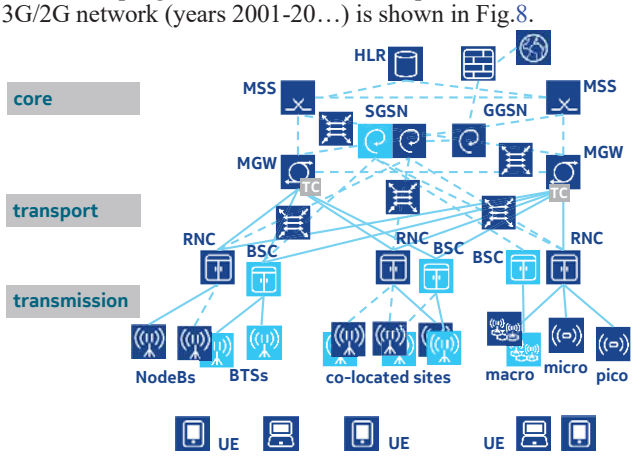


Fig. 8. Mesh of a 3G/2G mobile network.

Since 2010, with the introduction and increasing coverage of fourth generation (4G) mobile systems the mobile landscape is changing extremely quickly [21]-[32]. The front- and backhaul network (NW), commonly called 'anyhaul' must provide sufficient transmission capacity for the new 4G and existing 3G/2G cell sites (Fig.9). In the past years, the fifth generation (5G) network deployment started, making the mobile landscape of Fig.9 even more complex.

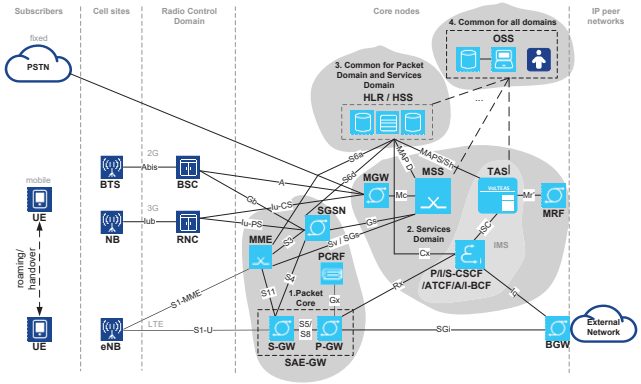


Fig. 9. Multi-RAT 4G/3G/2G mobile network [31].

The need for mobile broadband is not stopped in 2021. Besides the capacity demand for the legacy Radio Access Technologies the new 5G and future coming 6G technologies also require wider and wider bandwidths and increased capacities. As shown in Fig.10, 5G offers a variety of possible new services using a combination of existing and evolving systems. Existing systems like LTE-Advanced and WiFi is coupled with new 5G access technologies designed to meet actual requirements, such as reliability and low latency. As shown in Fig.10, there are three main requirement scopes for 5G systems:

- throughput,
- number of devices, cost, power, and
- latency and reliability.

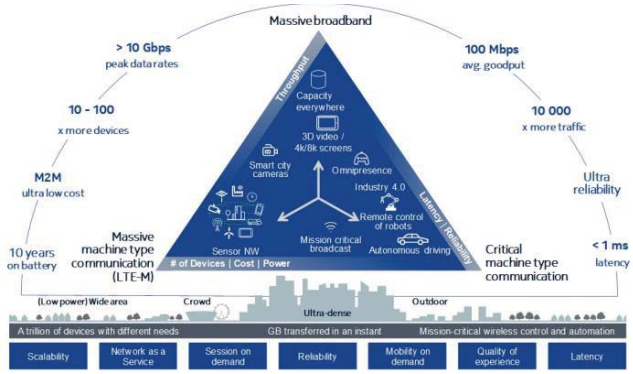


Fig. 10. 5G as an enabler for diverse use cases and services [21].

B. *Continuous Modernization and Optimization*

With the new 5G Radio Access Points (RAPs) the density of cell sites is further increasing, including sites having different combinations of 2G base stations (BTS), 3G Node-Bs, LTE eNode-Bs or 5G RAPs. The RATs, or simply the 'generations' are often co-located to save earlier site investments and to benefit the capacity of the existing anyhaul. Earlier RATs are continuously modernized and 're-farmed' towards 4G and 5G. In several countries, there are already ongoing discussions about the complete 2G or 3G 'switch-off'. Considering the facts mentioned above with the rapid 'Fiber-to-the-Site' deployments (Fig.11), a continuous expansion and evergreen optimization of the mobile anyhaul have become a daily job for network operators and design engineers [30]-[34].

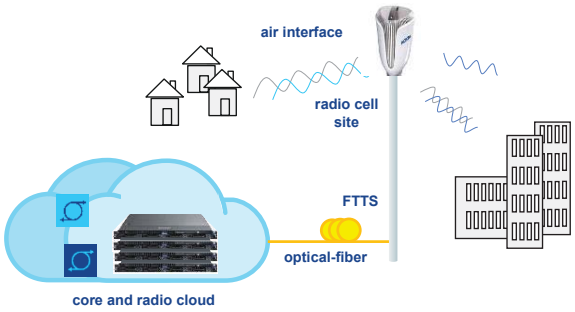


Fig. 11. 'Fiber-to-the-Site' deployment scenario [34].

In the near future, more and more cell-site locations will receive direct fiber-optical access. Since the introduction of mobile broadband data, there is an accelerated research of combined fiber-wireless networks. On one hand, fiber-optical

techniques can deliver high speed Gbps baseband digital data or Gbit Ethernet (GbE). On the other hand, even mmW carriers can be transmitted or generated optically [13][33][35]-[38]. Even though direct fiber-optical access to each radio cell site would be beneficial, due to technical difficulties and business reasons it is not yet possible. For a longer period, the mobile anyhaul will contain both fiber-optical and μ/mmW wireless links (Fig.12). When a cell site or transmission node receives fiber-access, there is a good possibility to optimize the neighboring network. Depending on the topology, the existing μ/mmW links "turn" towards aggregation points having fiber-access, as shown in Fig.12. Such way, the heavily overloaded transmission nodes (e.g., the one sown in Fig.7), that suffer from capacity and possible interference problems can be optimized [25][27].

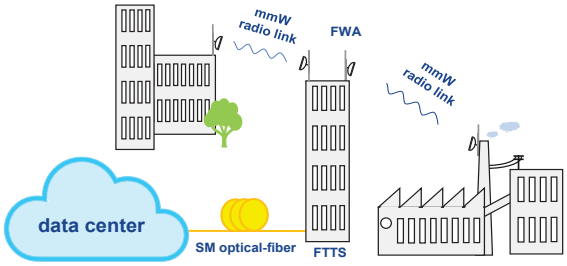


Fig. 12. Optical-fiber access supporting a transmission node [34].

III. Exploring New Frequency Bands

The early microwave links and long-haul BB connections were mainly output power and thermal noise limited. Quality of the MDR link was mainly determined by the achievable Signal to Noise Ratio (SNR). However, due to the very dense mobile access networks a new scenario started. Nowadays the hop-length of wireless links becomes shorter and shorter, but due to the high number of other links in the neighborhood, it is very difficult to find available interference-free radio channels [29][39][40]. A continuous need raised for new and interference-free frequency bands with allocation plans having wider radio channels to support higher and higher transmission capacities. A good example was the introduction of 58 GHz band for mobile access links. As seen in Fig.13, the atmospheric attenuation is very high at 58 GHz, exceeding 10 dB/km [41]. Therefore, only very short links can be built in this band [42]-[44].

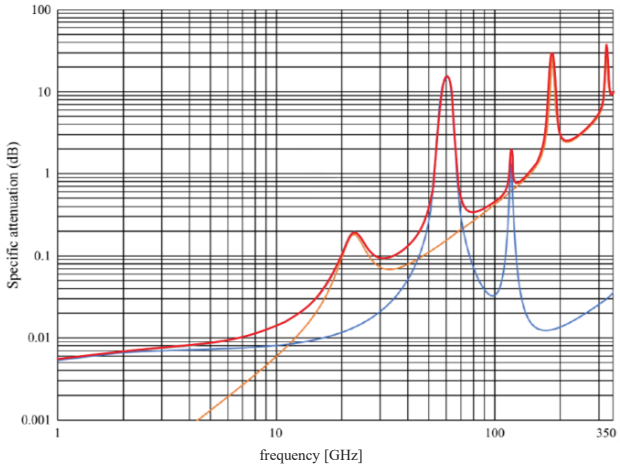


Fig. 13. Specific attenuation due to oxygen (blue line), water vapor (orange line), and total attenuation (red line) according to [41].

Due to the high additional loss of atmospheric attenuation, the interference becomes negligible in practice. In 2001, the first 58 GHz radio links were built in Hungary by Nokia (Fig.14). Bit Error Rate (BER) measured locally on the site showed that $BER=10^{-11}$ is achievable even in these very high frequency bands, supposed proper mmW link design. BER was measured with a hand-held BER tester closed inside the BTS cabinet (Fig.14) and BER was also monitored in the statistics of the Nokia 58 GHz 'MetroHopper' radio [42][44].



Fig. 14. 2001: The first 58 GHz digital radio link in Hungary and its field testing with hand-held BER tester [42][44].

As visible in Fig.15, there is a very wide 'communication window' between the high attenuation peaks of 60 and 120 GHz [45]. In this window, the atmospheric attenuation falls below 1 dB/km, so it is an ideal frequency range for either mobile or Fixed Wireless Access (FWA) links.

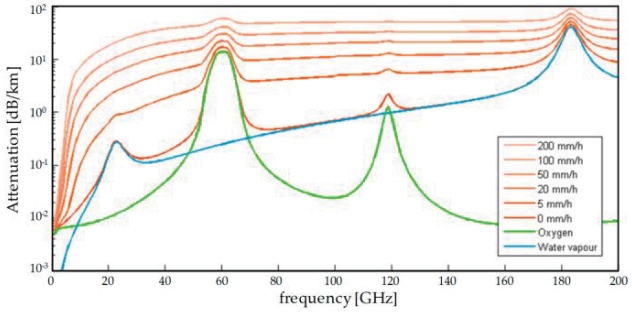


Fig. 15. Rain and atmospheric attenuation in dB/km vs. frequency [45].

As seen in Table 1, besides the traditional fixed-access communication frequency bands of 4, 6, 7, 13, 15, 18, 23, 26 and 38 GHz, the main standardization bodies, i.e., ITU, CEPT and ETSI allocated new frequency bands for fixed wireless links [46]-[48]. It is important to emphasize, that in the 71-86 GHz band (simply called 80 GHz or *E*-band) even 2 GHz wide RF channels are available. As seen in Table 1, radios of equipment class '6L' can communicate with bit rates reaching 10 Gbps.

ETSI EN 302 217 series																																
Common requirements ⇨	Part 1 (the present document) (System common characteristics and system-independent requirements)																															
Antenna requirements ⇨	Part 4 [17] (Antenna general and complementary requirements)																															
Equipment requirements ⇨	Part 2 [16] (HS for equipment characteristics relevant to article 3.2 of Directive 2014/53/EU [i.1])																															
Relevant annex Part 2 [16] ⇨	Annex F								Annex G				Annex J																	Annex I	Annex H
Frequency band (GHz) ⇨	23, 26, 28, 31, 32, 38, 42								50, 52, 55				71 to 76 and 81 to 86 (note)																	64 to 66	57 to 66 (note)
Spectral efficiency ⇩	Channel separation (MHz)								Channel separation (MHz)				Channel separation (MHz)																	Channel size free or multiple of predefined slots from 30/50 MHz to 2 000 MHz	
Minimum RIC (dBm/p) provided with relevant equipment characteristics	Reference index ⇩	Class ⇩	3,5	7	14	28	56	112 (e)	224 (e)	3,5	7	14	28	56	62,5	125	250	500	750	1 000	1 250	1 500	1 750	2 000								
	0									2	4(c)	8(c)	16(c)	32(c)	35	71	142	285	427	570	712	855	997	1 140								
	1	1								4	8	16	32	64(c)	71	142	285	570	855	1 140(a)	1 425	1 710	1 995	2 280								
	2	2	4(b)	8	16	32	64	128	256	8	16	32	64	128(c)	142	285	570	1 140	1 710	2 280(a)	2 850	3 420	3 990	4 560								
	3	3	8(b)	16	32	64	128	256	512	16	32	64	128(c)	256(c)	285	570	1 140	2 280	3 420	4 560	5 700	6 840	7 980	9 120								
	4	4L	8(b)	16	32	64	128	256	512	8	16	32	64	128(c)	142	285	570	1 140(a)	1 710	2 280(a)	2 850	3 420	3 990	4 560								
	5	4H		24	49	98	196	392	784						219	438	875	1 750	2 625	3 500	4 375	5 250	6 125	7 000								
	6	5L		29	58										262	525	1 050(a)	2 100(a)	3 150(a)	4 200	5 250	6 300	7 350	8 400								
	6	5L, 5LB				117	235	470	940																							
	7	5H		34	68																											
	7	5HA, 5HB				137	274(d)	548	1 096						306	612	1 225	2 450	3 675	4 900	6 125	7 350	8 575	9 800								
	8	6L	39	78																												
	8	6LA, 6LB				156	313	627	1 254						350	700	1 400	2 800	4 200	5 600	7 000	8 400	9 800	11 200								
	9	6H			88																											
	9	6HA, 6HB				176	352	705	1 410																							
	10				98																											
	10	7A, 7B				196	392	784	1 568																							
	11	8			107																											
	11	8A, 8B				215	431	862	1 724																							
Equivalent capacity for hierarchic only systems	Annex D of the present document and annex N of Part 2 [16]																															

NOTE: Alternative, in overlapping band, to annex I.
(a) RIC rounded down to closest N × 1 Gbit/s rate are also considered valid.
(b) Not provided in 42 GHz band.
(c) Not provided in 50 GHz band.
(d) STM-4 capacity as combination of two 2 × STM-1 equipment operating on two channels in ACAP or CCDP or even non adjacent operation is also described.
(e) 112 MHz not provided in 31 GHz band; 224 MHz not provided in 26 GHz and 31 GHz bands.

Table 1. New frequency bands at 50, 52, 55 and 71-86 GHz [46].

IV. Link Budget Calculation for Adaptive Radios

The Received Signal Level (RSL) is calculated as:

$$P_{\mathrm{RX}}[\mathrm{dBm}] = P_{\mathrm{TX}}{}^{[\mathrm{dBm}]} + G_{\mathrm{TXa}}{}^{[\mathrm{dBi}]} + G_{\mathrm{RXa}}{}^{[\mathrm{dBi}]} - PL^{[\mathrm{dB}]}, \quad (2.)$$

where PL is the Propagation Loss. With outdoor units (ODU) integrated directly to the antenna (Fig.16), there are no additional waveguide, feeder or branching losses in Eq.2 [7] [19][21]. According to Fig.16, P_{TX} is the output power at the transmitting antenna connection point. P_{RXth} is the receiver threshold, the input power at the receiving antenna connection point, that is required for demodulation. The receiver sensitivity threshold of digital links is defined for a given Bit Error Rate (BER). Usually, threshold values of BER=10^{-6} are used. G_{TXa} and G_{RXa} are the transmitter and receiver antenna gains (compared to the isotropic antenna). For simplicity, a single polarized link is discussed, so there is no additional loss of polarization combiner between the ODU and the antenna.

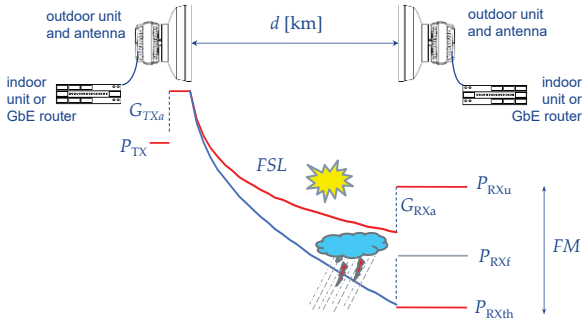


Fig. 16. Link budget of μ/mmW digital connections.

The propagation loss PL is calculated as:

$$PL[\mathrm{dB}] = FSL^{[\mathrm{dB}]} + A_{\mathrm{rain}}^{[\mathrm{dB}]} + +A_{\mathrm{atm}}^{[\mathrm{dB}]} + A_{\mathrm{mp}}^{[\mathrm{dB}]} + A_{\mathrm{obst}}^{[\mathrm{dB}]}. \quad (3.)$$

In clean Line-of-Sight (LoS) condition the obstacle loss A_{obst} is zero. At very high frequencies, the effect of multipath fading A_{mp} is not relevant due to the short hops and blocking of any potential secondary path by buildings in the urban environment. A_{rain} and A_{atm} are the terms of rain and atmospheric attenuation. The unfaded received signal level P_{RXu} is determined by the Free Space Loss (FSL, shown as sunny day in Fig.16), the output power and the antenna gains:

$$P_{\mathrm{RXu}}[\mathrm{dBm}] = P_{\mathrm{TX}}{}^{[\mathrm{dBm}]} + G_{\mathrm{TXa}}{}^{[\mathrm{dBi}]} + G_{\mathrm{RXa}}{}^{[\mathrm{dBi}]} - FSL^{[\mathrm{dB}]}. \quad (4.)$$

The Free Space Loss is calculated as [7][21][23]:

$$FSL(f,d)^{[dB]} = 92.44 + 20\log\left(f^{[\mathrm{GHz}]}\right) + 20\log\left(\mathrm{d}^{[\mathrm{km}]}\right), \quad (5.)$$

where f is the link frequency, and d is the hop-length. The Fading Margin (FM) is the difference of the unfaded received signal level and the receiver sensitivity threshold:

$$FM^{[\mathrm{dB}]} = P_{\mathrm{RXu}}{}^{[\mathrm{dBm}]} - P_{\mathrm{RXth}}(BER)^{[\mathrm{dBm}]} \quad (6.)$$

The System Gain (SG) suitably characterizes the transceivers of digital μ/mmW radio links:

$$SG_{\mathrm{mod}-n}[\mathrm{dB}] = P_{\mathrm{TX}}{}^{[\mathrm{dBm}]} - P_{\mathrm{RXth}}{}^{[\mathrm{dBm}]}. \quad (7.)$$

The International Telecommunication Union (ITU) defines the system gain as given in Eq.7 [49]. Please note, that an alternative definition also exists for SG, including the transmit and receive antenna gains [17]. This alternative SG definition is useful when the transceiver is physically integrated with an in-built antenna.

In Eq.7 mod-n refers to the possible modulation modes. State-of-the-art digital radios can change the modulation mode adaptively. At different modulation modes the SG values are different. A lower symbol rate has smaller throughput, but accordingly, a higher system gain. Depending on the weather conditions, the radio link automatically changes its modulation mode. As seen in Fig.17, during intensive rainfalls, the communication over a well-designed link is not broken, however the throughput is reduced [21][50]-[52].

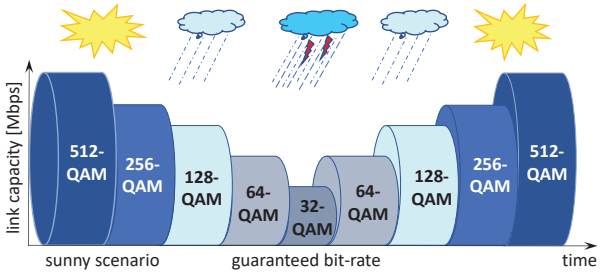


Fig. 17. Digital radio link employing adaptive modulation and providing guaranteed bit rate during intensive rainfall.

Combining equations 3-7, a fade margin set can be calculated for the possible modulation modes what the digital radio can adaptively use in its selected channel bandwidth:

$$FM_{\mathrm{mod}-n}^{[\mathrm{dB}]} = SG_{\mathrm{mod}-n}^{[\mathrm{dB}]} + G_{\mathrm{TXa}}{}^{[\mathrm{dBi}]} + G_{\mathrm{RXa}}{}^{[\mathrm{dBi}]} - FSL^{[\mathrm{dB}]}. \quad (8.)$$

As seen, the higher the system gain is, the better the fade margin of the link for given d hop-length and antenna diameters. The radio equipment type is usually specified in mobile anyhaul projects, so SG, P_{TX}, P_{RXth} are given. Only a few parameters remain free when designing new links. Therefore, during the planning phase frequency band and antenna diameters shall be selected carefully for a given hop-length. Lower frequency bands are more 'valuable' and shall be reserved for the longer links [25][27]. For reducing radio-interference [29][39][40] and increasing the FM, preferably bigger dish diameters and automatic transmit power control are recommended. At a given modulation mode mod-n, the link is operating, as long as the fade margin FM is greater than the attenuation caused by rain and atmospheric attenuation:

$$FM_{\mathrm{mod}-n}^{[\mathrm{dB}]} > A_{\mathrm{rain}}{}^{[\mathrm{dB}]} + A_{\mathrm{atm}}{}^{[\mathrm{dB}]}. \quad (9.)$$

When the attenuation approaches the fade margin due to actual path conditions (rainfall, fog, snow, atmospheric attenuation and link clearance problem, e.g., unexpected object like a crane), the link switches to a lower modulation mode (Fig.17). In sunny scenario, the link can switch back to higher modulation mode to carry more data again. If the link is already in its lowest possible modulation mode, e.g., BPSK ¼ (Binary Phase Shift Keying over quarter bandwidth) and the corresponding fading margin is exceeded, then the link has outage. Proper radio link design must ensure a FM that is sufficient to compensate rain and atmospheric attenuation for the desired link throughput [23][34] in 99.99-99.995% of the time.

V. Calculation Examples for E-band Links

In the calculations we used typical E-band radio and commercial antenna parameters. In the examples the Nokia 'Wavence' radio values are shown, with standard output power option and 2 GHz RF bandwidth [51][52]. Naturally, the

presented calculation method is general, and applicable for other *E*-band radios too. As seen in Table 2, 'optical-fiber like' wireless throughputs are achievable up to multi Gbps bit rates.

mod. mode	P_{TX} [dBm]	P_{RXth} [dBm]	*SG* [dB] *BER*=10^{-6}	Throughput [Gbps]
BPSK 1/4	13	-73	86	0.35
BPSK 1/2	13	-70	83	0.7
BPSK	13	-67.0	80	1.4
QPSK	13	-64.0	77	2.8
16-QAM	10.5	-57.4	67.9	5.6
32-QAM	10.5	-54.2	64.7	7
64-QAM	6.5	-51.5	58	8.4
128-QAM	6.5	-47.8	54.3	9.3

Table 2. System Gain and radio throughput values for the modulation modes in the 2 GHz channel bandwidth [52].

First, radio link throughput curves are calculated for a $d = 1$ km long link. In Fig.18, step curves are plotted with the time axis marked as % of the year. Steps of the curves show when fade margin of a modulation mode becomes smaller than propagation losses. The parameter of the curves is the size of the antenna pair. Three different antennas have been investigated. The smallest in-built antenna diameter is only 12 cm [52]. The slip-mount antennas are 38 cm or 65 cm diameter big [53][54].

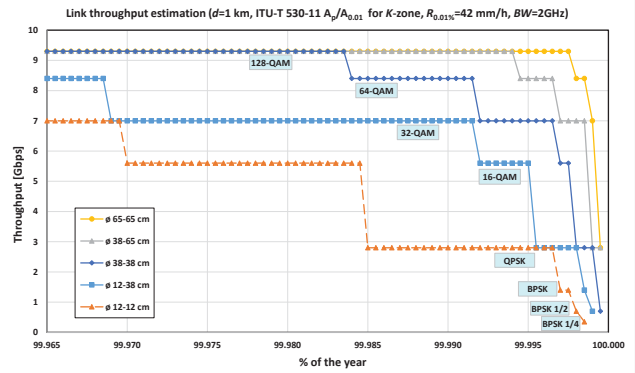


Fig. 18. Link throughput as a function of link availability due to rain

In the calculations, a rainfall intensity of $R_{0.01\%} = 42$ mm/h or stronger is considered in p=0.01% of the time. According to ITU-R Rec. P.837, it is a reasonable approach for Central Europe, e.g., in Hungary and Slovenia [55]. The ITU-R assumption of $R_{0.01\%}$=42 mm/h is confirmed by long term local meteorological data collection in Hungary [56]-[59]. When the fade margin of the link is not sufficient for the actual rain intensity, the radio changes its modulation mode and the link throughput is reduced. In Fig.18, the unavailability of 0.01% corresponds to a time of cc. 52 minutes per year.

The rain attenuation model and its calculation steps are discussed in [23][34] following ITU-R P.530 [60]. The path attenuation exceeded in 0.01% of the time is given as:

$$A_{0.01\%}[\mathrm{dB}] = \gamma_R \frac{d}{1+d/d_0} = kR^{\alpha}\frac{d}{1+d/d_0}, \qquad (10.)$$

where k and α are constants depending on the frequency and polarization of the link, according to ITU-R P.838 [61]. When the rain intensity is smaller than 100 mm/h, then:

$$d_0 = 35e^{-0.015R_{0.01\%}}. \qquad (11.)$$

Please note, that $R_{0.01\%} > 100$ mm/h rain is not relevant in Central and Eastern Europe.

The solution of Eq.9-11 can be obtained numerically for the maximum hop-length for a given frequency band, polarization and link availability against rainfall. Calculation results are plotted for the link availabilities against $R_{0.01\%} = 42$ mm/h rainfall and atmospheric attenuation as a function of hop length d of the *E*-band mmW link. Fig.19 shows the case of 38 cm single polarization slip-mounted antennas at both ends of the link.

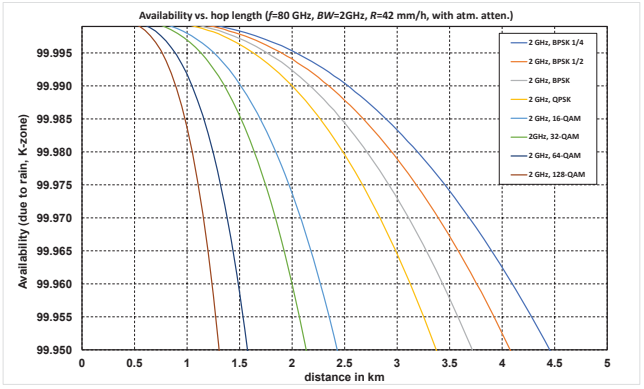


Fig. 19. Link availability as a function of hop-length and modulation, calculated with 38 cm antennas [53] on both ends of the hop.

Fig.20 shows availability calculations having 65 cm single polarization slip-mounted parabolic dishes at both ends of the wireless link. As seen in Fig.20, $d = 1.5$ km long links can operate with 128-QAM / 9.3 Gbps in 99.99% of the time. In the calculations $R_{0.01} = 42$ mm/h rain intensity is considered in p=0.01% of the time according to ITU recommendations and local weather condition statistics [55]-[61].

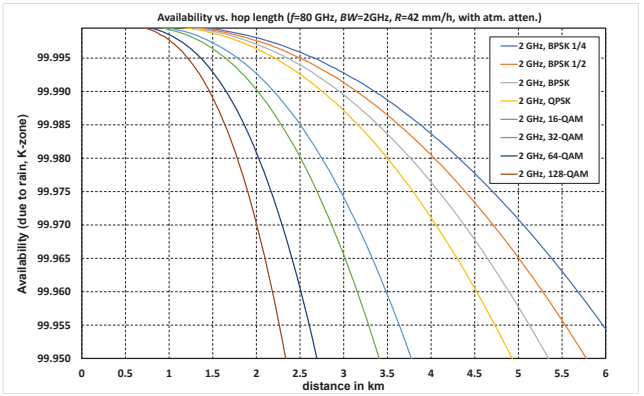


Fig. 20. Link availability as a function of hop-length and modulation, calculated with 65 cm antennas [54] on both ends of the hop.

VI. Conclusions

In the paper, several decades of fixed radio link research and development have been briefly overviewed. The history of microwave communications starting with the first transmission experiments and commercial applications of early analog radio-relays to digital PDH and SDH links have been discussed. The first 26 and 58 GHz digital PDH radio links deployed in Hungary were shown too.

It was pointed out that in several countries, the 'big boom' of μ/mmW links started with the rapid deployment of GSM systems. The links of recent μ/mmW anyhaul networks significantly differ from the links of legacy terrestrial backbone. The dense anyhaul is rather interference than noise limited. It can be explained with the densification of the radio network, where the individual hops are getting shorter. To deliver the required throughputs in multi-RAT mobile networks, and to reduce the possible interference in the crowded legacy communication bands, new frequency bands have been opened.

As shown, GHz wide RF channels are allocated in the *E*-band, where state-of-the-art mmW radios can provide 'fiber-like' throughputs in the Gbps range. Even though nowadays direct optical-fiber access delivers enormous bandwidth to several cell sites, it was shown that fixed μ/mmW digital radios are still required in mobile networks. Finally, a calculation method was given, and examples were shown for 80 GHz links. In the calculation examples, ITU recommendations and local rainfall statistics of Central Europe (e.g., Hungary and Slovenia) have been considered. In the calculation examples, for simplicity only single polarized and single frequency band links have been discussed. But the presented calculation method can be extended to the analysis of dual frequency band links using dual-band antennas (e.g., combined 23 GHz and 80 GHz link) or for dual-polarized links (vertical and horizontal polarization on same dual-polar antenna).

The 90 years history and the still ongoing very intensive research of μ/mmW radios as well as recent business forecasts clearly show that μ/mmW technology will remain widely used in mobile anyhaul networks in the coming years [45][51][62].

Acknowledgements

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List of Abbreviations

A	attenuation
A_{atm}	atmospheric attenuation
A_{rain}	rain attenuation
AT&T	American Telephone and Telegraph Company
B	bandwidth
BB	backbone
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BTS	Base Transceiver Station, base station
CEPT	European Conference of Postal and Telecommunications Administrations
d	distance, hop-length
dB	decibel
dBi	antenna gain in dB compared to the isotropic antenna
dBm	decibel, using milliWatt as the reference
ETSI	European Telecommunications Standards Institute
F	frequency
FM	Fading Margin
FSK	Frequency Shift Keying
FSL	Free Space Loss
FWA	Fixed Wireless Access
FTTS	fiber to the site
G	Gain
G_{RXa}	antenna gain of the receiver
G_{TXa}	antenna gain of the transmitter
GbE	Gigabit Ethernet
Gbps	Gbit/s
GSM	Global System for Mobile Communications, (in French 'Groupe Spécial Mobile')
ITU	International Telecommunication Union
LL	Leased Line
LoS	Line-of-Sight
LTE	Long Term Evolution (4G)
MDR	Microwave Digital Radio
Mbps	Mbit/s
mmW	millimeter-wave
NW	network
ODU	outdoor unit
OPBW	occupied power bandwidth
PDH	Plesiochronous Digital Hierarchy
PL	Propagation Loss
PSTN	Public Switched Telephone Network
P_{RXth}	RX threshold, measured at the receiver input
P_{RXu}	unfaded received signal, measured at the receiver input
P_{TX}	TX power measured at the transmitter output
QAM	Quadrature Amplitude Modulation
n-QAM	n-ary QAM (n=16, 32, 64, 128, 256, etc.)
QPSK	Quadrature Phase Shift Keying (often called 4-QAM)
R	bitrate
$R_{0.01\%}$	rainfall intensity that is exceeded in 0.01% of time
RADAR	Radio Detection and Ranging
RAP	Radio Access Point
RAT	Radio Access Technology
RF	Radio Frequency
RSL	Received Signal Level
RX	receive or receiver
SDH	Synchronous Digital Hierarchy
SG	System Gain
SNR	Signal to Noise Ratio
TX	transmit or transmitter
TV	television
WiFi	Wireless Fidelity
μW	microwave
2G	2nd generation mobile system (GSM)
3G	3rd generation mobile system (UTRAN)
4G	4th generation mobile system (LTE and LTE-A)
5G	5th generation mobile system ('New Radio')
6G	6th generation mobile system – research topic

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From metamaterials to smart materials - overview of meta-concepts in microwave applications

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Abstract

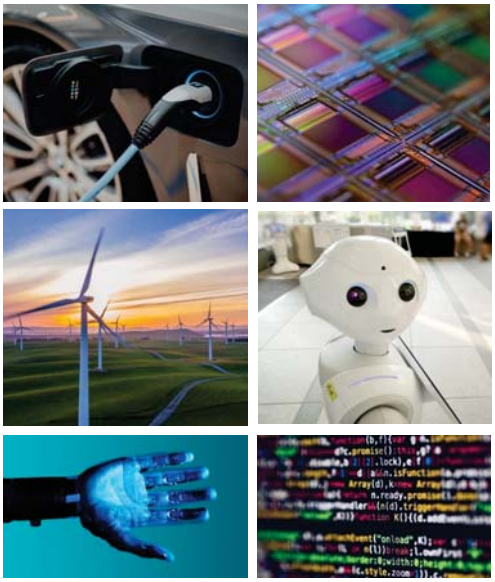
Speculations about materials that could have negative electromagnetic parameters and strange properties started in 1940s and 1960s, but it wasn't until year 2000 that these ideas truly came to life with the first demonstrations of metamaterials. Although various artificial electromagnetic structures were developed also before, the idea of metamaterials or "beyond" materials developed in 2000 initiated a major evolution in the field of electromagnetics resulting in many new communication and microwave devices and applications. Metamaterial is defined as any material which has been engineered to have properties not found in naturally occurring materials and usually it is a composite of different materials arranged in some kind of periodic lattice where the period is much smaller than the operating wavelength. This concept has resulted in many various demonstrations that were later extended and converted to actual applications, such as super-lenses with infinite resolution, electromagnetic "invisibility cloaks", miniaturization of waveguides, resonators, antennas and other communication and microwave components. Also, the original term of metamaterials diversified in many other directions in electromagnetics, and today there are passive and active metamaterials, metasurfaces, higher-symmetry metamaterials and many other concepts. This overview will summarize the most important results achieved in the past, present applications and on-going projects and highlight future research activities leading to a concept popularly known as "smart materials".

Author's biography



Marko Bosiljevac *was born in Zagreb in 1980. He received B.Sc., and Ph.D. degrees in electrical engineering from the University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Zagreb, Croatia, in 2005 and 2012, respectively. From March 2006 he was working at the Department of Wireless Communications at FER. He was a visiting researcher at the University of Siena, Italy in 2010 and 2011. As of March 2016 he is Assistant Professor at the Department of Wireless Communications at FER. He published more than 50 papers in journals and conference proceedings in the area of analytical and numerical modelling and development of various electromagnetic and optical structures and systems. Dr. Bosiljevac also participated in the organization of several doctoral schools and international conferences and he serves as a technical reviewer for several international scientific journals. He received silver medal "Josip Lončar" from FER for outstanding Ph.D. thesis in 2012.*



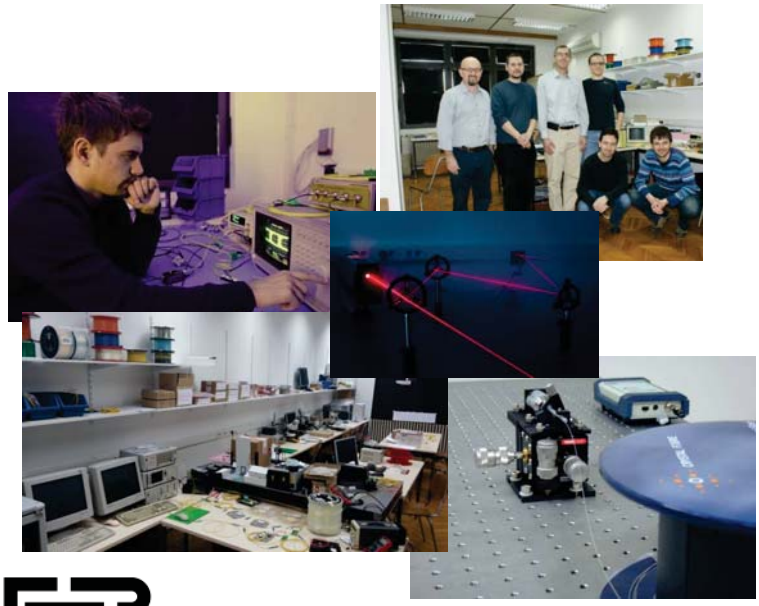


Faculty of Electrical Engineering and Computing

AI
ICT
Robotics
Sustainable Energy
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Advanced Components
Transportation Systems



aolab.fer.hr – Applied Optics Laboratory



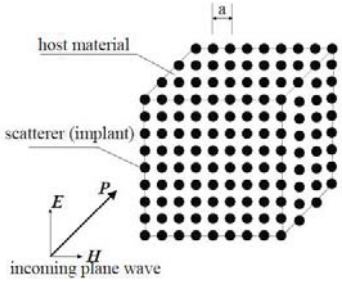
- Research and development of optical sensors based on optical fibers as sensing elements
- Development of advanced RF circuits and amplifiers
- Microwave components analysis and development
- Development of novel radar systems and applications
- Analysis and development in the field microwave metamaterials, metasurfacas and higher-symmetry devices

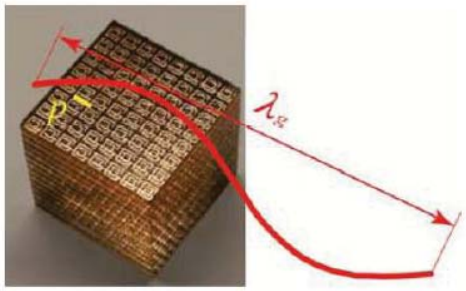
Outline

- What are metamaterials?
- “Metamaterials” before 2001 and after
- Limitless possibilities?
- Diversification of the metamaterials idea
  - “Meta” is a great prefix!
  - Passive and active structures
  - Metasurfaces
  - Higher-symmetry structures and surfaces
- Conclusion: Smart materials and surfaces

What are metamaterials?

- Concept of metamaterial (for radio/microwave field)
- μετα = meta = beyond





Providing that $a << \lambda$, the structure behaves as a homogeneous material with some new μ and ε $\Rightarrow$ artificial materials $\Rightarrow$ ***Metamaterials***

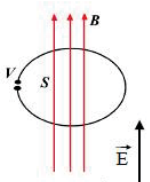
What are metamaterials?

- From electricity and magnetism towards electromagnetic theory

1831



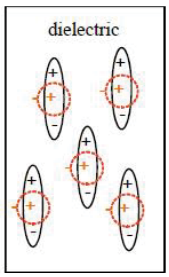
Michael Faraday



$$V \sim \frac{\Delta \vec{H}}{\Delta t}$$

EM induction

Dielectric polarization

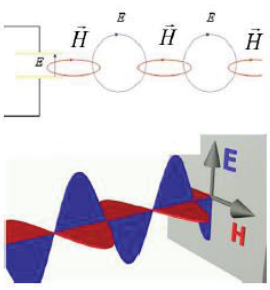


$$\nabla \vec{E} = Q$$

$$\nabla \times \vec{H} = \vec{J} + \varepsilon \frac{\partial \vec{E}}{\partial t}$$

$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}$$

$$\nabla \mu \vec{H} = 0$$



1873



James Clerk Maxwell

What are metamaterials?

- From electromagnetic theory towards radio communications









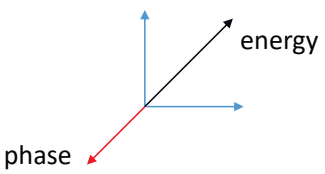
Basic concepts in electromagnetism are described with two fields and two "positive" numbers!

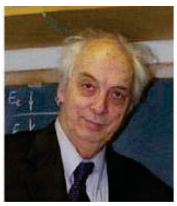
$$\vec{E}, \vec{H}, \hat{\varepsilon}, \hat{\mu} \ldots \ldots k \infty + \sqrt{\varepsilon\mu}$$

What are metamaterials?

- Many forms of artificial materials were investigated in the past – stained glass in churches, chiral structures by Jagadis Chunder Bose, etc…
- Major shift happened with the question –
  What would happen if μ and ε were negative numbers?

$$\vec{E}, \vec{H}, \hat{\varepsilon}, \hat{\mu} \ldots \ldots k \infty \pm\sqrt{\varepsilon\mu}$$



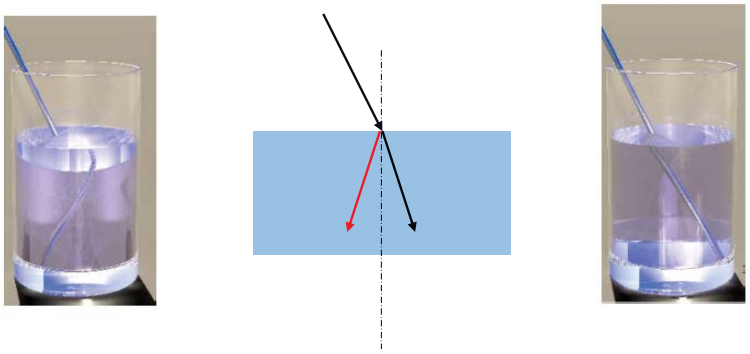


Victor Veselago (1967)

- Negative-index materials were first described theoretically by Victor Veselago in 1967. He proved that such materials could transmit light and that the phase velocity vector could be made anti-parallel to the direction of Poynting vector (direction of the energy). *This is contrary to wave propagation in naturally occurring materials*.

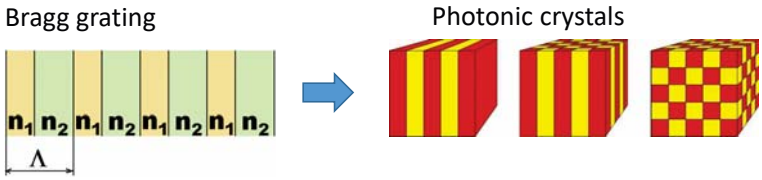
What are metamaterials?

- There are no "negative" ($\mu < 0$ and $\varepsilon < 0$) materials in nature!
- If there were, we could have inverted Snell's law!



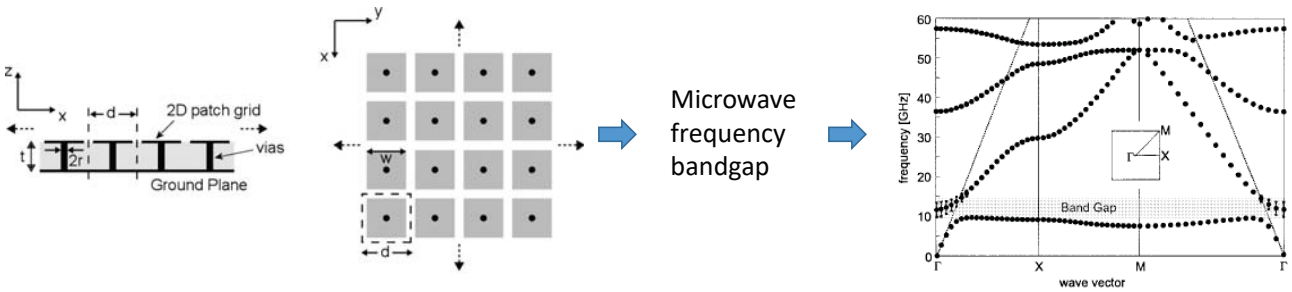
"Metamaterials" before 2001

- Historical artificial materials examples:
  - 13th century stained glass windows in Notre-Dame Cathedral and La Sainte-Chapelle in Paris - their colors originate from plasmonic effects arising from various metallic inclusions in the glass.
  - In the late part of the 19th century, Jagadis Chunder Bose published his work on the rotation of the plane of polarization by man-made twisted structures = artificial chiral structures by today's definition.
- In 1980s interest grew for periodic optical structures with more than one dimension – photonic crystals (Eli Yablonovitch)
  - Essential idea was to expand the Bragg grating principle to 3D



"Metamaterials" before 2001

- Different concepts similar to Bragg gratings were present in microwaves – corrugations, soft and hard surfaces, ...
- Small revolution came with Sievenpiper/Yablonovitch paper on "*High-Impedance Electromagnetic Surfaces with a Forbidden Frequency Band*"
- This renewed and ignited the interest for artificial EM materials



D. F. Sievenpiper, L. Zhang, R. Broas, N. G. Alexopolous, E. Yablonovitch, "High-Impedance Electromagnetic Surfaces with a Forbidden Frequency Band", IEEE Transactions on Microwave Theory and Techniques, vol. 47, no. 11, pp. 2059-2074, November, 1999

"Metamaterials" before 2001

- Sir John Pendry in 2000 theoretically extended the work of Veselago, Yablonovitch and Sievenpiper and published a paper "*Negative Refraction Makes a Perfect Lens*"

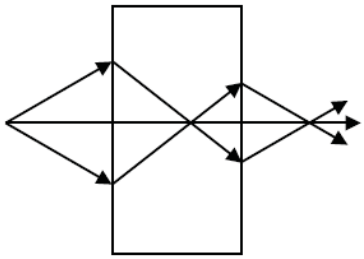
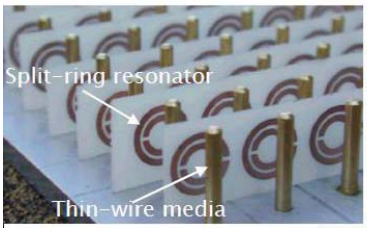


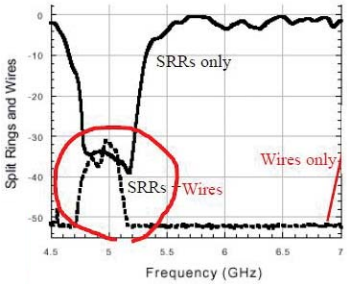
FIG. 1. A negative refractive index medium bends light to a negative angle with the surface normal. Light formerly diverging from a point source is set in reverse and converges back to a point. Released from the medium the light reaches a focus for a second time.

J. B. Pendry, Negative Refraction Makes a Perfect Lens, Phys. Rev. Lett. 85, 3966 – October 2000

Metamaterials after 2001

- The first "negative" metamaterial – Smith at al. (UCSD) 05/2000

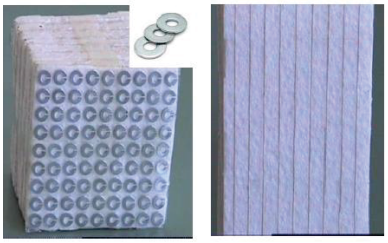


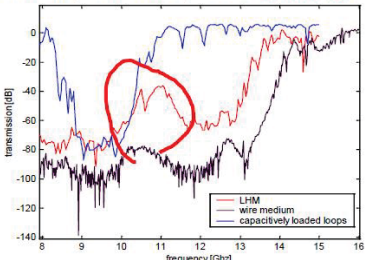


Wires: negative ε
Rings: negative μ

$$k \infty \pm \sqrt{\varepsilon\mu}$$

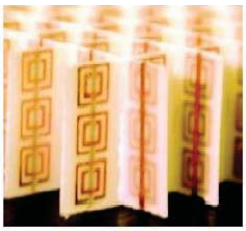
- Second experiment - confirmation of Smith results – Hrabar, Barbarić, Ereš, 07/2000

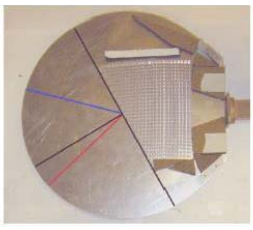


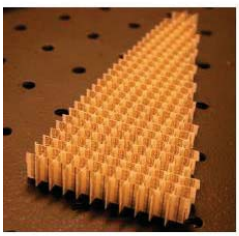


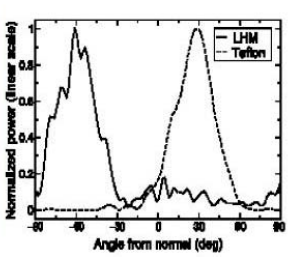
Metamaterials after 2001

Experimental verification of Negative Refraction (Shelby et al. 2001)

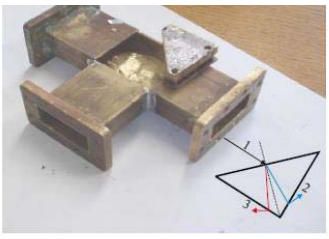


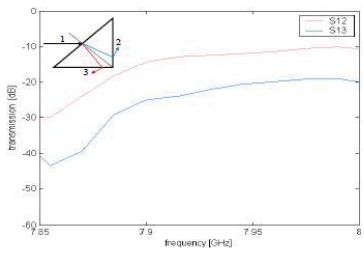






Experimental verification of Negative Refraction (Hrabar, Bartolic, 2002)

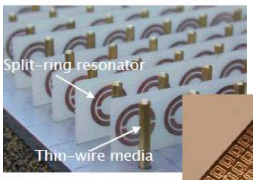




Metamaterials after 2001

- Since the first experiment the idea has reached maturity and practical applications

UCSD, 2000



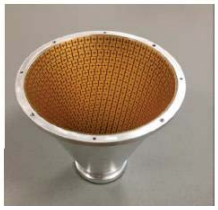
The Boing Group, 2004



The LG Group, 2009



European Space Agency, 2021

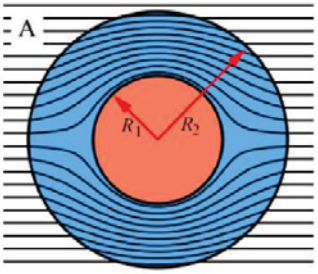


Possibilities – Invisibility cloak?

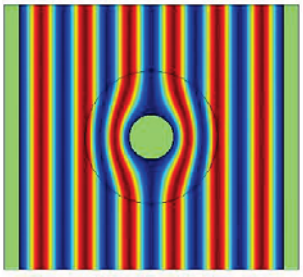
Schurig, Pendry et al. Science Express 2006

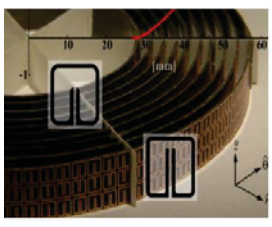


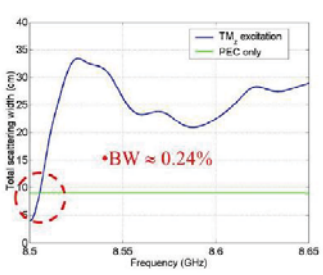
Ivsic, Sipus et al. IEEE TAP, 2009.

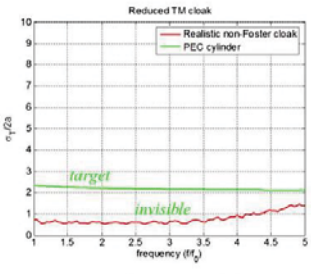


Hrabar, Sipus et al. IEEE TAP, 2010.



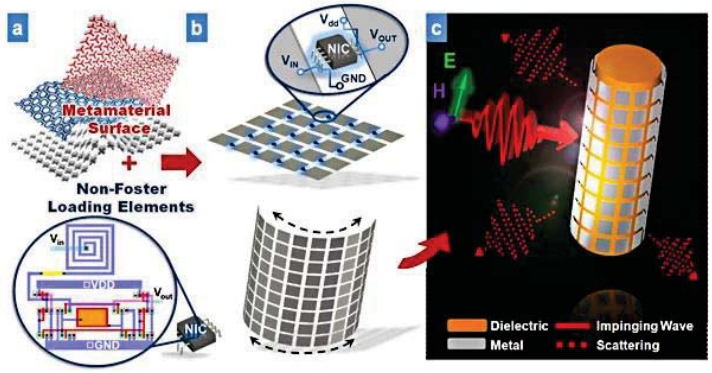






"Meta" is a great prefix!

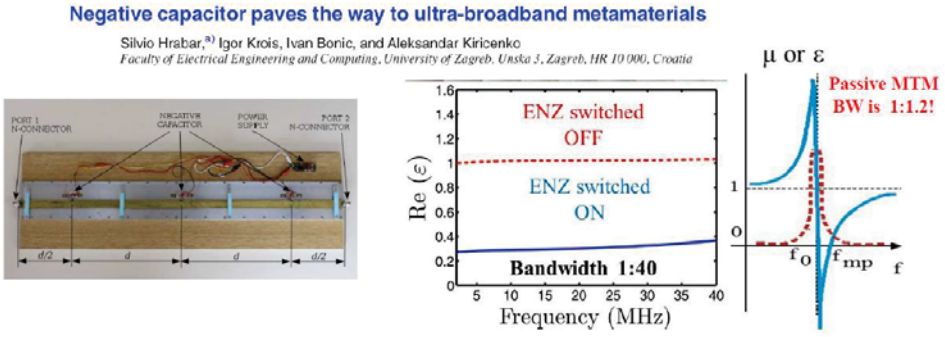
- The term "metamaterials" was extremely successful in the science community and gave rise to various meta-concepts
- Metasurfaces
- Meta-atoms instead of unit cells
- Active metamaterials
- Metatronics
- ...



Pai-Yen Chen, Christos Argyropoulos, and Andrea Alù, Broadening the Cloaking Bandwidth with Non-Foster Metasurfaces, Phys. Rev. Lett. 111, 233001 – December 2013

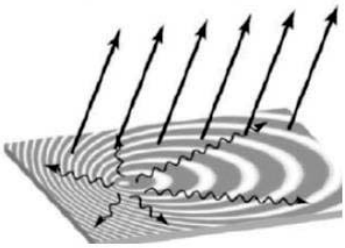
Passive and active metamaterial structures

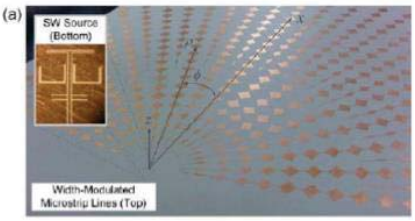
- Passive "negative" metamaterials – due to resonance they are always narrowband
- Broadband operation is possible with the use of active metamaterials based on negative capacitors and inductors (non-Foster elements)

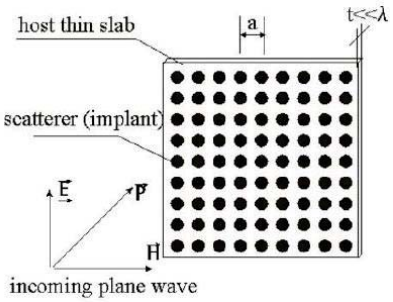


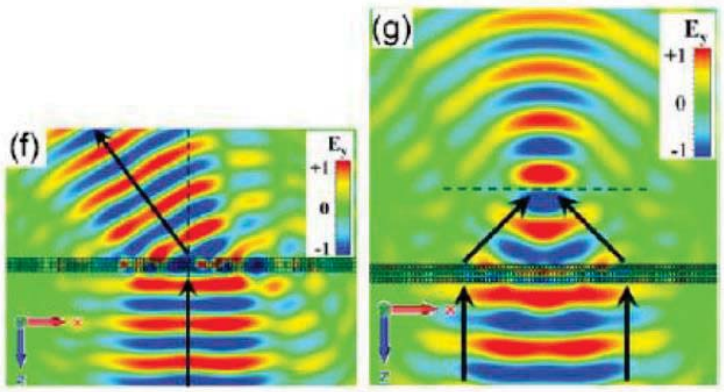
Metasurfaces

- From metamaterials to metasurfaces

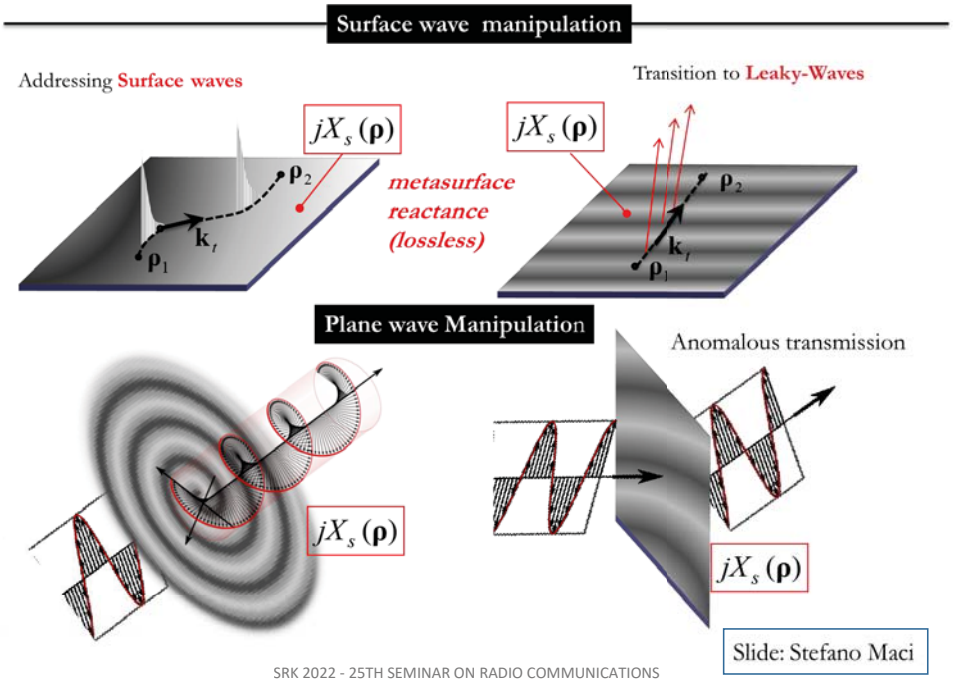






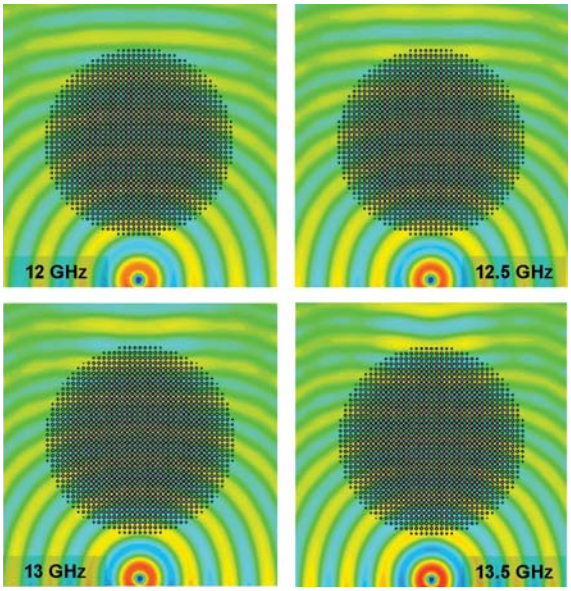


Metasurfaces



Metasurfaces

- Example: Surface-waves supporting metasurfaces
  Application: Luneburg lens antenna
- The ideal Luneburg lens is a spherical lens that posses the property to focus an incoming plane wave into a single point on the lens edge.

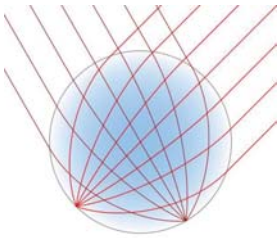


Luneburg law for the refractive index

$$n = \sqrt{2 - \left(\frac{\rho}{R}\right)^2}$$

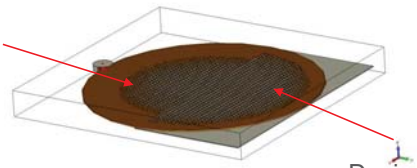
radial coordinate

lens radius

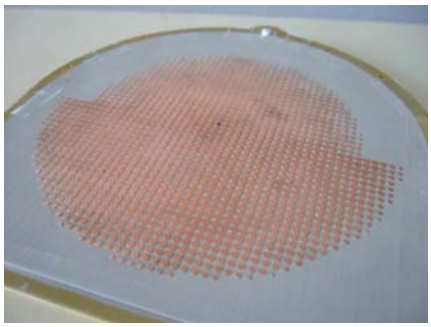


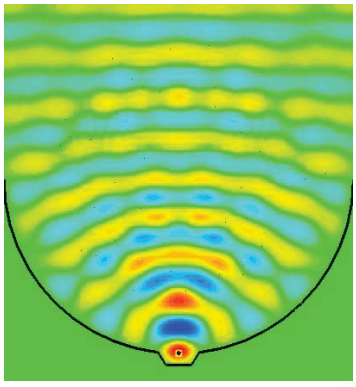
Metasurfaces

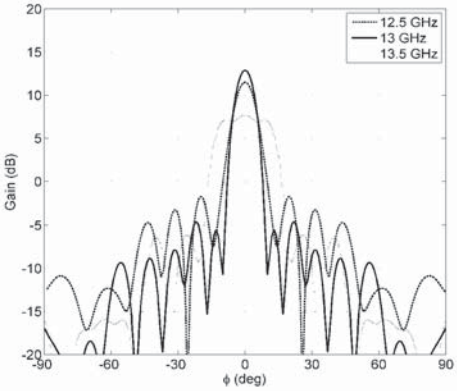
Designed for $h_1 = 2.3$ mm

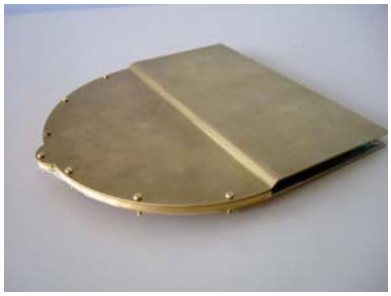


Designed for $h_2 = 5.75$ mm





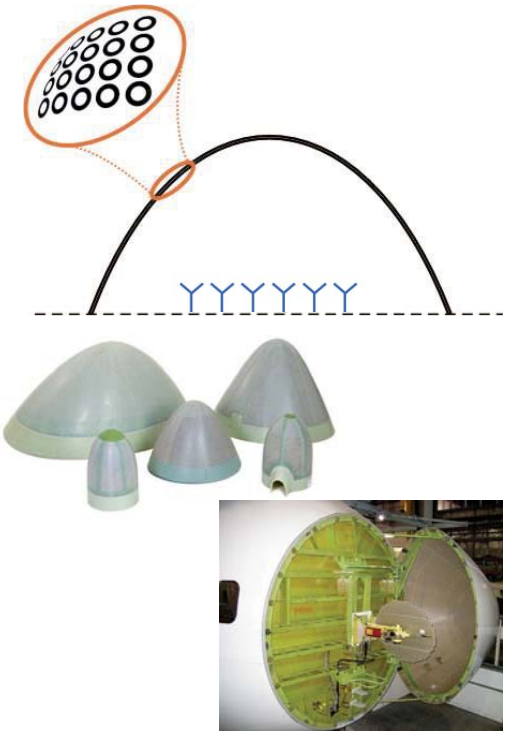




M. Bosiljevac, M. Casaletti, F. Caminita, Z. Sipus, S. Maci, "Non-uniform Metasurface Luneburg Lens Antenna Design," *IEEE Transactions on Antennas and Propagation*, Vol. 60, pp. 4065-4073, Sep. 2012.

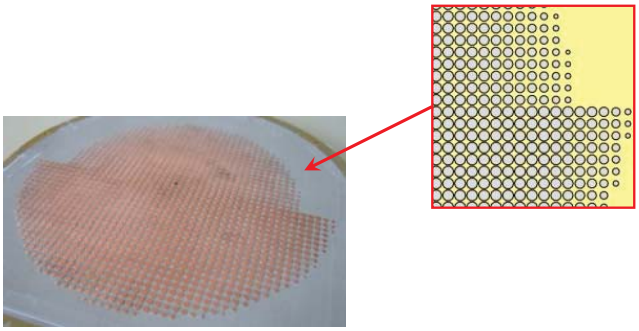
Metasurfaces

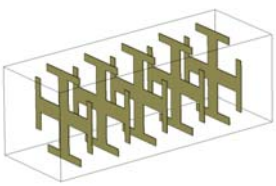
- Example: Analysis and design of cascaded curved metasurfaces
- Radomes and vehicle (e.g. airplane) covers
  - dielectric radome – mechanical protection for antennas
  - metasurface – electromagnetic filter and focusing lens
  - radome + metasurface = mechanical & electromagnetic protection and focusing element



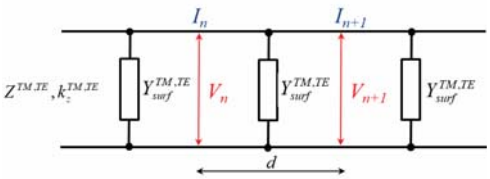
Metasurfaces

- Example: Analysis and design of cascaded curved metasurfaces
- Analysis of one metasurface layer
  - local periodicity approach
- Analysis of multilayer metasurface structure
  - transparent surface impedance & ABCD matrix formulation:





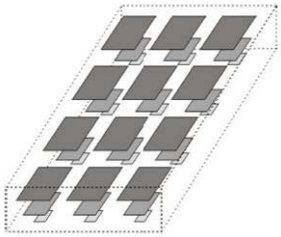
$$Y_{surf} = Y_{surf}(\omega, \mathbf{k}_t)$$

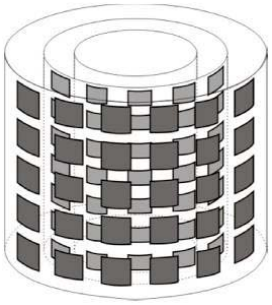


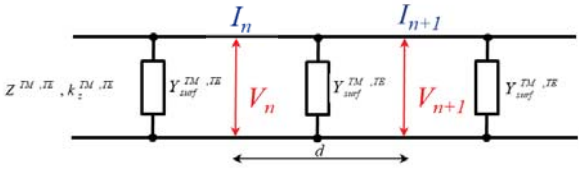
Z. Sipus, M. Bosiljevac, A.Grbic, "Modelling Cascaded Cylindrical Metasurfaces Using Sheet Impedances and a Transmission Matrix Formulation," *IET Microwaves Antennas & Propagation*, Vol. 12, No. 7, pp. 1041-1047, 2018.

Metasurfaces

- Example: Analysis and design of cascaded curved metasurfaces





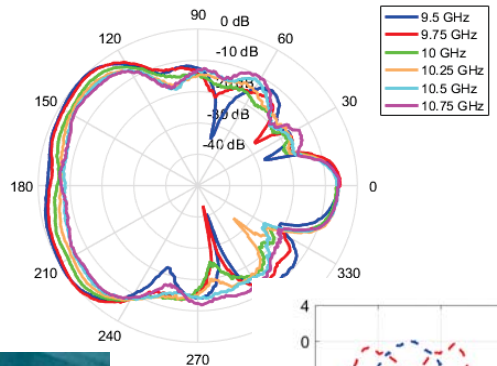


$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ Y_{surf,1} & 1 \end{bmatrix} \cdot \begin{bmatrix} A_{TL,1} & B_{TL,1} \\ C_{TL,1} & D_{TL,1} \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ Y_{surf,2} & 1 \end{bmatrix} \cdot \ldots \cdot \begin{bmatrix} A_{TL,N-1} & B_{TL,N-1} \\ C_{TL,N-1} & D_{TL,N-1} \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ Y_{surf,N} & 1 \end{bmatrix}$$

Z. Sipus, M. Bosiljevac, A.Grbic, "Modelling Cascaded Cylindrical Metasurfaces Using Sheet Impedances and a Transmission Matrix Formulation," *IET Microwaves Antennas & Propagation*, Vol. 12, No. 7, pp. 1041-1047, 2018.

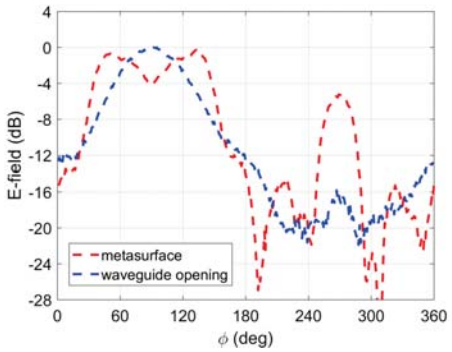
Metasurfaces

- Example: Analysis and design of cascaded curved metasurfaces





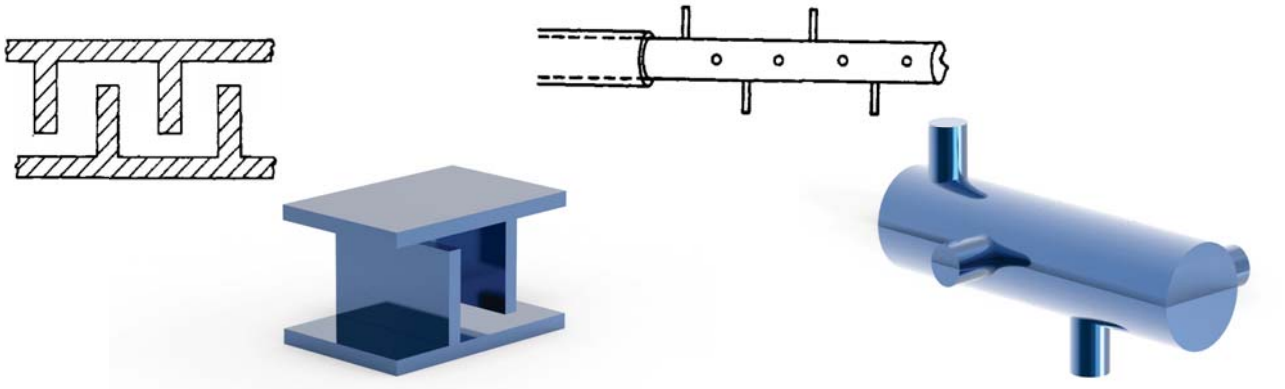




D. Barbarić, M. Bosiljevac and Z. Šipuš, "Analysis of Curved Metasurfaces Based on Method of Moments," *2020 14th European Conference on Antennas and Propagation (EuCAP)*, 2020, pp. 1-5,.

Higher-symmetry structures and surfaces

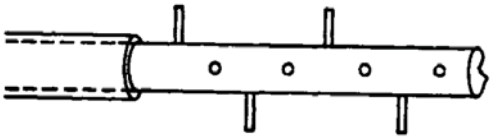
A UNIFORM periodically loaded guiding structure is said to possess a higher symmetry if the latter consists of more than a simple translation or reflection.



1) A. Hessel, M. H. Chen, R. C. M. Li, and A. A. Oliner, "Propagation in periodically loaded waveguides with higher symmetries," *Proceedings of the IEEE*, vol. 61, no. 2, pp. 183–195, Feb. 1973.
2) R. Mittra, S. Laxpati, "Propagation in a Wave Guide With Glide Reflection Symmetry", *Can. J. Phys.*, 43, 353-372 (1965)
3) R. Kieburtz, J. Impagliazzo, "Multimode propagation on radiating traveling-wave structures with glide-symmetric excitation", *IEEE Trans. Antennas and Propag.*, 18, 3-7 (1970).

Higher-symmetry structures and surfaces

- Twist symmetry in nature:

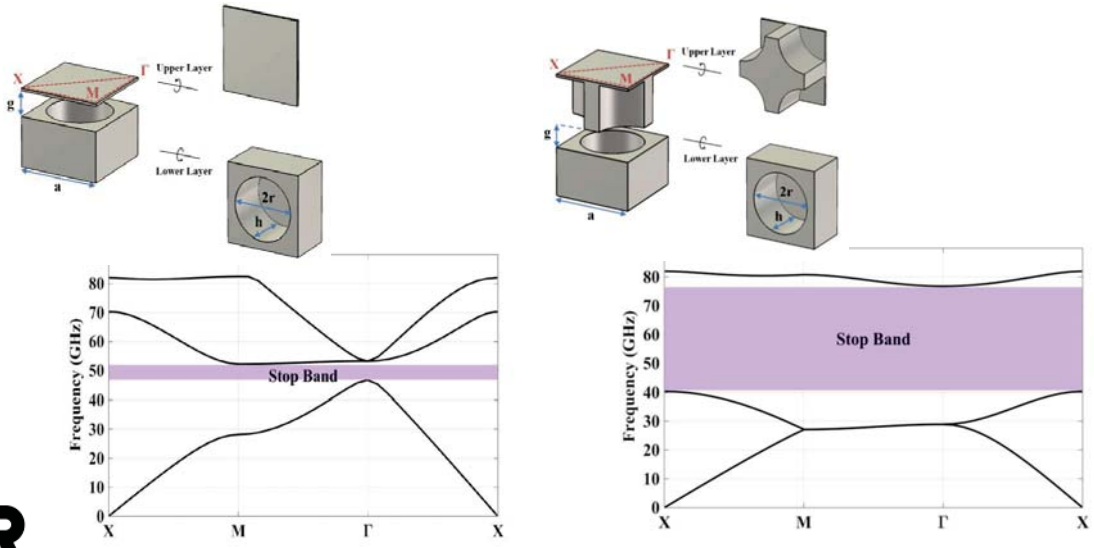






Higher-symmetry structures and surfaces

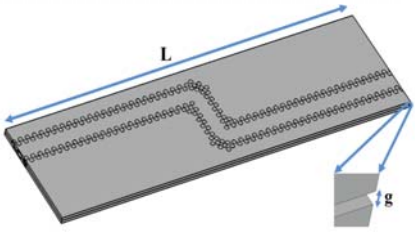
- Conventional structure versus glide symmetry:

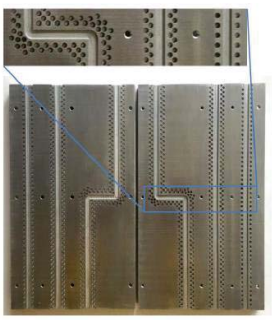


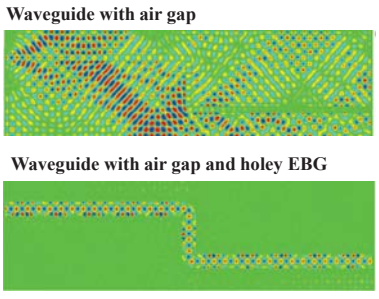
M. Ebrahimpouri, E. Rajo-Iglesias, Z. Sipus, O. Quevedo-Teruel, "Cost-effective Integrated Waveguide Circuits Based on Glide-Symmetry Holey EBG Structure", *IEEE Transactions on Microwave Theory and Techniques*,

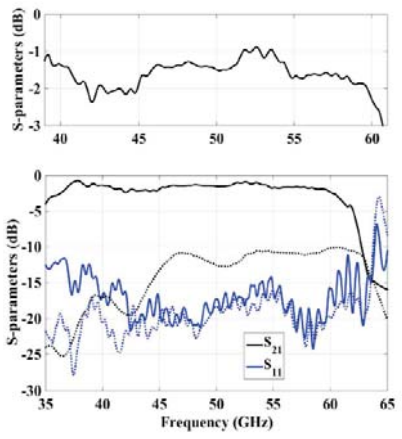
Higher-symmetry structures and surfaces

- This technology can be employed to design a number of electromagnetic components:
  - Example: Waveguides



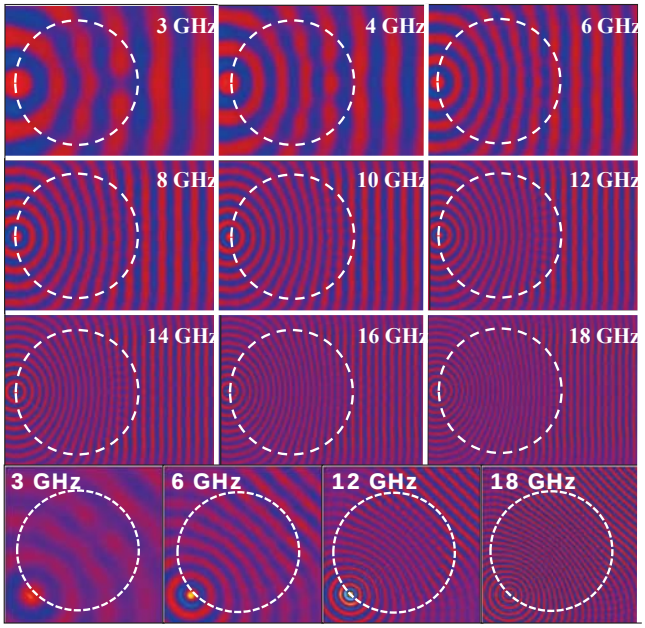






Higher-symmetry structures and surfaces

- Ultra-wide band response demonstrated from 3GHz to 18GHz:
  - Electric field distribution:
  - Point source to plane wave transformation.

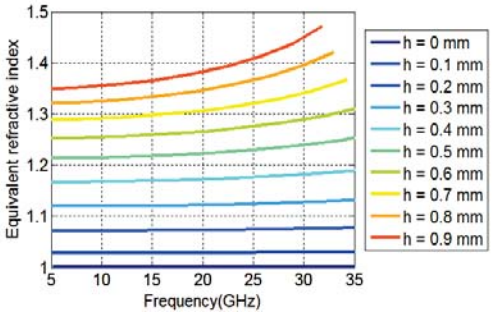


O. Quevedo-Teruel, M. Ebrahimpouri, M. Ng Mou Kehn, "Ultra wide band metasurface lenses based on off-shifted opposite layers," *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 484-487, 2016.

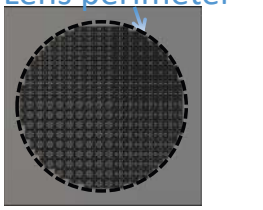
Higher-symmetry structures and surfaces

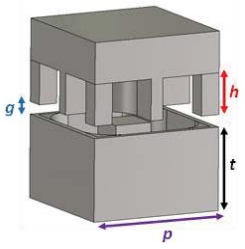
- Glide-symmetric holes loaded with pins

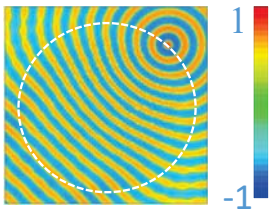
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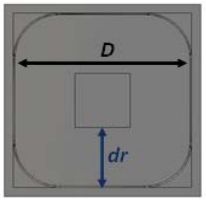


Lens perimeter







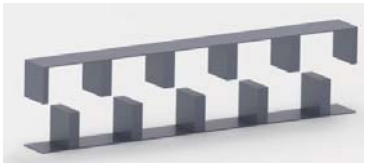


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COST Symat

- SYMAT - COST ACTION CA18223 – FUTURE COMMUNICATIONS WITH HIGHER-SYMMETRIC ENGINEERED ARTIFICIAL MATERIALS
  - The SyMat COST Action has the ambition to promote an international research community proposing innovative solutions to the demand of omnipresent connections in today's society. Higher data rates and shared platforms can only be achieved if a new class of communicating devices becomes available at millimeter waves.





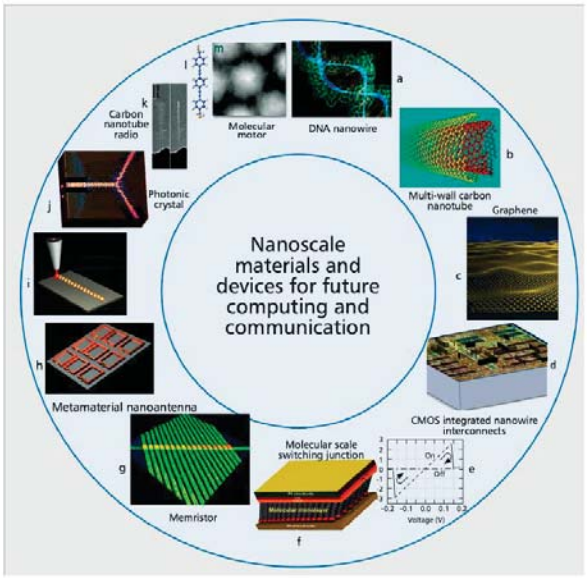


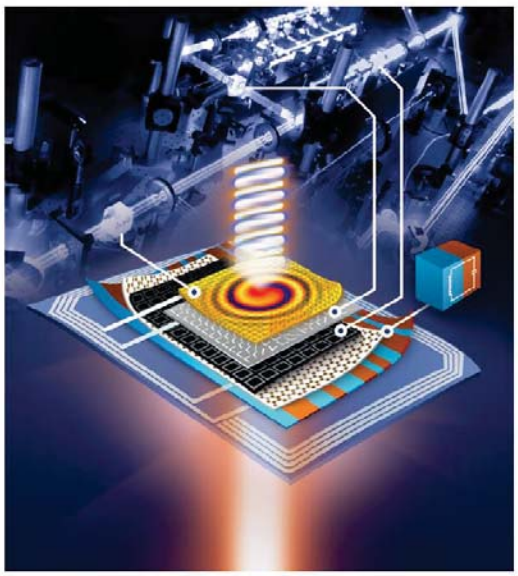


Smart materials and surfaces

- NANOARCHITECTRONICS is a new technology aimed at conceiving, designing and developing reconfigurable, adaptive and cognitive structures, sensorial surfaces and functional "skins" with unique physical properties and engineering applications in the whole electromagnetic spectrum; through assembling building blocks at nanoscale in hierarchical architectures
- Overview of the concept:
- https://ec.europa.eu/futurium/en/system/files/ged/foreseen_ntx_roadmap_1.pdf

Smart materials and surfaces



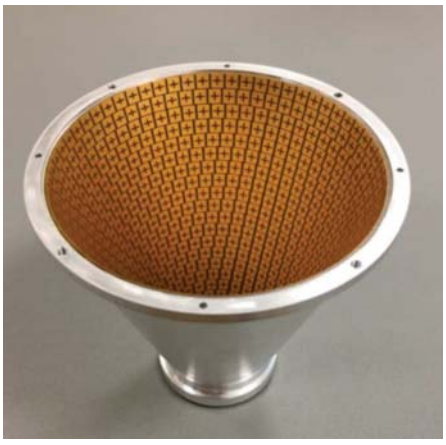


Examples of new Nanomaterial for computing and communications http://web.ece.ucdavis.edu/~saif/pub/papers/NanomatIEE7ECOM.pdf b) construction of NTX devices (artistic rendering from Nature Nanotechnology 10, 11–15 (2015) doi:10.1038/nnano.2014.314)

Conclusion

- Thank you for your attention!

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ESA 2021 Metasurface TEM horn

PLAKATI

POSTERS

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SRK 2022
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Priložnosti, temelječe na avtentikaciji signalov sistema Galileo

Univerza v Ljubljani
Fakulteta za pomorstvo in promet
60

Franc Dimc

Preverjanje pristnosti?

Splošno uporabljani sprejemniki satelitske radijske navigacije (GNSS) lahko z avtentikacijo razločujejo pristne signale satelitov od lažnih. Možnost, da bi sprejemniki GNSS lahko uporabnikom dajali napačne rešitve položaja, hitrosti ali časa zaradi napadov s potvarjanjem, prvič zabeležena po ukinitvi potvarjanja efemerid satelitov GPS leta 2000, je spodbudila iskanje tehnik zaznavanja takšnih napadov, preučevanja šibkosti in prizadevanja za učinkovito odpornost nanje. Vojaški krogi, kjer so za takšno odpornost bili pripravljeni sprejeti 'nošenje s seboj malo več železja', so se 2009 ogreli za rešitev s sprejemniki z večjimi antenami, kasneje tudi rabo dvojno polariziranih, a šele vključitev asimetričnih kriptografskih algoritmov v letu 2011 je napovedala rešitev za uporabo v samostojnem sprejemniku, rešitev, ki je poskusno dostopna v organizaciji Agencije Evropske unije za vesoljski program (EUSPA).

Področja uporabe

Galileo Open Service Navigation Message Authentication (OSNMA) je mehanizem za preverjanje pristnosti navigacijskih signalov [1], ki sprejemnikom GNSS omogoča, da preverijo pristnost podatkov GNSS in se tako prepričajo, da so podatki, ki jih prejmejo, res iz Galilea in niso bili spremenjeni. EUSPA trenutno izvaja zainteresirani javnosti odprt preizkus avtentikacije signalov Galileo svetovnih razsežnosti, s čimer preizkušajo storitev OSNMA, ki omogoča izračun overjenega položaja, hitrosti in časa. Napovedi rabe samostojno odločujočih se robotskih vozil in plovil povzročajo največ zanimanja in raziskav uporabe OSNMA na področjih rabe brezpilotnih letalnikov, nadzora nad morskim krivolovom, sinhronizacije telekomunikacijskih 5G omrežij, pametnih tahografov za nadzor nad vožnjami prevoznikov in nasploh sledenje tovorom, v sistemih, ki nadzorujejo pretok energije ter celo v rudarski industriji.

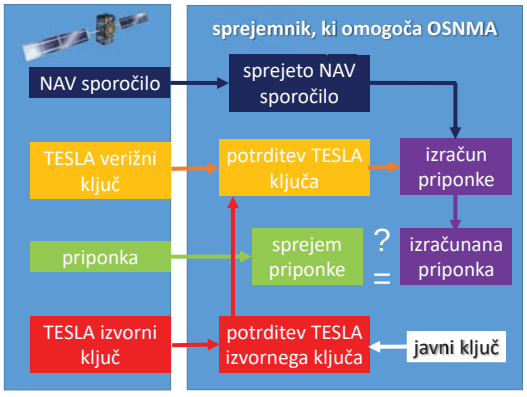
Prenose GNSS z odprtim signalom bi torej zaščitili. Krivolov: v EU so vsa plovila nad 15 metrov opremljena z napravo Vessel Management System (VMS) in „modro škatlo", ki posreduje centru za spremljanje ribolova države, v katere ladijski register je vpisana, z GNSS pridobljen položaj plovila, ta center pa nato sporoči informacije državnemu ali regionalnemu organu za ribištvo, v katerega vodah plovilo lovi. Prilagojena ladijska oprema VMS bo dekodirala informacije o položaju, hitrosti in času iz Galileovih signalov na dveh frekvenčnih področjih E1 (1575,42 MHz) in E5a (1176,45 MHz) ter izvajala avtonomno preverjanje pristnosti podatkovnih sporočil GNSS z OSNMA. Sinhronizacija telekomunikacijskega omrežja 5G: raba dvofrekvenčnih sprejemnikov GNSS omogoča večjo odpornost časovnih virov, ki temeljijo na GNSS in preverjanje pristnosti v zemeljski infrastrukturi, ki je odvisna od podatkov o času, ki jih prenašajo sateliti [2]. Pametni tahografi, se uporabljajo za nadzor izkoriščenja delovnega časa voznikov med vožnjami po javnih površinah v tovornjakih [3], taksijih in drugih vrstah vozil. Z vključitvijo OSNMA bodo še bolj zaupanja vredni tudi podatki naprav za sledenje posameznim tovorom, uporabljanih v komercialnih prevozih. Rudarstvo: storitev visoke natančnosti Galileo (HAS) omogoča v kombinaciji s Galileovima storitvama za preprečevanje ponarejanja odprto OSNMA in tržno Commercial Authentication Service (CAS), natančnost in varnost orodij za avtonomne stroje. Energetika: povečana odpornost proti ponarejanju GNSS, ki jo omogočata OSNMA in CAS, bo izboljšala odpornost energetskih omrežij. Storitev s satelitsko dostopnimi popravki določanja položaja EGNOS prispeva tudi k izboljšani časovni natančnosti in stabilnosti. Zanesljivost je izboljšana tudi z zagotavljanjem neodvisnega časovnega vira, omrežnega časa EGNOS, in vgrajene integritete, ki bi jo lahko uporabili za zagotavljanje certificirane časovne storitve v prihodnosti.

Kaj se dogaja med NMA?

Tehnike avtentikacije predvidevajo, da so v pristnih signalih prisotna zagotovila ali kriptografska potrditev *od kod* izvira koda ali da je koda oddajana *pravočasno* [4] ali *prstni odtisi fizičnih* oddajnikov. Samostojni sprejemniki GNSS s signalom javno znane civilne GPS kode (C/A) v področju L1 ne morejo določiti avtenticiranega položaja. Dokler imajo navigacijska sporočila današnjo obliko, je civilne signale možno avtenticirati tudi s povezavo strežnik-klient z vključevanjem vojaške kode ali s primerjavami signalov, sprejetih na različnih krajih. Napadalcu je treba preprečiti vpliv na koščke oddajane kode (chips) in podatkovne bite navigacijskih sporočil, kar omogočajo štiri tehnike: NMA, SCA (spreading code auth), NME (nav. message encryption) in SCE (spreading code encryption).

V NMA se z digitalnim podpisovanjem avtenticira satelitovo navigacijsko sporočilo, zaradi česar ga ni treba šifrirati. Modulirani navigacijski podatki so digitalno podpisani s pomočjo načeloma asimetričnih kriptografskih algoritmov. Ključ za podpis je znan le kontrolnemu segmentu GNSS, potrjevalni ključ pa je javen. Z zasebnim ključem podpisane podatke o času in efemeridah satelitov (priponke), ki lahko vsebujejo tudi pretekle ali prihodnje podatke, sateliti oddajajo kot del navigacijskega sporočila. Sprejemnik prejete podatke avtenticira z javnim ključem. Če je kriptografska moč para ključev dovolj velika, napadalec z javnim ključem in zadnjimi prejetimi sporočili ne more razvozlati in sam uporabiti zasebnega ključa. Avtentikacijo otežuje dolg čas sprejemanja celotnega navigacijskega sporočila, vključno s podpisom, zaradi česar je v NMA vključen protokol TESLA (Timed Efficient Stream Loss-tolerant Authentication), ki temelji na tehniki veriženja blokov, uporabi simetričnih kriptografskih MAC funkcij in doseganju asimetrične avtentikacije, ohlapni časovni sinhronizaciji satelit-sprejemnik ter kljub velikem številu sprejemnikov omogoča avtentikacijo v oteženih pogojih.

Kakšen sprejemnik torej rabimo za OSNMA? Sprejemati mora na področju E1B, biti se sposoben dovolj sinhronizirati z Galileovim sistemskim časom (GST), da se lahko začne postopek OSNMA, izvajati kriptografske funkcije ECDSA, SHA-2, SHA-3, HMAC in CMAC in se poveže s strežnikom OSNMA Evropskega centra za storitve GNSS (GSC), da pridobi kriptografsko gradivo ([5], str. 7).



Postopek obdelave signalnih elementov OSNMA v ustreznem sprejemniku [5], str. 6.

Povabilo

Vsak se lahko udeleži javnega preizkušanja storitve OSNMA.

Prijavite se tukaj:

Reference

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Automated Inorganic Pigment Classification in Plastic Material using Terahertz Spectroscopy

Andrej Sarjaš , Blaž Pongrac, Dušan Gleich

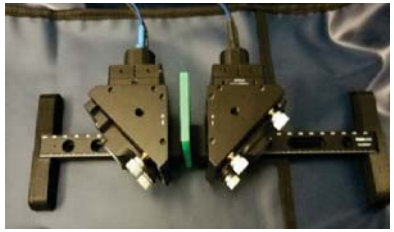
The University of Maribor, Faculty of Electrical Engineering and Computer Science, Koroška Cesta 45, 2000 Maribor, Slovenia; andrej.sarjas@um.si, blaz.pongrac1@um.si, dusan.gleich@um.si

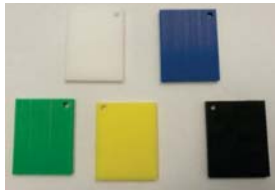
Introduction

This work presents an automatic classification of plastic material's inorganic pigment using Terahertz spectroscopy and Convolutional Neural Networks. The plastic materials were placed between the THz transmitter and receiver, and the acquired THz signals were classified using a supervised learning approach. A THz frequency band between 0.1-1.2 THz produced a one dimensional (1D) vector that is almost impossible to classify directly using supervised learning. In this approach a novel pre-processing of 1D THz data that transforms 1D data into 2D data, which are processed efficiently using a Convolutional Neural Network. The proposed preprocessing algorithm consists of four steps: Peak detection, envelope extraction, and a down-sampling procedure. The last main step introduces the Windowing with Spectrum Dilatation that reorders 1D data into 2D data. The spectrum dilation techniques ensure the classifier's robustness by suppressing measurement bias, reducing the complexity of the THz dataset with negligible loss of accuracy.

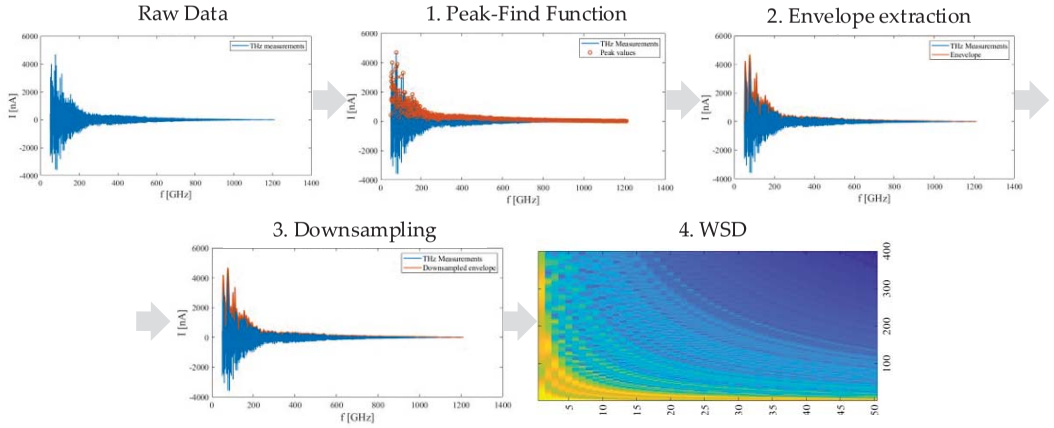
Experimental setup

Experimental setup with TeraScan 1550 device. The plastic sample is placed in the measurement gap in between two PCAs antennas.

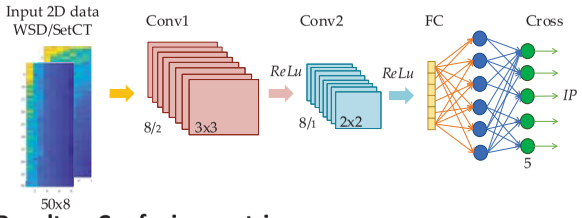




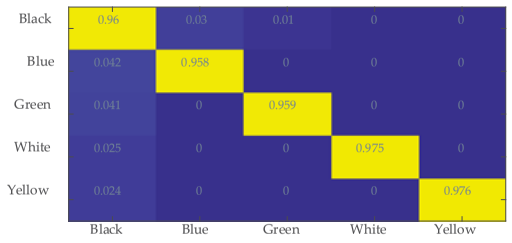
Data preprocessing with novel Windowing Spectrum Dilation-WSD technique



Optimized CNN structure



Results – Confusion matrix WSD low



Conclusion

The efficiency of 2D WSD transformation with CNN classification gave promising results, and outperformed similar classification techniques based on 1D input data. The 2D transformation of THz-FDS data showed a strong correlation with the classification accuracy, where the efficiency of WSD was confirmed with the experiment results. The WSD was more robust on uncertainties and bias, and enabled considerably more data simplification with insignificant reduction of the classification re-liability.

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Regression Neural Network for Soil Moisture Estimation using fully polarimetric Synthetic Aperture Radar Data

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Introduction

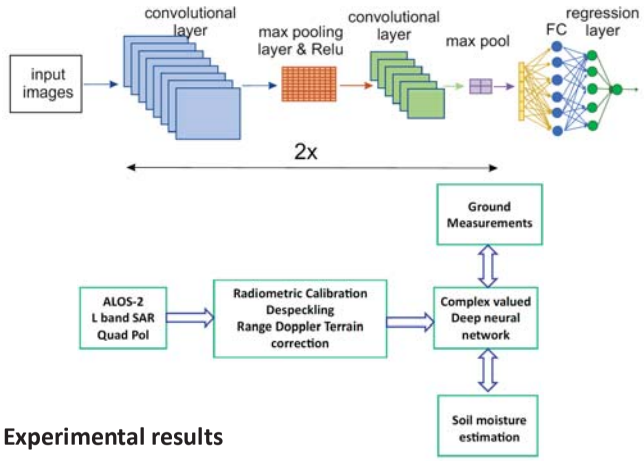
Over the past few years image categorization using deep learning became very popular, because it can handle large databases and has shown good recognition results. This paper presents the complex valued convolutional network (CV-CNN) for Synthetic Aperture Radar (SAR) soil moisture estimation. The CV-CNN consist in general of a real or complex valued input layer, output layer and one or more hidden layers. Hidden layers represent any combination of convolutional layers, pooling layers, activation functions, and are fully defined within complex valued domain. This paper proposes a deep Convolutional Neural Network (CNN) for soil moisture parameter estimation. A 9 layer convolutional neural network was used, consisting of convolutional, pooling, dropout, fully connected and regression layers. We used 1000 ground measurements for each SAR acquisition using L-band fully polarimetric SAR data. The experimental results were verified using 100 ground points.

Structure of complex valued convolutional network

A CNN consists of input layer followed by optional sub-sampling and regularization layers and ending in fully connected layers. The input into CNN is an image which is processed by several filters. The response of the filter is obtained by the convolution, therefore the convolutional response encodes the input and determine features by reducing dimensionality.

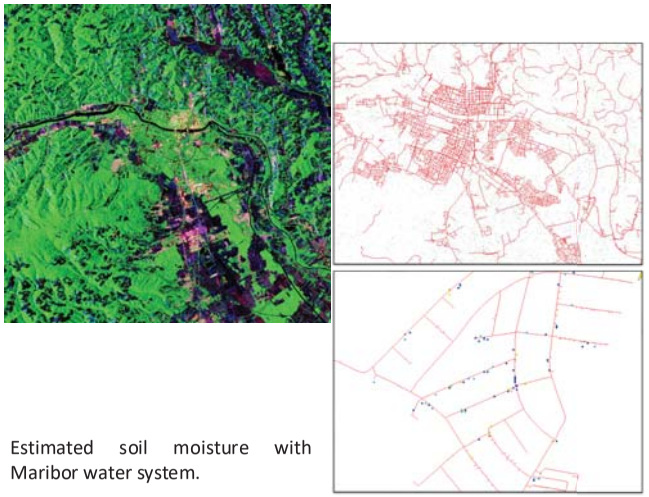
Same as with the real value CNN, the CV-CNN is also based on the 2D multichannel input or co-called channel maps. However, the main difference between the two is that each channel array value in CV-CNN is represented in the complex domain as well as hidden layers, which are convolutional filters, pooling filter and activation functions with complex valued inputs and outputs.

Deep convolutional regression network for soil moisture detection



Experimental results

ALOS-2 SAR image from year 2018 in Pauli RGB representation



Estimated soil moisture with Maribor water system.

Comparison between ground points and datasets acquired in 2018 and 2021



Conclusion

This work proposed a deep convolutional network for estimation of soil moisture using L band Synthetic Aperture Radar data. The neural network consisted of 9 convolutional layers, Relu and activation layers. The last layer is a regression layer, which was used to reduce the dimensionality of the data. Experimental results showed that the proposed method is able to adapt to the real valued soil moisture for volumetric scattering. The experimental results using multi temporal data analysis showed that the proposed method well estimates the moisture of the vegetated areas within 13 % accuracy, when the measured values are compared with the ground measurements, and thus indicates the possibility of soil-moisture estimation from the L-band radar radiation.

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Research supported by H2020 AI Regio.

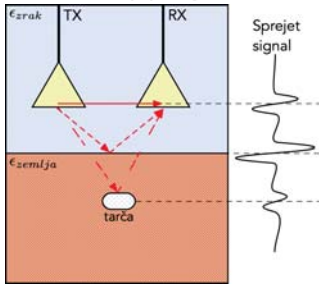
Zračno sklopljen radar za detekcijo eksplozivnih teles

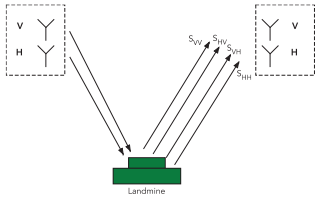
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Uvod

Doktorska disertacija prikazuje razvoj zračno sklopljenega georadarja za detekcijo eksplozivnih teles pod površjem zemlje in je primarno namenjen za uporabo na brezpilotnem zrakoplovu. Ker je teža in avtonomija takšnega brezpilotnega zrakoplova zelo omejena to zahteva posebno skrb pri razvoju georadarskega sistema. S tem namenom je bil izdelan radar, ki oddaja kontinuirano valovanje in deluje po metodi s stopničastim frekvenčnim korakom (ang. Stepped Frequency Continuous Wave - SFCW). Z uporabo te metode je bilo mogoče izdelati celoten sistem z uporabo integriranih elektronskih komponent in s tem zagotoviti nizko porabo energije ter kompaktno izvedbo. Kljub temu pa sistem nudi resolucijo v nekaj centimetrskem območju, kar omogoča detekcijo tudi najmanjših eksplozivnih teles. Skrbno načrtovan sprejemnik, ki temelji na hibridni analogno-digitalni super-heterodinski strukturi izloči potrebo po močnostnem ojačevalniku oddanega signala. Da bi dodatno izboljšali kakovost merjenja, je v delu predstavljen sistem za odpravljanje nezaželenih odbojev ter uporaba polarizacije, ki razširi dimenzije georadarske slike, in tako nudi boljšo prepoznavo eksplozivnih teles. Sistem je bil preizkušen v laboratorijskem okolju kot tudi na testnem poligonu v kombinaciji z komercialnim brezpilotnim zrakoplovom.

Zračno sklopljen georadar

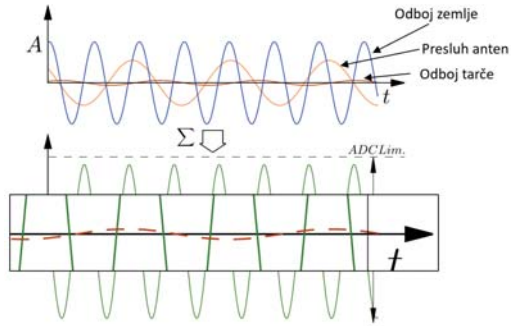




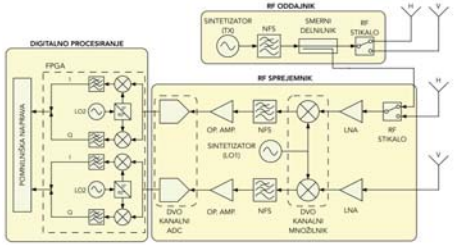
Polno polarimetrični način delovanja

Problematika nezaželenih odbojev pri SFCW georadarju

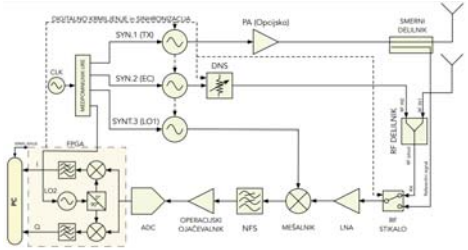
Na podobnem principu temelji rešitev v zvočni tehniki (t.i. aktivno odpravljanje šumov).



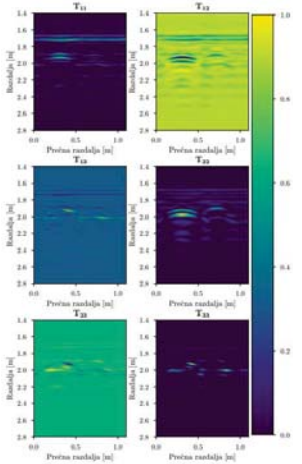
Predlagan sistem za možnost zajema več polarizacij



Predlagana super-heterodinska struktura SFCW radarja z integriranim sistemom odpravljanja nezaželenih odbojev



Rezultati



Posamezne georadarske slike koherenčne matrike T v realni obliki, kjer je zakopana kovinska AP mina (levo) in plastična mina (desno). Zakopani sta na globini 15 cm.



Sklep

Prvi sklop, ki se je navezoval na izdelavo GPR za uporabo na UAV. Za ta namen smo uporabili večinoma IC komponente in tako uspeli izdelati GPR, ki je po omenjenih lastnostih boljši od trenutnih predlaganih rešitev. Drugi sklop se je navezoval na razširitev sistema z možnostjo koriščenja polarizacije. Tretji in tudi zadnji sklop se ni navezoval le specifično na problematiko, ki je prisotna pri SFCW GPR-jih, temveč pri vseh CW radarjih. Za ta namen nam je uspelo uspešno implementirati EC sistem, ki na fizični ravni odpravlja nezaželene statične tarče. Delovanje je bilo potrjeno v laboratorijske okolju in na poligonu s šolskimi minami.

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2.-4. februar 2022
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MIMO komunikacije

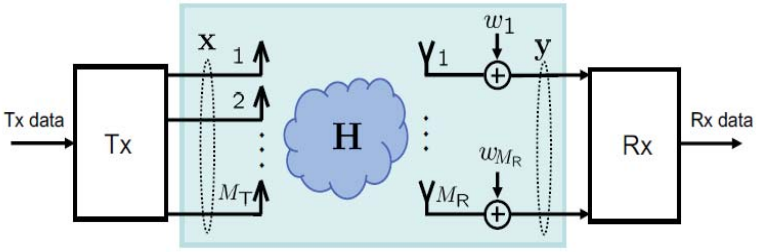
Jure J. Marković, Boštjan Batagelj

Motivacija

Optimizacija obstoječih brezžičnih komunikacijskih sistemov je privedla do raziskovanja sistemov z več vhodi in več izhodi (angl. Multiple Input Multiple Output – MIMO). V zadnjih desetletjih se brezžična omrežja namreč soočajo s fizikalnimi omejitvami zmogljivosti, ki jih klasični sistemi ne morejo več prebroditi. Tehnologija MIMO ponuja razmeroma ugodno alternativno rešitev, ki ne zahteva velikih posegov v frekvenčni prostor, prinaša pa pomembne izboljšave v komunikacijskih zvezah za multimedijsko uporabo pri dostopu do brezžičnega interneta in omogočanje širokopasovnih brezvrvičnih rešitev. Vse to so obetajoče projekcije uporabe tehnologije MIMO, ki jo omogočajo dodane antene.

Koncept MIMO

Komunikacijski sistem MIMO ima na obeh prenosnih straneh več anten, ki med seboj sodelujejo in s tem ustvarjajo zanesljivejšo in robustnejšo komunikacijo. V primerjavi s eno-antenskimi sistemi je prisotna višja kompleksnost pri zasnovi, prenosu in obdelavi podatkov. Z uvedbo sodelujočih anten se iz enotskih premikamo v vektorske vrednosti. Veliko vlogo pri zasnovi sistema MIMO igra radijski kanal, po kateremu se prenašajo informacije, ki pa je največkrat nepredvidljiv in spreminjajoč. Pri tem predmeti, ki se znajdejo na radijski poti, niso nujno moteči, ker lahko blagodejno vplivajo na raznolikost sprejetega signala. Raznolikost predstavlja eno izmed štirih kategorij dobitkov v sistemih MIMO. Preostale so dobitek skupine, ki je posledica M_R-kratnega povečanja SNR, ki je bil dosežen s koherentnim kombiniranjem na sprejemniku. Sledita raznolikostni ter multipleksni dobitek, ki pa se izključujeta. Prvi je posledica več prostorskih kopij signala (natančneje $M_T M_R$), drugi pa je posledica M_T neodvisnih podatkovnih tokov, ki se prenašajo brez povečevanja energijskega vložka in pasovne širine. Preostane dobitek zaradi oblikovanja snopov, ki je tehnika, pri kateri se usmeri brezžični signal proti določenemu sprejemniku, s čimer se zmanjšajo motnje med signali.



Za povrnitev originalnega signala je pomembno poznavanje kanalskih lastnosti, ki se jih pridobi z ločitvijo »kanalnega« in »signalnega« dela. Informacije o kanalu se uporabi pri procesih na oddajni (predhodno kodiranje, predekvalizacija, prilagajanje zvezi itd.) in sprejemni strani (ekvalizacija, detekcija itd.). Raznolikost lahko interpretiramo kot prisotnost več kopij oddanega signala. Brezžičen prenos ustvari razmere, kjer je posamezna pot vsaj deloma neodvisna. Odprt medij povzroči, da različne veje signala pridejo do sprejemnika ob različnih časih, frekvenčnih premikih, poteh in polarizacijah. To povzroča časovno, frekvenčno, prostorsko in polarizacijsko raznolikost. Poti so torej neodvisno presihajoče.

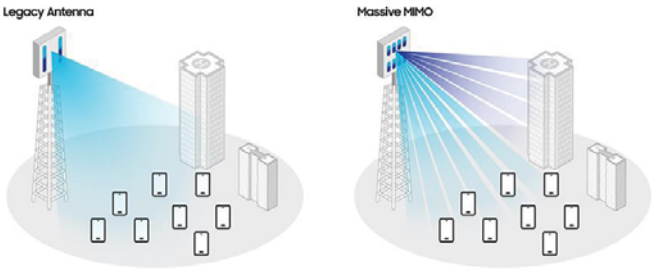
Uporaba

Pri zasnovi signala MIMO je treba imeti model kanala. Način analiziranja se izbere na podlagi najpomembnejših lastnosti sistema MIMO, ki sta konfiguracija anten in uporabljena pasovna širina. Ker je tehnologija MIMO še relativno nova, je večina vidikov modeliranja še v povojih in obstajajo le v teoriji. Kateri model je najboljši za uporabo, je zelo odvisno od razmer na kanalu ter parametrov, ki so na voljo. Na voljo so že uveljavljeni standardizirani modeli, izmed katerih so najbolj uporabljeni 3GPP SCM, IEEE 802.11n in IEEE 802.16 WiMAX, ki pa se razlikujejo glede na uporabljene teoretične metode.

Da kompleksnost sistema ne bi presegla sistemskih virov si pomagamo z raznimi shemami, ki optimizirajo prenesene informacije. Optimizacija se največkrat izvede o obliki reorganizacije oddajnih bitov s pomočjo časovno prostorskih kod, ki še dodatno izboljšajo raznolikost z uvedbo redundantne informacije v prostorsko in časovno dimenzijo. Pogosto se jih uporablja v kombinaciji s kodami za popravljanje napak. Njihova glavna naloga je načrtovanje podatkovnih bitov v oddajni vektor.

$$h(t,\tau) = \sum_i A_i e^{j2\pi f_i t} \delta(\tau - \tau_i)$$

$$H(t,\tau) = \begin{bmatrix} h_{1,1}(t,\tau) & \cdots & h_{1,M_T}(t,\tau) \\ \vdots & \ddots & \vdots \\ h_{M_R,1}(t,\tau) & \cdots & h_{M_R,M_T}(t,\tau) \end{bmatrix}$$



MIMO ponuja izboljšave obstoječih komunikacij, kot so višja podatkovna hitrost, večja spektralna učinkovitost, večje število uporabnikov, izboljšana pokritost in doseg, boljša kakovost storitve (angl. Quality of service – QoS), nižja pogostost napak (angl. bit-error rate – BER) in nižja poraba energije na oddajni strani.

Z dodajanjem anten se ustvari raznolikost, ki poviša zanesljivost prenosa zaradi podvajanja prenesenih informacij. Ta tehnologija se danes uporablja v omrežjih WiFi, poleg tega pa se uveljavlja kot nepogrešljiv del brezžičnih mobilnih sistemov pete generacije (5G) mobilnih sistemov.

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O seminarju
The seminar

Strokovni seminar Radijske komunikacije se je razvil iz izobraževalne dejavnosti, ki jo je pod okriljem projekta TEMPUS JEN-04202 v letih 1993 do 1997 izvajala Fakulteta za elektrotehniko Univerze v Ljubljani. Seminar je namenjen strokovnemu izpopolnjevanju strokovnjakov radijskih komunikacij in drugih, ki jih to področje zanima. Vključen je v program izvajanja vseživljenjskega izobraževanja na Fakulteti za elektrotehniko v Ljubljani. Njegov namen je osveževanje, razširjanje izpopolnjevanje in poglabljanje znanja ter dvig strokovnosti zaposlenih strokovnjakov na področju optičnih komunikacij. Seminar obsega uvodni del, namenjen obnavljanju in razširjanju znanja, ter strokovni del, namenjen seznanjanju in poglabljanju v strokovna vprašanja o sistemih in njihovih sestavnih delih. Izvedenski del seminarja, ki ga izvajajo priznani vabljeni strokovnjaki, obsega nekatera pomembnejša razvojna vprašanja.

Seminar on Radio Communications evolved from the activities running at the Faculty of Electrical Engineering University of Ljubljana, during the period from 1993 to 1997 under the auspices of the European project TEMPUS JEN-04202 granted for the same period. The seminar si intended to communication professionals and other involved into the field of radio communications. It is part of the continuing education programme at the Faculty of Electrical Engineering in Ljubljana. Its primer porpuse is to enhance the expertise of professionals in the field of radio communications. The seminar consists of two parts: one part is dedicated to basic technical topics aiming to refresh fundamental knowledge in radio communications, and the second part is intended to the latest research and development achievements and trends from spectrum regulation, standardization, systems and solutions, all from international and national experts.

Ključna gesla
Keywords

0G, 2G, 3G, 3GPP, 4G, 5G, aktuatorji, antena, antena cigara, BLE, brezžične tehnologije, Brezžično globalno omrežje (WGAN), CEPT/EU, časovno kritične komunikacije, DECT, EC/CEPT, elektromagnetno valovanje, eMBB, EMS, ETSI, Giga-bitni radio, govorna komunikacija, GSM-R, IoT, IoT naprave, ITS, ITU-R, LTE-M, metamateriali, milimetrski valovi, MMDS/BWA, MU-MIMO, NB-IoT, Nesamostojno omrežje 5G, nevtroni, NMT450, nosljive naprave, NR-RedCap, OFDMA, O-RAN, pametna mesta, pametna območja, pametni telefon, PPDR, Prihodnji sistem radijskih komunikacij za železnice (FRMCS), privid varnosti, radar s sintetično odprtino (SAR), satelitski internet, senzorji, sevanje, sinhronizacija, smernost, Sodostop z ortogonalno frekvenčno porazdelitvijo (OFDMA), SpaceX, Starlink, UIC, WiFi6, WiFi 6 Mesh, Wireless Broadband Alliance (WBA), WLAN, WRC-23

0G, 2G, 3G, 3GPP, 4G, 5G, actuators, antenna, BLE, CEPT/EU, cigar antenna, Digital Enhanced Cordless Telecommunication (DECT), directivity, EC/CEPT, electromagnetic waves, eMBB, EMF, ETSI, Future Railway Mobile Communication System (FRMCS), Gbit radio, GSM-R, IoT, IoT devices, ITS, ITU-R, LTE-M, metamaterials, millimeter waves, MMDS/BWA, MU-MIMO, NB-IoT, neutrons, NMT450, Non-standalone 5G network, NR-RedCap, Orthogonal Frequency Division Multiple Access (OFDMA), O-RAN, PPDR, radiation, satellite internet, security theater, senzors, smart areas, smart cities, smart phone, SpaceX, Starlink, synchronization, Synthetic Aperture, Radar, Time-critical communication, UIC, voice communication, werable devices, WiFi 6, WiFi 6 Mesh, Wireless Broadband Alliance (WBA), Wireless Global Area Network (WGAN), wireless technologies, WLAN, WRC-23

Avtorji
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