SIMULATION OF TACTICAL NETWORKS USING SYSTEM-OF-THE-LOOP

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Key words: tactical network, simulation, system-in-the-loop, C2IS, real-time

Abstract: The successes of military missions strongly depend on quality planning. The need for near-real time simulation tools has become apparent, which allows the realistic network planning and training of command personnel on real Command and Control Information Systems (C2IS). Real hardware and C2IS software are, in these cases, connected to the simulator via a Local Area Network, where the tactical radio communication infrastructure is simulated on a virtual terrain. Such simulation of the network runs real-time with the simulated use of the C2IS. Operators of C2IS systems can simultaneously evaluate the qualities of tactical networks from the points of view of network throughput, end-to-end delays, radio visibility, etc., for each individual tactical unit. This paper presents some simple examples of using this new simulation methodology, which can be easy adapted to more complex C2IS scenarios.

Simulacija taktičnih omrežij z realnim sistemom v simulacijski zanki

Kjučne besede: taktična omrežja, simulacija, sistem v simulacijski zanki, C2IS, realni čas

Izvleček: Uspeh vojaških akcij je v veliki meri odvisen od kakovostnega planiranja le teh. V zadnjem času se je pojavila potreba po simulacijah taktičnih omrežij v realnem času, ki omogočajo realistično načrtovanje operacij in trening povelniškega osebja na realnem informacijskem sisemu poveljevanja in kontrole (C2IS). Za te namene se je razvil nov tip simulacij, ki omogoča povezavo realne strojne in programske opreme s simulacijskim orodjem. Simulacijsko orodje je namenjeno simulaciji virtualnega terena na katerega postavimo omrežje ter simulacijo povezav ali omrežij, preko katerih poteka komunikacija med realnimi napravami, ki jih priključimo na simulator. V članku predstavljamo simulacijo taktičnih omrežij z realnim sistemom v simulacijski zanki, ki je bila namensko razvita za Slovensko vojsko. V takšnem sistemu smo povezali realni informacijski sistem poveljevanja in kontrole (C2IS) s simuliranim taktičnim radijskim omrežjem na virtualnem terenu. V nadaljevanju smo predstavili različne ekperimente in simulacijske rezultate, kot je prenos digitalnega videa preko simulirane radijske povezave, ter rezultate simulacij v katere smo vključili realne naprave s programsko opremo informacijskega sistema poveljevanje in kontrole (C2IS) Slovenske vojske. S pomočjo takšnih simulacij lahko načrtovalci operacij ovrednotijo kakovost preiskušenih taktičnih omrežij na osnovi prepustnosti, radijske vidljivosti, zakasnitev, itd.

1. Introduction

Since joining NATO, Slovenia has had to face new challenges in terms of modernization and connectivity with other members. In 2001, the Multilateral Interoperability Programme (MIP) was established to advocate successful and harmonized operational functions for international peace-keeping forces /1/. Interoperability is achieved by C2IS (Command and Control Information Systems) at all military levels. C2IS is designed to control the operational, logistical and communication information stored in the C2IEDM (Command and Control Information Exchange Data Model) data bases. The success of this command and control system is highly correlated with the capacities of the data information carriers.

Most of the developed tools for tactical network simulations are "off-line" simulation tools, where we can analyze a tactical network after a simulation run. The most prominent problems in tactical networks are limited bandwidth, big round-trip delays, and the influence of terrain and nodes' mobility under radio link conditions /2/. Simulation of tactical networks is an important task in the process of military mission planning. Such methodologies assure a higher probability of success for critical tactical operations in military arenas. One of the early papers about tactical radio systems' simulation presented a solution /3/, where a specialized FORTRAN program was developed to simulate radio propagation effects, interference, SNR etc. The most often used simulation tool is the OPNET Modeler /4/ which is also used as a basic tool in our work. The results of tactical network simulations can be used when evaluating the performances of tactical communication networks /5/. Two-well known tools have been developed specifically for military tactical network simulations based on OPNET. The first tool is NETWARS /6, 7, 8/, which enables simulation of different tactical simulation scenarios by using diverse combinations of tactical network devices and military concepts. The second tool is INCOT, which represents an intelligent specialized tool for the optimization of communication networks /9-11/. In our case we have developed new simulation methodologies and tools for "off-line" analysis that enable C2 (Command and Control) communication systems' optimization /6-18/. We have developed the helper application TPGEN (Slovenian acronym for Tactical Information Traffic Generator), which enables user-friendly entering and editing of tactical network parameters to an OPNET simulation data model /15/. We have also developed an expert system application, which enables automatic analysis of OPNET simulation results /17/, and a tactical player visualization tool which combines MAK 3DNV (3D network visualization) simulation records with the results of expert system application /18/.

Over recent years the new concept of »on-line« tactical network simulation has also appeared where simulation is executed in "near-real" time. One of the earlier near- real-time simulators with a military application is the Battlespace communication network planner and simulator /19, 20/. This simulator is based on the OPNET simulation tool, where special communication hardware and software interfaces were developed that allow interconnection with actual command and control (C2) systems. In contrast to what we have described, we have also developed our real time simulator using OPNET with its System-in-the-loop (SITL) module which allows connections between real devices and the simulation. In this case, special communication devices are no longer needed. The SITL module provides packet translation between real and simulated packets /21/, where we show the basic concept of SITL simulations for simple voice application.

This paper presents a simple near real-time simulations example of tactical networks, where the real C2IS equipment of tactical units is connected through the simulator. The developed simulation system enables the testing and training of different tactical missions in a lab-environment, where the radio part of a wireless tactical network is simulated by an OPNET Modeler simulation tool. Within the simulated tactical communication infrastructure we can define radio parameters, position, trajectories of movement, etc., according to real radio equipment, and the mission plan. Radio wave propagation models based on virtual terrain modeling are used in simulation. During the simulation run, tactical planners and operators can analyze situations when a long delay appears, units have lost radio visibility, or lost the connection or data. Such a simulator enables early predictions of any possible problems that may appear during a real mission. In such a way, simulation tool can improve the probability of mission success, depending also on C2IS being dramatically improved. This new simulation methodology, presented in this paper, can be easy adapted to more complex C2IS scenarios, which is schematically shown in Figure 1. This figure shows schematic of connections between real tactical units, equipped with C2IS, and a simulator. External units are connected to the hub, which is connected to the physical interface (NIC) of the computer, where the simulator is installed. In the simulator the external connected units are represented as tactical wireless radio devices. On these modeled wireless stations, planners can set different parameters, such as channel frequency, bandwidth, antenna pattern, etc.

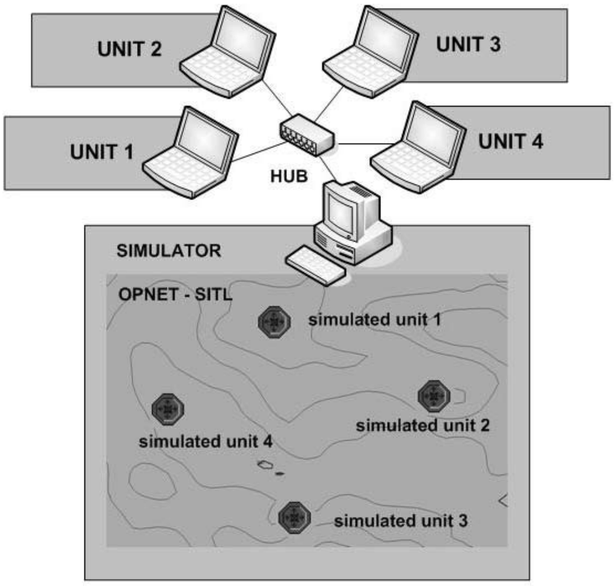

Fig. 1: LAN connections between real tactical units and the simulator, where the tactical radios of tactical units are modeled on virtual terrain.

This paper is organized as follows. The second section briefly describes the command and control information system (C2IS) used by the Slovenian Army. The third section describes advanced methods of OPNET Modeler for near-rear-time simulations. Two examples of near real-time simulations are presented in the fourth section. The first example presents the transmission of a video stream over the simulated wireless link. The second example presents the simulation, using real C2IS software. This section also presents the simulation results for both cases. This paper concludes with some guidelines for future work.

2. Command and control communication system in the slovenian army

Command and Control Information System (C2IS) (TISPINK is the Slovenian acronym) is designed to control the operational, logistical and communication information stored in the operation data bases (C2IEDM/JC3IEDM). The C2IS system provides information about operational developments, the state of your own, other friendly, and hostile units. This information is very important for modern international military operations and for the successes of many international operations. Figure 2 shows the main structure of the TISPINK unit. The core of the TISPINK system represents two main programs developed by a Danish company Systematic Software Engineering A/S /22/, in accordance with MIP recommendations. These programs are IRIS replication mechanism (IRM) and Sitaware. The IRM program /23/ is responsible for data exchange (replications) between the C2IS data bases of military subjects in accordance with so-called agreements. Agreements, which are set between the subjects, are comprised of the addressee of the military unit, the collection of data to be shared, and of used communication protocol (peer-to-peer or broadcast). This replication mechanism enables flexible control and supervision over information exchange in tactical networks.

The Sitaware program packet /24/ is a graphic interface of the command and control system. It is used for the planning, checking and analyzing of tactical units' activities on the battlefield. It enables the operators or planners of the operations to ascertain information about the situations of individual units in the field, and share this information with other military units. Sitaware is distinguished by a powerful graphical interface which is supported by GIS (Geographical Information System). GIS in turn, supports various geographical map formats and has different user layers thus enabling the entering of different information about tactical conditions on the battlefield.

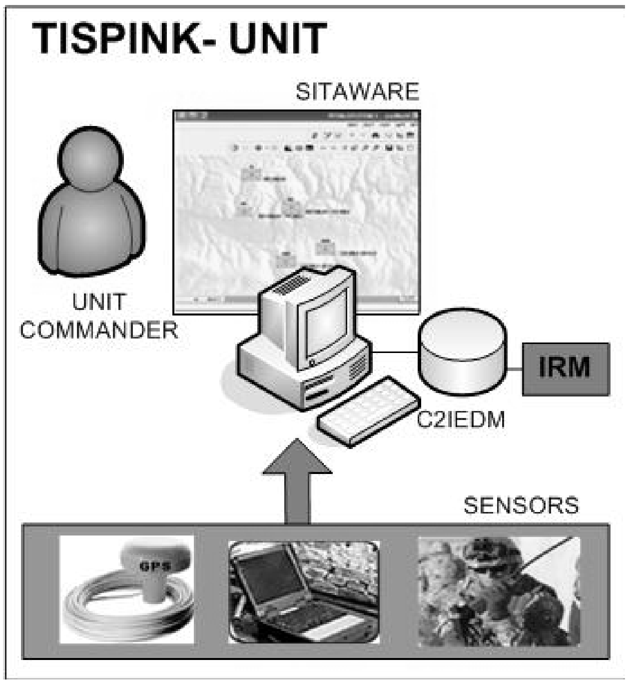

Fig. 2: TISPINK army unit

Figure 2 shows C2IS typical tactical unit. Each unit has its own C2IEDM data base, IRM replication mechanism and Sitaware. Various sensors can be connected to the tactical units, such as GPS. TISPINK units compose the hierarchical tactical network, as shown in Figure 3, where units can communicate by inferior and superior units based on defined IRM contracts, which are described in more details in /14/.

3. Advanced modules for tactical simulator in real time

3.1 OPNET Modeler

The developed tactical network simulation system for near real-time simulations is based on OPNET simulation tool /4,

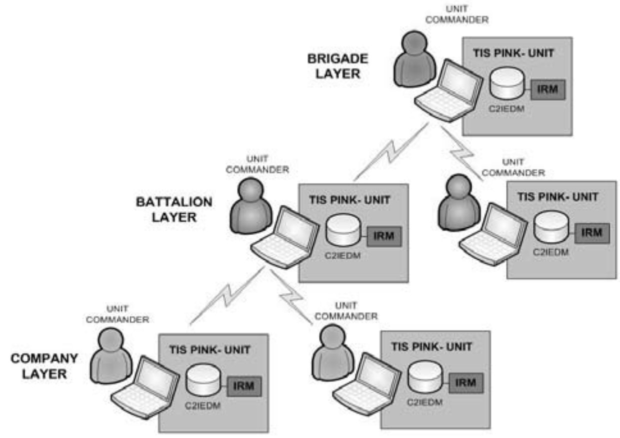

Fig. 3: Hierarchical structure of tactical network

6, 7, 8, 14/. We used the OPNET Modeler Wireless Suite for Defence, which supports high-fidelity protocols and equipment models with a scalable simulations environment capable of simulating wireless and also wired networks. It supports wireless simulations incorporating terrain influences in path-loss calculations with different propagations models, mobility, and 3D visualization.

OPNET Modeler is an object-oriented event driven communication simulation tool, with a hierarchical modeling environment, which uses graphic user interfaces (editors) – Network, Node and Processes editors. The *Network editor* enables a graphical description of network topology, while a *Node Editor* is used for describing communication device protocols and connections between them using layers of the ISO/OSI model. The *Process editor* is an upgrade of language C and uses a powerful finite state machine (FSM) approach to represent different communication algorithms and protocols. The OPNET Modeler is used for the modeling and simulation of communication networks and, at the same time, enables construction and study of communication infrastructure, individual devices, protocols, and applications.

3.2 System-in-the-loop module

System-in-the-loop (SITL) /4, 21, 33/ is an OPNET Modeler program module, which provides an interface between physical and simulated networks. It provides packet exchanges between real and simulated communication devices. SITL gateway represents an external device by which the simulation exchanges the packets, where the WinPcap /35/ library is used to route those packets selected by user defined filter, from an Ethernet network adaptor to the simulation process. In such a simulation manner, physical hardware and simulation can interact as a unified system. There are three main simulation topologies for using the SITL module /33/:

- real-to-real (communication between real devices over simulated network)
- sim-to-sim (communication between simulated devices over real network)

- sim-to-real (communication between real and simulated devices)

SITL module is used for near real-time simulations and can be used for many different purposes, such as: testing the effect of a simulated network on a real application, simulating the impact of network traffic amount to real network generating in simulation using a traffic generator, testing new prototypes of newly-developed devices and protocols, testing the performances of new protocols being developed by driving real network traffic over simulated traffic, etc. Simulated models running in the OPNET Modeler affect real applications and devices, providing various network effects, such as packet loss, delay, jitter, duplicate delivery, etc.

Using the module SITL we achieved packet exchanges using discrete event simulation via mapped interfaces. It also allows for multiple interfaces for mapping different network addresses in the simulated network. The SITL module directly routes packets from the network adapter to the simulation, and translates the entire packets, but the IP datagram stays unchanged in the regard to the rest of the simulation. Figure 4 shows the real-sim-real case of SITL simulation.

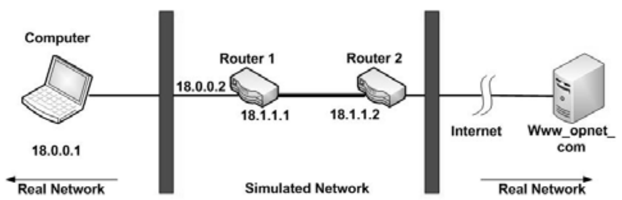

Fig. 4: Example of real-to-real type of SITL simulation, where real devices (client and server) communicate through a simulated network consists from routers.

In the OPNET Modeler 14.0 together with the SITL module support the following protocols /33/:

Ethernet
- IPv4 and IPv6 (except for fragmentation)
- Higher layer protocol conversion (real-sim-real, sim-real)
  - ICMP, ICMPv6
  - OSPFv2
  - RIPv1 and RIPv2
  - TCP, UDP
  - Limited FTP standard model application support
- Users can add support for their own protocols

When developing our own protocols, we wrote our own translation function (SITL translation function) to convert simulation packets to real packets, and vice versa. In the case of real-sim-real simulation, virtually all application-layer protocols are supported because, in this case, the simulation network is only used as a transit network for IPv4 or IPv6 packets.

3.3 3DNV

A 3D Network Visualizer (3DNV) /18, 21, 34/ is an additional OPNET Modeler module, which enables 3D animation simulated network topology, network devices, and link status. It can be used for visually demonstrating how terrain features, such as hills and mountains interfere with the wireless communication devices of mobile networks. Visual presentation can also be enhanced by network statistics, such as received packets, transmission quality, throughput, delay, message status information, etc. The communication devices used in the OPNET Modeler can be visualized in 3DNV by many different 3D objects, which are stored in a library of 3D models (cars, planes, ships, tanks, etc.). Figure 5 shows an example of communication unit visualization in 3DNV. 3DNV allows viewing animation of the whole network or just one or a few units, from any perspective. It also allows viewing animation of unit movement by predefined trajectories from different viewing angles at different altitudes. A set of 3D animation configuration objects used in animations are also included, as are lines between nodes which represent packets transmission, spheres to represent the transmitter's range, and numbers which represent the simulation results.

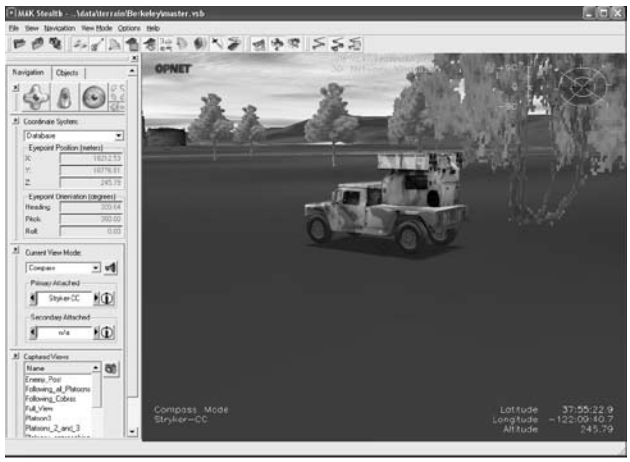

Fig. 5: An example of communication unit visualization by 3D Network Visualizer (3DNV)

3.4 Wireless package

The OPNET Modeler Wireless package is flexible and a scalable environment for the modeling and simulation of wireless networks /25, 26/. All the characteristics of wireless networks are integrated into lower layer protocols, which enables the modeling of all viewing points regarding wireless transmission, such as the spreading of RF electromagnetic waves /27/ by considering ground impact to the diffraction, fading, interferences, characteristics of the receiver and transmitter, nodes mobility, etc. OPNET allows efficient development of various wireless communication technologies such as MANET, 802.11, 3G/4G, Ultra Wide Band, WiMAX, Bluetooth, Satellite links /25, 26, 28/. In OPNET, wireless package wireless links between transmitter and receiver are simulated by using an open-concept called a transceiver pipeline. The transceiver pipeline enables delay computations during the spreading of radio waves, closing radio links, consideration of an aerial's emissive diagram, background noise, modulation effects, interference, bit-error rate, forward error corrections, etc.

3.5 Terrain modeling module (TMM)

The Terrain Modeling Module (TMM) is a special OPNET module which enables improvement in the accuracy of the wireless network simulations, by taking into account signal loss due to terrain effects. They include the impact of natural barriers on simulations (mountains and the earth's curvature) and the physical characteristics of the environment (conduction, permeability, surface refractivity) spreading of radio waves. TMM supports various propagation models:

A free space propagation model /29/ using the theory of spreading electromagnetic waves in an ideal vacuum. This model does not use terrain effects or any other physical limitations.

Longley-Rice model /30, 31/, also known as Irregular Terrain Model (ITM), is a more accurate propagation model of radio waves spread, as a model of optical visibility (LOS). It is used within frequencies ranging between 20 MHz and 20 GHz. It was originally developed for television transmission in 1960's.

The TIREM model /32/ is the most detailed, with the fewest limitations. It is used within a frequency range between 1 MHz and 40 GHz. It also includes effects such as multiple diffraction on edges and barriers, reflections from the troposphere, absorption in atmosphere, surface guiding of waves because of ground conductance, troposphere dispersing, long-term fading etc. It is one of the best choices for use in models of non urban terrain.

Virtual terrain is modeled by using DTED (Digital Terrain Elevation Data) and USGS (U.S. Geological Survey) DEM (Digital Elevation Model) maps. Figure 6 shows a terrain profile between the transmitter and receiver, and an estimation of the received power for different propagation models.

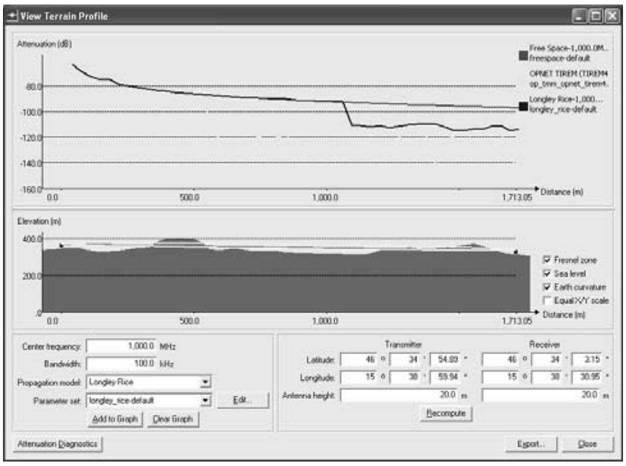

Fig. 6: Terrain profile with calculation of radio signal power between transmitter and receiver by using different propagation models.

4. Tispink system simulation in real time

We used the real-sim-real type of SITL simulation, where real C2IS equipment communicates through a simulated wireless environment. Figure 1 shows the basic connections between tactical units and the simulator. This is more detailed in Figure 7 which shows configuration of our test simulation scenario. Here, two real TISPINK tactical units are connected to the hub. On each of these TISPINK units we define IP addresses, gateway, disabled firewall, etc. The hub is also connected to the physical interface (NIC) of the computer, where OPNET simulation tool is installed. On this computer we must also set IP addresses, gateways, disabled firewall, etc. It is important that each of tactical the unit is from a different subnet. In other cases they will communicate directly across the hub and not to over the OPNET simulator.

In the simulation environment we modeled the tactical radio equipment on virtual terrain, as shown in Figure 7, where tactical radios are labeled as simulated units (Unit 1 and Unit 2). Externally connected real tactical equipment serve as traffic sources and sinks. Modified real packets of TISPINK application run through simulation, where the SITL gateway translates real packets to simulation packets, and vice versa.

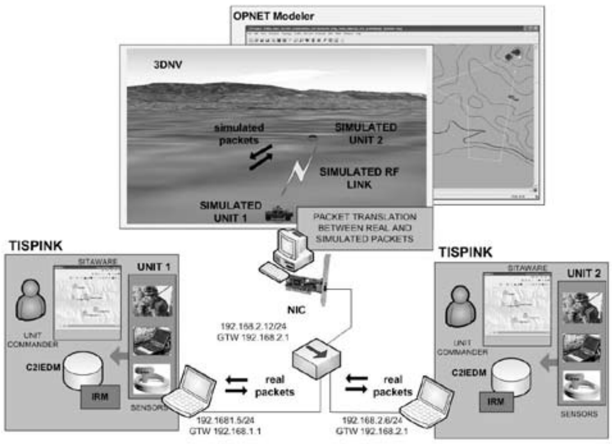

Fig. 7: Topology of test network for data transmission between real Unit 1 and Unit 2 over simulated wireless link.

In the OPNET Modeler, we created a model of tactical radio for the purpose of simulations in near real-time, as shown in Figure 8. It consists of three devices: SITL gateway (node_2), SITL link, and wireless router as tactical radio model (node_1). SITL gateway translates packets between simulated and real communication equipment. Using its attributes, it can configure a filter that defines which packets from which network interface card will be imported or exported via the SITL gateway. Using the wireless router we can define the tactical radio's attributes such as the transmitter's power, receiver's sensitivity, channel frequency, types of modulations, types of antenna, etc.

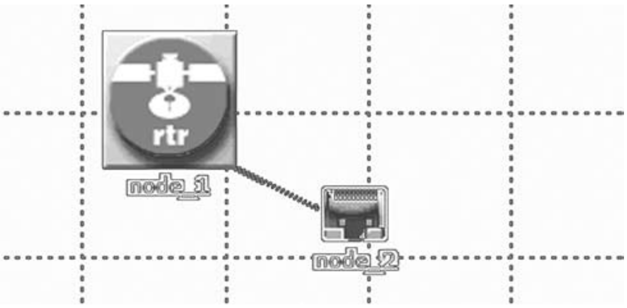

Fig. 8: Model of tactical radio device for SITL simulations: connection between SITL gateway and wireless router with SITL link

4.1 Video over simulated wireless link

In this example, of near real-time simulation, we show the transmission of video stream over the simulated wireless link. Figure 7 illustrates the topology we used in our experiments with the exception that we did not use any special C2IS on the tactical unit stations. The simulation scenario on the OPNET Modeler's side is shown in Figure 9, where the radio equipment of Units 1 and 2 are located at certain positions on the virtual terrain. Unit 1 (video stream receiver) represents the fixed node. Unit 2 (video stream transmitter) is the mobile unit, which moves by a predefined trajectory, as shown in Figure 9.

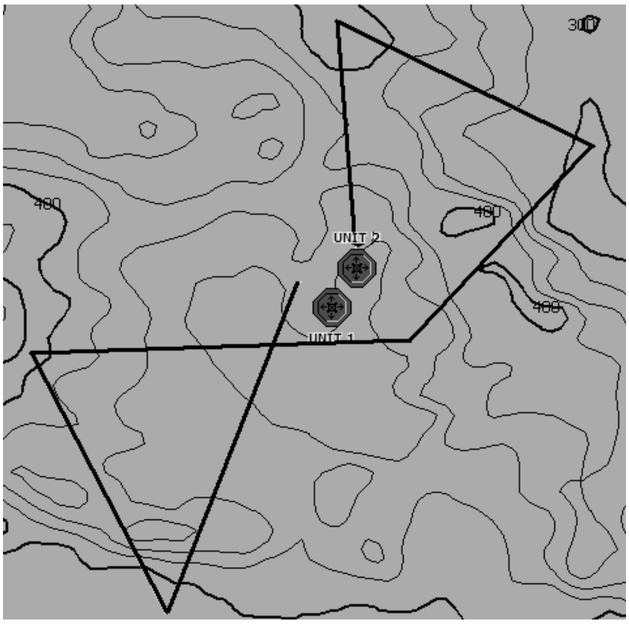

Fig. 9: Simulation scenario in OPNET Modeler, where tactical units are located at certain position on the virtual terrain. Unit 1 presents the fixed tactical unit, Unit 2 presents the mobile tactical units, which moves during the simulation run along a predefined trajectory.

The speed of unit movement is 60km/h. The radio equipment of both units act as wireless 802.11g devices with channel capacity of 54Mbps. Virtual terrain is defined by using a DTED Level 2 elevation map with 30m resolution. For a propagation model we chose TIREM. With these requirements we can ensure the best possible realistic transmission of live video stream over simulated wireless link. We used the well known VLC media player - the cross-platform media player and streaming server as video streaming equipment. It can be used for unicast or multicast streaming in IPv4 or IPv6 high-bandwidth networks for various audio and video formats (MPEG-1, MPEG-2, MPEG-4, DivX, mp3, etc.). Both tactical computer workstations are connected to the Ethernet network interface card (NIC) of simulation computer over hub (Figure 7). Such a kind of connection is possible in the case, where the external computers (Unit1 and Unit 2) have network IP addresses from different subnets; otherwise, communication between them would go directly over the hub and not over the simulation process. Multiple network interface cards are needed (one NIC for each external computer) to support such configurations, where both external computers have IP addresses from the same subnet.

During a near real-time simulation run, we can observe video signal on the real transmitter and receiver. For video source at the transmitter side, we chose the AVI movie. Real packets of a test movie video stream were transmitted through the simulated wireless link, which is affected by simulated conditions such as distances, radio visibility, etc. During simulation runs we could see that, over some time intervals, we lost some packets and errors appeared in received video signal. Sometimes the receiver lost the video signal for several seconds or for even longer periods up to 60 seconds. In these cases there was no radio visibility between receiver and transmitter. Figure 10 shows the examples of the captured video frames from transmitter (left) and receiver side (right) under various link conditions.

Fig. 10: Captured video stream on the transmitter (left side) and receiver (right side) for two cases. In the first case (upper figures) without packets lost and in the second case (lower figures) distortions appears on receiver caused by lost packets.

The graphs in Figure 11 represent the traffic of the transmitted video stream from Unit 2 (first graph) and received video stream from Unit 1 (second graph). On the second graph parts without received traffic and some additional peaks are noticeable some, which represent packets' repetitions in the conditions of the transmission errors on radio's visibility borders. Figure 12 shows the received power (first graph) and bit-error rate - BER (second graph) for the receiver (Unit 1). In those cases, where the receiver power is lower than the threshold (sensitivity), the receiver is unable to detect incoming traffic. On the radio visibility boundary, the S/N ratio increases what is visible through increasing BER. In those intervals, where radio visibility between receiver and transmitter is established, BER is almost equal to 0. In the intervals where radio visibility was almost lost, BER strongly increased. At these intervals the packet-rate of the received traffic is also increased, caused by packet repetitions, as can be seen on the second graph in Figure 11. BER was not calculated for intervals without radio visibility

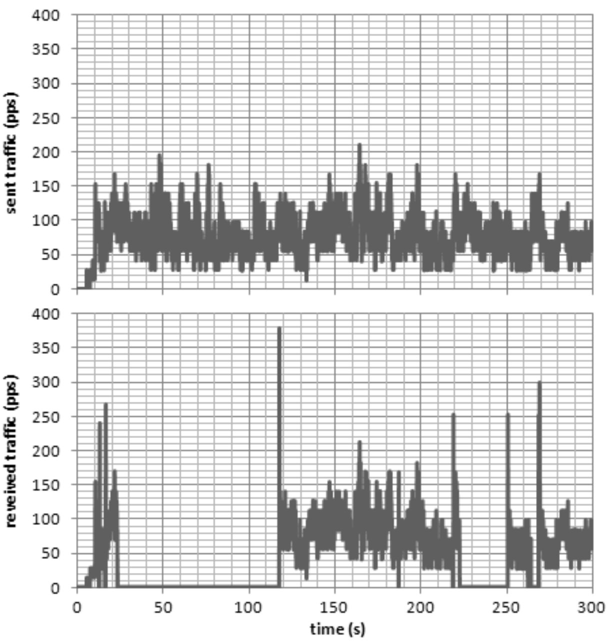

Fig. 11: Comparison between sent traffic from Unit 2 (video transmitter) and received traffic by Unit 1 (video receiver).

4.2 Tispink system simulation in near real-time

In the second example, we used TISPINK applications (Sitaware and IRM replication mechanism) installed for tactical units Unit 1 and Unit 2, instead of video streaming application. Unit 1 is the role of the Battalion and Unit 2 represents the Brigade. Using the IRM user interface shown in Figure 13, we defined "peer-to-peer" contract between units Unit1 and Unit 2. Traffic between these units was caused manually by sending and requesting management or the operational bulks of the IRM replication mechanism. In this simulation case we used the same topology (shown in Figure 8), as in the first example. We also used the same virtual terrain, the same predefined trajectory from Figure 9, and the same tactical radio parameters.

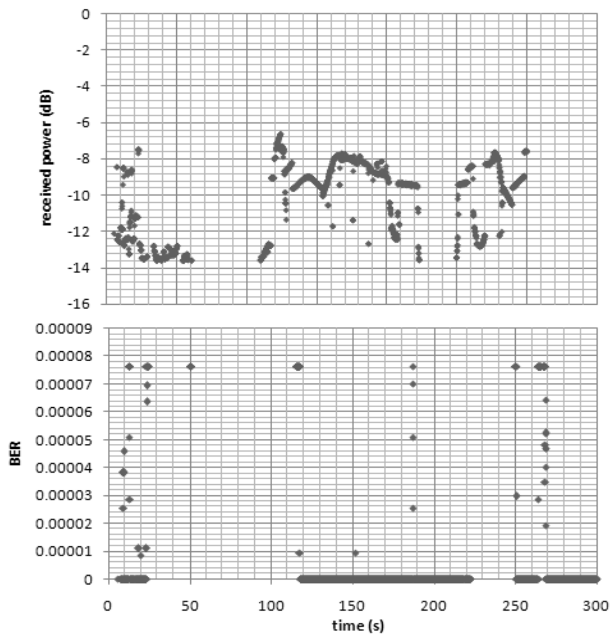

Fig. 12: First graph represents received power and bit-error rate (BER) on receiver side (Unit 1).

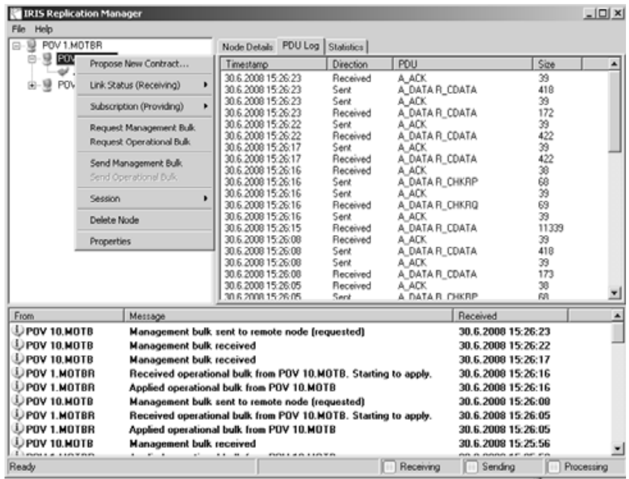

Fig. 13: IRM application user interface at Battalion unit, where we sent and requested operational and management bulk during near-real time simulation.

We created two different scenarios for the OPNET simulation tool. In the first scenario the Battalion and Brigade units (Unit1 and Unit2) are stationary and between them is all the time-assured radio visibility. In the second scenario, Unit 1 is mobile along a defined trajectory and Unit 2 is stationary (Figure 9). In both scenarios, the network traffic is generated by sending and requesting operational and management bulks. In the first scenario, where radio visibility is assured, there are no communication problems during the replication process. From the simulation results (in Figure 14), we can see, that radio visibility between units in the first scenario is possible during all simulation runs. The receiver power at the Brigade tactical unit is almost the same (with some exceptions) during all simulation, and is above the receiver's threshold.

In the second scenario, we repeated simulation when the Brigade was moving along a predefined trajectory (as in Figure 9). For the Battalion we sent and requested operational and management bulk, but at some intervals there are no response from the Brigade unit when connection was lost. In these cases, we cannot successful send management or operational bulks. At the moment when connection has been reestablished, replications of all data changes were accomplish during lost connection. In these cases a large amount of replication traffic appears. This is visible in Figure 15, which shows the sent traffic from the Battalion unit and received traffic of the Brigade unit, where there are some intervals within the range between 50 and 150 seconds, where radio visibility between units is unavailable.

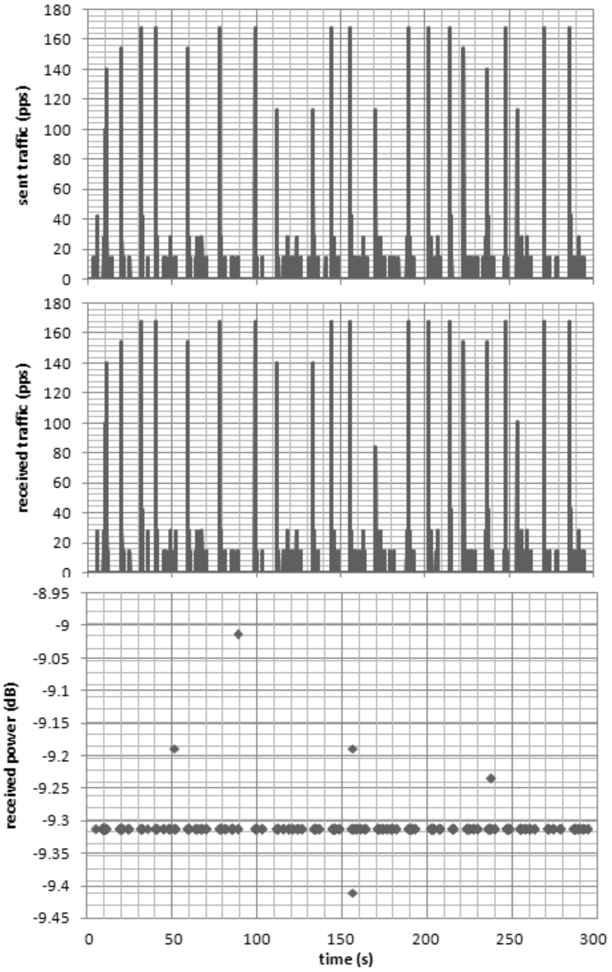

Fig. 14: The first graph shows sent traffic of the Battalion tactical unit, the second graph shows received network traffic by the Brigade tactical unit and the third graph shows the received power of the Brigade unit. The threshold of the receiver is -12.5dB.

Graphs in Figure 16 shows the estimated values for received power and signal-to-noise ratio (SNR) of the Brigade unit, which can only be estimated in cases where connections between units are established. Figure 17 illustrates an example of the 3D Network Visualizer (3DNV) representation of the tactical network.

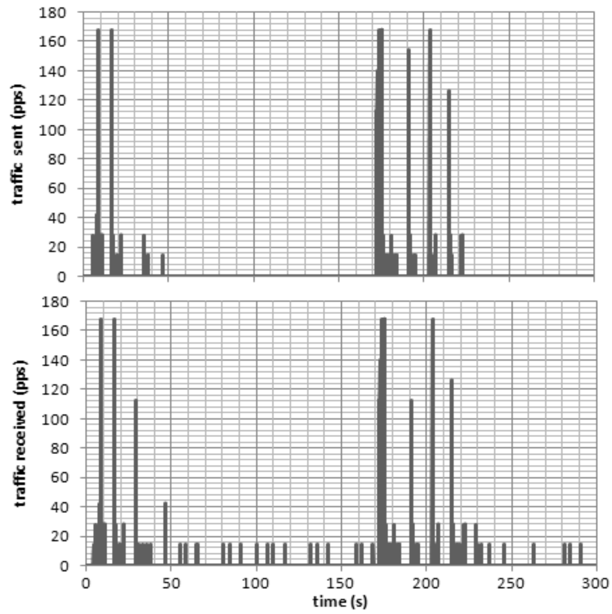

Fig. 15: The first and second graphs show the sent and received network traffic between tactical Unit 1 and Unit 2 for the second scenario.

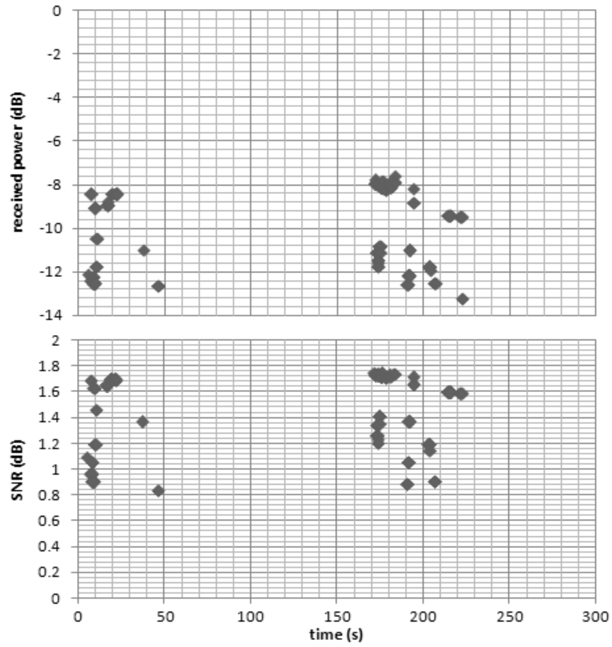

Fig. 16: Received power and signal-to-noise (SNR) parameter for the Brigade.

Conclusions

This paper presents the development of near-real time simulation methodology, where real tactical units can communicate with each other over simulated wireless links. This methodology enables training and planning for tactical missions in laboratory environments. Such a simulator allows the testing of different action scenarios on virtual terrain and to evaluate tactical networks in the sense of network delay, congestion, data lost, etc. We show two different examples of real-time simulations. In the first scenario

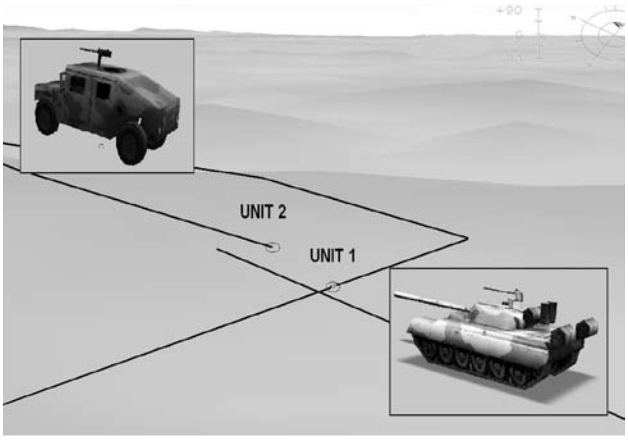

Fig. 17: Tactical network in 3DNV, where Unit 1 (Battalion) is represented as a tactical vehicle, Unit 2 (Brigade) with predefined trajectory on virtual terrain is presented as a combat tank.

we simulate the transmission of real video streams over a simulated wireless link. This is a typical broadcast application. In the second scenario we did simulation, where army units with C2IS applications were connected to the near-real time simulator.

A near-real time simulation of tactical networks is a novelty in the area of tactical network simulations. Such simulations help to predict how tactical networks will act on real terrain in real tactical situations. We can see, what happens if tactical units move on virtual terrain and lose radio contact. For such cases we can observe real application responses on real devices in the sense of traffic delay, losing connections, utilization, etc. Such kinds of results offer substantial help to the tactical mission planners and operators when evaluating tactical networks in real circumstances. This also allows operators and planners to optimally plan tactical missions in such a way, that as much as possible consider simulation results. It is also used for testing the effectiveness of different network topologies and protocol type's, such as peer-to-peer or broadcast. It can also be used for optimizing the amount of traffic between units defined by IRM contracts. Such kinds of simulations are also very important and suitable for the evaluation of new radio equipment before real purchase. It is also possible to evaluate communication parameters such as the necessary bandwidth of radio devices, power levels, antenna gains, etc. We can also carry-out tests with new C2IS software without the need for real tactical radio communication infrastructure. We also show, using two different application examples (video streaming and C2IS), that the presented simulation methodology does not depend upon the application type.

In future research, we would try to fully support this near-real time simulator for the Slovenian Army's needs. One very big problem appeared for the case when tactical units communicate with each other in a broadcasting manner, because the current version of SITL does not support wireless bridge to bridge communication functionality, which is needed in this case. Another important goal is also the reading of certain information (units' positions for example) from units' C2IEDM database and importing that information to the simulator in the real time. For all the presented reasons, we can expect a wider use of such simulators and applications in the near future, which will help in the optimization of networks and in the development of devices and protocols in all fields of communications.

Acknowledgment

This work is part of the target research programme "Science for Peace and Security": M2-0140 - Modeling of Command and Control information systems, financed by the Slovenian Ministry of Defence.

References

/1/ Multilateral Interoperability Programme, http://www.mip-site.org/

/2/ V. Jodalen, A. Eggen, B. Solberg, O. Gronnerud, Military messaging in IP networks using HF links, IEEE Communications Magazine 42 (11), (2004) 98–104.

/3/ W.C.Y Lee, H.L Smith, A computer simulation model for the evaluation of mobile radio systems in the military tactical environment, IEEE Transactions on Vehicular Technology 32 (2) 1983 177-190.

/4/ Opnet: http://www.opnet.com/products/modeler/home.html

/5/ V.T.S Shi, "Evaluating the performability of tactical communications networks, IEEE Transactions on Vehicular Technology" 53 (1) (2004) 253-260.

/6/ Netwars: http://www.disa.mil/netwars/documentation.htm

/7/ S.L. Ferenci, C. Alspaugh, "Efforts to Enhance Interoperability for Netwars", Proceedings of MILCOM 2004 - IEEE Military Communications Conference, 2004.

/8/ W.S. Murphy Jr., M.A. Flournoy, Simulating crises communications, in: Proceedings of WSC2002 - Winter Simulation Conference, San Diego California, 2002.

/9/ Incot: http://www.stottlerhenke.com/incot/

/10/ R.A. Richards, An Intelligent Tool for Network Configuration and Optimization, in: Proceedings of IEEE **Aerospace Conference, Big Sky, Montana,** 2003.

/11/ R.A. Richards, T. Coskun, "Intelligent Network Configuration Optimization Toolkit (INCOT)", in: Proceedings of MILCOM 2004 - IEEE Military Communications Conference, Monterey, CA, 2004.

/12/ M. Fras, J. Mohorko, Z. Cucej, A new approach to the modeling of network traffic in simulations, Inf. MIDEM, mar. 2009, letn. 39, št. 1, str. 41-45.

/13/ M. Fras, J. Mohorko, Z. Cucej, "Packet size process modeling of measured self-similar network traffic with defragmentation method", in: Proceedings of IWSSIP2008 Conference, Bratislava, Slovakia, 2008.

/14/ J. Mohorko, M Fras, Ž. Čučej, "Modeling methods in OPNET simulations of tactical command and control information systems", in: Proceedings of IWSSIP2008 Conference, Maribor, Slovenia, 2007.

/15/ J. Mohorko, M. Fras, Ž. Čucej, "Modeling of IRIS Replication Mechanism in a Tactical Communication network, using OPNET", Comput. Networks,2008, Available online 30 December 2008, http://dx.doi.org/10.1016/j.comnet.2008.12.018.

/16/ J. Mohorko, M. Fras, Ž. Čucej: "Modeling of IRIS replication mechanism in tactical communication network with OPNET", in: Proceedings of OPNETWORK 2007 - the eleventh annual OPNET technology Conference, August 27th-31st, Washington, D.C., 2007.

/17/ J. Mohorko, S. Klampfer in Ž. Čučej,, Ekspertni sistem za analizo rezultatov simulacij taktičnih radijskih omrežij,. Inf. MIDEM, mar. 2009, letn. 39, št. 1, str. 46-52.

/18/ S. Klampfer, J. Mohorko, P. Planinšič in Ž. Čučej, Določanje radijske vidljivosti uporabnikov AIR storitev s pomočjo simulacijskega orodja OPNET modeler in modula 3DNV, Inf. MIDEM, sep. 2009, let. 39, št. 3, str. 135-143.

/19/ L. B. H. Ernest and L. C. W. Clement, BattleSpace Communications Network Planner and Simulator (BCNPS), OPNETWORK 2004 - Aug 30th - Sept 3rd - Washington, D.C.

/20/ L. J. Phang, A. Y. P. Chua, T. H. Beck and E. B. H. Lee, Battle Space Communications Network Planner and Simulator (BCNPS), Proceedings to 10th International Command and Control Research and Technology Symposium: The Future of Command and Control, June 13-16, McLean, VA. Command and Control Research Program (CCRP), Washington, D.C, 2005.

/21/ M. Fras in J. Mohorko, Simulacija komunikacijskih sistemov v realnem času z realno komunikacijsko opremo v simulacijski zanki. Inf. MIDEM, jun. 2009, letn. 39, št. 2(130), str. 71-77.

/22/ Sytematic, http://www.systematic.dk

/23/ Sytematic, „IRIS Replication Mechanism'', White Paper, Revision 1.16, December 2006.

/23/ Sytematic, „SitaWare'', White Paper, Revision 1.16, December 2006.

/25/ B. Vujičić, ''Modeling and Characterization of Traffic in Public Safety Wireless Networks'', Master of Applied science, Simon Fraser University, Vancouver, Canada, 2006.

/26/ M. Z. Jiang, ''Analysis of wireless data network traffic'', Master of Applied Science, Simon Fraser University, Vancouver, Canada, 2000.

/27/ P. Vieira, P. Queluz and A. Rodrigues, A Dynamic Propagation Prediction Platform over Irregular Terrain and Buildings for Wireless Communications, Lisbon Polytechnic Institute (ISEL), Portugal.

/28/ M. Jiang, S. Hardy in Lj. Trajkovic, Simulating CDPD networks using OPNET, OPNETWORK 2000, Washington D.C., August 2000.

/29/ S. R. Robinson and P.S. Idell, ''Free-space propagation model for coherence-separable broadband optical fields'', Optical Society of America, Journal, vol. 70, Apr. 1980, p. 432-437.

/30/ K. A. Chamberlin and R.J. Luebbers, ''An Evaluation of Longley-Rice and GTD Propagation Models'', IEEE Transactions on Antennas and Propagation, vol. AP-30, Nov. 1982, p. 1093-1098.

/31/ M. M. Weiner, ''Use of the Longley-Rice and Johnson-Gierhart Tropospheric Radio Propagation Programs:0.02-20 GHz'', IEEE Journal on Selected Areas in Communications, VOL. SAC-4, No. 2, March 1986.

/32/ D. Eppink and W. Kuebler, ''TIREM/SEM Handbook, Department of defense'', Electromagnetic compatibility analysis center, Annapolis, Maryland, 1995.

/33/ OPNET presentation (session 1933), Developmental and interoperability testing with OPNET system-in-the-loop, OPNETWORK 2007 - the eleventh annual OPNET technology Conference, August 27th-31st, Washington, D.C., 2007.

/34/ OPNET presentation (session 1942), Introduction to using 3D network visualize (3DNV), OPNETWORK 2007 - the eleventh annual OPNET technology Conference, August 27th-31st, Washington, D.C., 2007.

/35/ WinPCap documentation: http://www.winpcap.org

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Prispelo: 10.03.2010 *Sprejeto: 03.03.2011*