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HOME AUTOMATION ON THE MOVE

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Abstract: In this article we would like to show how an arbitrary home and building electronic system based on the home automation standards such as X10 might be addressed and controlled by an appropriate mobile technology. Urge for mobility of users, which may be at the same time either the inhabitants of these homes or even administrators and supporters, is growing. The possibility to control and observe the status of home appliances while being on the move away from home using our mobile phones is becoming reality today. As an example we will introduce the prototype system, which gained a lot of attention on the last INFOS conference and was made functional throughout the cooperation of two Slovenian companies, Gorenje and HERMES SoftLab. While Gorenje developed a so-called kitchen center, an unique all-in-one home appliance controlled by the personal computer, HERMES SoftLab contributed the X10 PLC protocol environment and HERMES SoftLab's Smart Service Mediator (SSM) platform, well known from the mobile operators' world, which enable mobile users to control their automated home remotely using ordinary mobile phones and short messaging system (SMS). When developed, this prototype system presented one of the world's first attempts to integrate the home automation system with the GSM network using the SMS.

Hišna avtomatizacija na pohodu

Ključne besede: hišna avtomatizacija, X.10, SMS, mobilnost, storitve z dodano vrednostjo, kuhinjski center

Izvleček: V članku bi radi pokazali, kako lahko nek poljuben dom in stavbni elektronski sistem, ki temelji na standardih hišne avtomatizacije kot je X10, usmerjamo in nadzorujemo s pomočjo primerne mobilne tehnologije. Potreba po mobilnosti uporabnikov, ki so lahko hkrati prebivalci teh domov ali celo administratorji in vzdrževalci, vedno bolj narašča. Možnost upravljanja in opazovanja statusa hišnih naprav s pomočjo mobilnega telefona med uporabnikovo odsotnostjo z doma postaja dandanes stvarnost. Kot primer bomo predstavili prototip takšnega sistema, ki je na zadnji konferenci INFOS požel veliko zanimanja in sta ga v sodelovanju razvili dve slovenski podjetji, Gorenje in HERMES SoftLab. Medtem ko je Gorenje razvilo takoimenovan kuhinjski center, edinstveno, vse-v-enem hišno napravo, ki jo nadzoruje osebni računalnik, je HERMES SoftLab prispeval strojno rešitev, temelječo na standardu X10, in sporočilno platformo Smart Service Mediator (SSM), dobro znano v svetu mobilnih operaterjev. Vse to omogoča mobilnim uporabnikom nadziranje avtomatiziranega doma na daljavo z uporabo navadnega mobilnega telefona in pošiljanja kratkih sporočil (SMS). Ob razvoju je ta prototip predstavljal enega prvih poskusov integracije sistema hišne avtomatizacije z omrežjem GSM, ki temelji na pošiljanju kratkih sporočil.

Home automation

In recent years there have been several attempts worldwide to develop a home and building electronic system (HBES) based on the Power Line Carrier (PLC) technology. The PLC technology uses existing electrical power lines in home and buildings to send the control signals for controlling various home appliances. However the different system specifications have confused planning engineers, contractors, installers as well as resellers, end-users, building owners and investors. This situation is hindering market acceptance and growth. Consequently each system lacks the necessary volume success. In Europe specifically there are three solutions, which are candidates to become the home and building electronic system standard:

- BatiBUS - represented by BatiBUS Club International (BCI)
- EIB (European Installation Bus) - represented by European Installation Bus Association (EIBA)
- EHS (European Home Systems) - represented by European Home Systems Association (EHSA)

The three above mentioned associations have agreed to provide the technical basis for the convergence of these three systems so that in future there will be only one common system supported by relevant industrial companies. A common Association resulting from the amalgamation of BCI, EIBA and EHSA will promote the KNX standard.

In the USA and in the last few years also in Europe another system, X10, gained high popularity due to its simplicity, low price, and adoption by the manufacturers. X10 is a PLC protocol that allows compatible devices throughout the home to communicate with each other via the existing 110/220V electrical power lines. Using X10 it is possible to control lights and virtually any other electrical device or collect the data from the sensors (temperature, humidity, motion etc.) from anywhere in the house with no additional wiring.

X10 Power Line Carrier Protocol

The X10 PLC protocol /1/ defines the procedure for communication between the transmitting device and receiving device by sending and receiving signals over the power line wiring. These signals represent short RF bursts, a 120

kHz-coded signal superimposed on the 60Hz/50Hz electrical power line, with encoded digital information. The X-10 signals are synchronized to the zero-crossing point of the AC power line - they are transmitted within 200 µs of the zero crossing point. Power line interfaces provide 50Hz square wave with a max. delay of 100 µs from the zero crossing point to the AC power line. The maximum delay between signal envelope input and 120 kHz output bursts is 50 µs. A binary 1 is represented by a 1 ms burst of 120 kHz, at the zero crossing point. If burst is not presented in this period, a binary 0 is assumed. These 1 millisecond bursts are transmitted three times to cover the zero crossing points of all three phases in a three phase power distribution system, as shown in Figure 1.

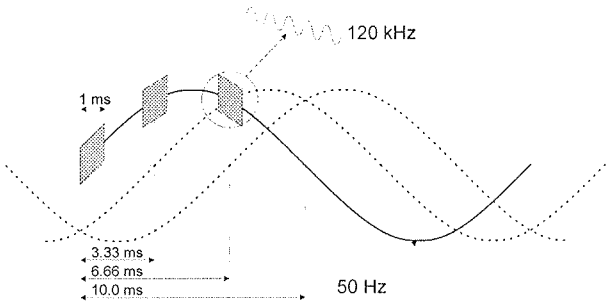


Figure 1: The Power Line Cycle and the X10 signals.

One cycle of the 50Hz power line carries one bit of information. In X10, transmission of the complete information consists of a sequence of three groups of bits (codes): start code, house code, and a number or function code (see Figure 2).

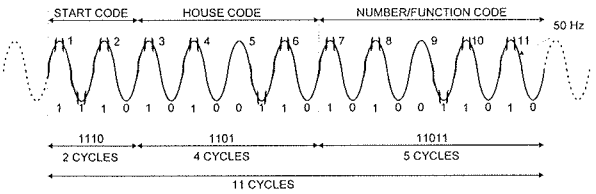


Figure 2: The X10 coding scheme.

The start code is a standard code denoting the start of the transmission and is transmitted within the first 2 power line cycles. The house code is a 4-bit code (any code from 0000 to 1111) and serves as the address of the target device to which the transmission is addressed. The number/function code is a 5-bit code (any code from 00000 to 11111). Transmission of the house code takes 4 power line cycles, while the transmission of the number/function code takes 5 power line cycles. The house codes and the number/function codes are transmitted in a true compliment form on alternate half cycles of the power line - if a binary 1 is transmitted on one half cycle (1 millisecond burst of signal) then binary 0 (no signal) should be transmitted on the next cycle (See Figure 3). The Start Code is always 1110, which is a unique code and unlike the house and number/function codes does not follow true complimentary relationship on alternate half cycles. The start code is transmitted within 2 power line cycles (see Figure 2).

The complete transmission (start code, house code, and a number/function code) hence requires 11 power line cycles and is always repeated twice with 3 power line cycles between each transmission: transmission of start, house, and number code followed by the transmission of the start, house, and function code. The house, number, and function codes are listed in Table 1.

	House codes
A	0110
B	1110
C	0010
D	1010
E	0001
F	1001
G	0101
H	1101
I	0111
J	1111
K	0011
L	1011
M	0000
N	1000
O	0100
P	1100

	Number codes
1	01100
2	11100
3	00100
4	10100
5	00010
6	10010
7	01010
8	11010
9	01110
10	11110
11	00110
12	10110
13	00000
14	10000
15	01000
16	11000

	Function codes
All units OFF	00001
All Lights ON	00011
ON	00101
OFF	00111
Dim	01001
Bright	01011
All Lights OFF	01101
Extended Code	01111
Hail Request	10001
Hail Acknowledge	10011
Pre-Set Dim	101X1
Extended Data	11001
Status=ON	11011
Status=OFF	11101
Status Request	11111

Table 1: The list of available house, number, and function codes.

We can connect a large number of X10 receiving devices to the power line. To each of them we can assign one of 16 available house codes and one of 16 available number codes giving 256 different possible combinations.

The X10 PLC home automation network consists of the following types of X20 devices:

Receiving devices (executing the commands, no feedback information): light switches, receptacles, chimes

Transmitting devices (transmitting signals to the power line: phone and PC controllers)

Transceiver devices (receiving data and report status): motion detectors, flood detectors, thermometers

X10 PLC Network devices: passive couplers, coupler repeaters, surge protectors, noise filters, and signal blocks that are installed in or near the electrical service panel. Such devices are necessary for providing consistent and reliable signaling performance, especially in the densely populated areas.

Kitchen center of Gorenje

Gorenje's kitchen center (Figure 3) is designed to become not only the central automation/information point of the kitchen but also the central point of the whole home. From outside it looks like a very modern and futuristically shaped kitchen-range. However, many are surprised when instead of a standard button-like control panel a modern flat panel touch screen silently rolls-out from the center whenever we want to monitor or control the system. By pressing the images on the touch screen we are able to turn on/off the oven or heating plates, control their temperature, start different cooking programs, set timers etc.

The brains of the kitchen center represent a personal computer hidden in the very bottom of the center and transparent from the user's point of view. Internal electronic devices (heating plates, oven) are controlled by a proprietary controller maid by engineers from Gorenje, which is connected to the computer's serial port /2/.

Another serial port is used for a X10 PLC modem, which connects the computer to the home's power line. This subsystem enables controlling of the X10 compliant home devices from the same point. The prototype system includes several light dimmers and switches as well as IR motion detectors. In general we could control also many other devices, such as heating and air-conditioning system, automatic doors, video and sound devices etc. /3/

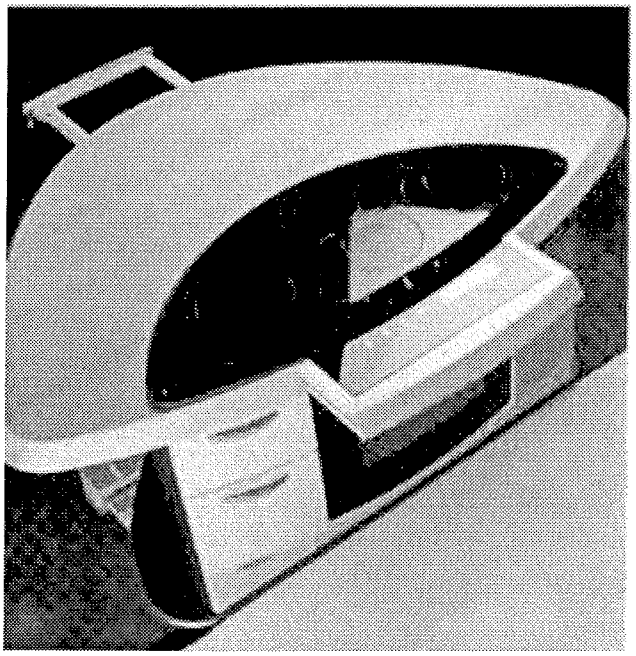


Figure 3: Kitchen center of Gorenje

Mobile phone as a remote control device

To have a complete control over the wide variety of home devices is at least a nice feature. But wouldn't it be nice if we turned on the air-conditioning system when we were still on our way home? Or we could even use our mobile phone to open the garage door remotely. Some suggestions would perhaps bring a smile to the reader while some others are definitely attracting much more attention. For instance, wouldn't it be very useful if we got an alarm in shape of a short message (SMS) or a voice call in case that motion or fire detectors register some problems? There are several proprietary and closed systems, which provide exactly those functionalities, but there are as many different standards as there are solutions. At the same time, the cost of several isolated and non-compliant solutions exceeds the cost of the solution we are about to introduce.

Today, almost everybody has a mobile phone. The penetration in some countries is reaching numbers higher than 70% of the whole population /4/. Mobile phone is not only voice-based communication device but is also becoming a payment instrument, electronic wallet, gaming device, and of course a special type of a remote controller.

On the other hand, engineers from HERMES SoftLab developed a messaging platform, of which main task is to connect a mobile user with information resources and applications anywhere on the Internet. Starting from the fact that Gorenje's kitchen center is controlled by a built-in personal computer, it seemed a logical step to connect that computer to the Internet and enable users to remotely control the home automation system.

But nonetheless, on the way to the final solution several problems were encountered, such as authentication and authorization issues, real-time message routing, security etc., which are successfully addressed and solved by the messaging platform.

Smart Service Mediator platform

SSM is a multi-channel platform that connects mobile users with the web servers using different communication channels /5/. While primarily it is being used for communication with short messages, voice, WAP, and HTTP channels are supported as well. Besides short messages, voice interaction is becoming more and more used, but in that case the cost of solution is higher because voice recognition system and text-to-speech synthesis must be involved.

Basically, there are two different types of SSM installations, depending on the usage model. SSM platform may be installed either at the mobile operator (Figure 4) or in home servers /6/. In the first case, home servers must be connected to the mobile operator's infrastructure via Internet, while in the second case an in-house GSM modem is needed. Both installation types have their advantages and disadvantages depending on cost, business models, Internet availability etc. First option is cheaper for the end user and is promoted by the mobile operator. Second option is operator independent, needs no Internet connection but is less

suitable for the individual use because of the higher complexity at the user's side. Anyway, the solution with the GSM modem might be appropriate for larger enterprises. In the prototype version web server was connected to the mobile operator's (Mobitel) SSM platform over the Internet.

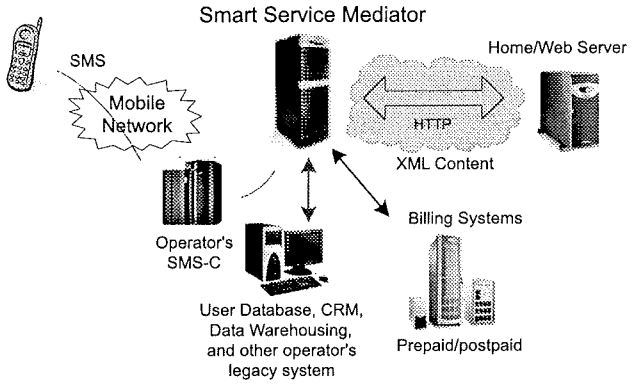
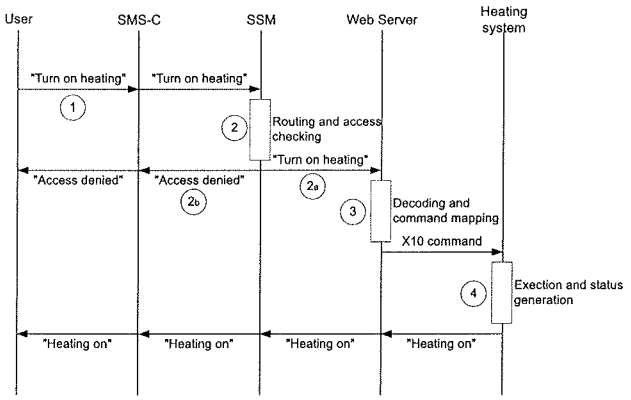


Figure 4: SSM platform as a part of mobile operator's service network.

SSM platform communicates with the external world using standard communication and security protocols, such as XML for message coding, HTTP and HTTPS for transport and message encryption. In Figure 4, reader can notice also a connection between the SSM and mobile operator's billing systems - SSM is used also as an additional revenue generator because it handles and counts the messages traveling through the system. To these messages we can attach service data records (SDR) meaning that users would pay more than just a cost of short messages for this extra service.

Following is a communication scenario between a mobile user and home automation system while remotely turning on the heating device:



1. User initiates the action by sending an SMS with the predefined content structure (i.e. "Turn on heating" or "Heating on") to the certain number or to the so-called large account[1] (i.e. 1010). The message reaches the SMS Center (SMS-C), which is a vital part of the mobile operator's infrastructure and takes care of all in/outcoming SMS messages. SMS-C forwards the message to the SSM.
2. SSM performs two main tasks - it routes the messages to the relevant home web server depending on a LA number and performs the authorization checks. SSM enables an easy user grouping and generation of access check lists. Only authorized users are allowed to control the devices in a certain home automation environment. If the access is granted (step 2a) the message is routed to the destination web server determined by the URL specified in the SSM settings. Otherwise, user gets a message containing denial of a service (step 2b).
3. Web server parses the message sent by a mobile user. If the message is valid appropriate action is taken - in our case, an X10 command is sent via X10 PLC modem to the heating system with the aim to turn it on.
4. Heating system performs the action and returns the status, which is then forwarded back to the user.

The example shown above is only about turning on the heating system in a house. For controlling the kitchen center devices, such as oven, heaters, fan, and some other household devices, such as lights, alarm and dimmers, the following syntax is used:

command device arg

where

command	ON, OFF, STATUS, HELP (abbreviations allowed: ON, OFF, S, H)
device	ALARM/1..m/, LIGHT/1..n/, OVEN, (abbreviations allowed: A, L, O, S)
arg	If command = ALARM, arg can vary between SILENT and LOUD (set by default) If command = LIGHT, arg can vary between 1 to 10 (default is 10). Arguments from 1 to 9 dim the light (if lights are actually attached to dimmer X.10 devices). Arguments 0 and 10 have the meaning of turning the lights ON/OFF.

Following are some examples used in connection with the kitchen center:

- ON L1 30 (dim light1 to 30%)
- ALARM2 ON (turn on the second alarm in the house)
- OWEN OFF (switch the oven off)
- STATUS OWEN (get the oven status) etc.

1 *Large accounts (LA) or large account numbers are short mobile numbers, usually up to 4 digits long, which are used for easier dialing/addressing of mobile data services.*

All examples from above were used in a so-called pull mode, where users send messages and trigger some activities or status reports. However, SSM enables also push functionality, where messages can be sent to mobile users without their requests in case some special situation occurs - i.e. user can be notified with a short message triggered by the motion detector. Motion detectors are not the only originators of pushed messages. You can imagine some other devices, such as fire/smoke/water detectors, timers etc.

Conclusion

Mobile phones have definitely marked current generations in the same way radios, TV sets and cars did in the past. They have become a necessity alowing users of mobile phones to be constantly in contact with each other and in contact with information. The work described in the paper presents a step further - it alows users of mobile phones to be constantly in contact also with a number of different devices either at home or at work. Eventhough the integration of home appliances with the mobile network may seem an insignificant task, it requires a deep knowledge of a number of different technologies and tight cooperation of partners from a different areas. In this case, two inovative companies, HERMES SoftLab - a software engineering company, and Gorenje - a manufacturer of home appliances, have joined their effort and brought ideas to life. Integration of home appliances with the mobile network opens a variety of possibilities both in the business and in consumer environments and the full potential of the features it brings is yet to be discovered.

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