Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 2, 2010, vol. LVI
article No. 1789

Miroslav MAHDAL[*], Marek BABIUCH[**]

IMPLEMANTATION OF WIRELESS SENSOR NETWORKS

IMPLEMENTACE BEZDRÁTOVÝCH SENZOROVÝCH SÍTÍ

Abstract

We are dealing with design and implementation of wireless sensor networks with various topologies and different architecture of ISO-OSI network layer at the Department of Control Systems and Instrumentation. The paper deals with problem of wireless sensor networks, used hardware resources, created software support for collection, processing and archiving of measured data from sensor network. Created Jenie Net application also enables network setting of wireless modules, remote control of periphery on sensor's boards with respect to a power consumption of particular node in the network.

The paper describes two created wireless networks. Whereas one of them is with predefined structure and uses a tunnel connection, second of them is as universal with tree network topology. Jenie Net application is also available from web pages for both network structures.

Abstrakt

Na katedře Automatizační techniky a řízení se v současné době zabýváme návrhem a implementací bezdrátových senzorových sítí s různou topologií a odlišnými architekturami síťové vrstvy ISO-OSI modelu. Příspěvek se zabývá problematikou inteligentních senzorů tvořících bezdrátovou síť, použitým hardwarem a vytvořenou softwarovou podporou pro sběr a vyhodnocení měřených dat. Vytvořená Jenie Net aplikace umožňuje konfiguraci bezdrátových modulů, vzdálené ovládání periferií senzorových desek s ohledem na energetickou spotřebu jednotlivých uzlů sítě.

V práci jsou dále uvedeny dva typy senzorových sítí, z nichž první má předdefinovanou strukturu a využívá tunelového spojení, zatímco druhá je univerzální se stromovou topologií. Pro obě možnosti byl naprogramován přístup z webového rozhraní.

1 INTRODUCTION

Flexibility is a big advantage of wireless technologies especially free from cable distributions. This area becomes a trend in the field of communication and finds use in different applications where sensor network is one of important structures. The creation of sensor networks, based on IEEE 802.15.4 standard is main topic of this paper. Devices working on this standard are characterized by very low power consumption, low data rate about 250 kb/s and with lower range.

This standard is directly intended for industry areas for data collection, monitoring of device states, remote control, in safety systems, etc. It can find use for control of technologic processes, here it is needed to set for which processes this usage is suitable and structure of whole control system. It is needed to have in a mind that problems related with signal outage can arise with wireless control eventually we don't have any information about a feedback, problems with synchronization etc., which can lead to fatal accidents. More advantage solution is in straight cable control of technologic processes with wireless sending of the data to central station and possibilities of wireless setting regulator parameters.

[*] Ing., VŠB-Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Control Systems and Instrumentation, 17.listopadu 15, Ostrava, tel. (+420) 59 732 4118, miroslav.mahdal@vsb.cz

[**] Ing.,Ph.D., VŠB-Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Control Systems and Instrumentation, 17.listopadu 15, Ostrava, tel. (+420) 59 732 4173, marek.babiuch@vsb.cz

The paper describes used hardware resources for realization of wireless sensor networks with respect to power consumption of wireless modules. Two types of networks based on JenNet network layer and Jenie network stack API have been proposed and practically tested. Jenie Net. application has been created for visualization, data collection and their presentation to the Internet network in SCADA/HMI system, Control Web 5, [Control Web 5 2010-02-15]. Wireless sensor network are generally very wide and if they are not directly used inside buildings, ideal solution for their power supply is to use alternative energy sources. For purposes of power supply of wireless modules it is very effective to use battery supply in a combination with solar cell.

2 HARDWARE RECOURCES FOR CREATION OF SENSOR NETWORKS

The hardware resources from Jennic company have been used for realization of designed wireless networks. The whole development kit consisting of JN5139 modules and boards forging the interface for easier design and realisation of applications for wireless modules has been used for purpose of testing of different algorithms and creation of wireless network.

Modules operate in 2.4 GHz band and are based on 32-bit RISC microprocessor unit with very low energy consumption, ROM and RAM, flash memory, communication unit and interface for connection of external peripherals.

12-bit ADC converters, 11-bit DAC converters, application and system timers and counters, more than 21GPIO (General Purpose Input/Output) are available and for communication and programming of wireless modules the UART interface is used.

Controller boards and sensor boards dispose of hardware resources which enable easily development of applications and these boards with wireless modules we can compare to smart sensors [Smutný L., Mahdal M., Škuta J. 2009]. It is concerned LED diodes, LCD display, buttons, temperature and relative humidity Sensirion SHT11 sensor, light level TSL2550 sensor, expansion ports for other sensors connection, UART interface for communication and loading programs from computer to the module, etc. Communication of sensors with microprocessor unit proceeds with the help of two-wire serial interface. Data have to be re-counted and suitable adjusted for their processing of measurement values and their correct displaying. Wireless module and controller board, eventually sensor board we can see in the figure 1.

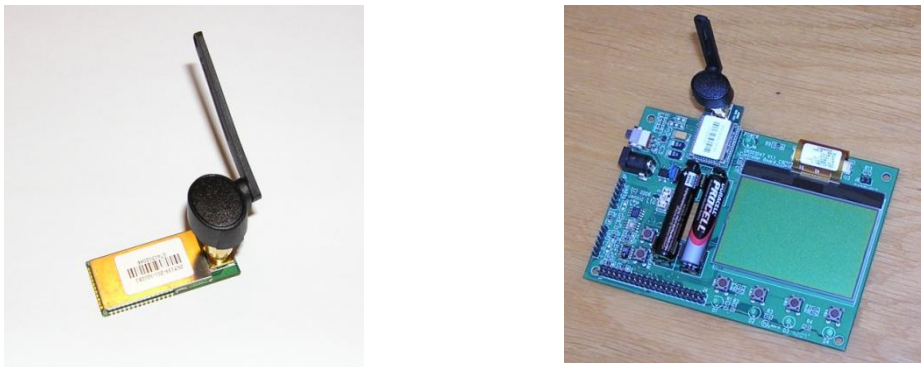

Fig. 1 Wireless module JN5139 and controller board with connection of wireless module

It is possible to use two kinds of environment for development of applications. Interface of command line (CLI – Command Line Interface) and integrated development environment (IDE – Integrated Development Environment). The first makes it possible to development of applications with the help of command line in Cygwin environment, which is the Linux emulator for Windows. The second environment makes it possible to development of applications in graphical user environment to integrating Jennic C libraries, see [Jennic User Guides 2010-02-10].

3 WIRELESS SENSOR NETWORK BASED ON JENNET NETWORK LAYER

Modules connected to the sensor boards eventually to controller boards have been used for realization of sensor networks. With the help of that boards we can use above mentioned sensors. Two types of wireless networks have been designed and tested in practical usage. Both wireless networks are based on JenNet network layer and Jenie network stack API (figure 2).

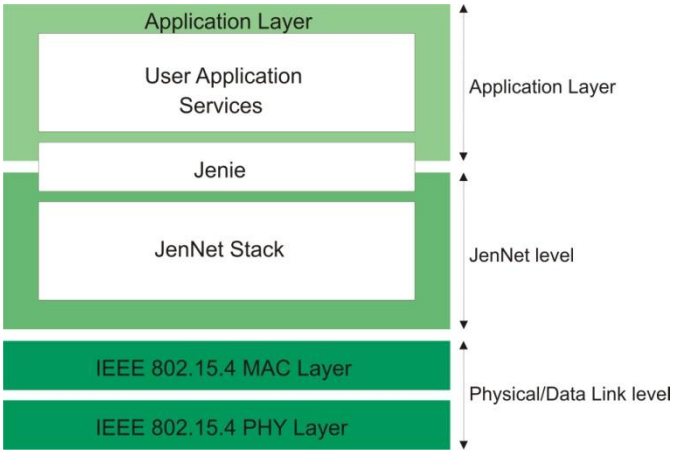

Fig. 2 Jennic architecture - JenNet network layer

JenNet uses range of techniques to ensure reliable communications - that is, to ensure communications reach their destinations uncorrupted. Corruption could result, for example, from radio interference or poor transmission/reception conditions. The coding method employed in the 2400 MHz band uses QPSK (Quadrature Phase-Shift Keying) modulation. Next it can be method of listen on chosen channel where the station listens if it is clear, or method of acknowledgement, when the message arrives at its destination, the receiving device sends an acknowledgement to indicate that the message has been received.

Created wireless networks have three types of wireless modules in a function of network coordinator, router and end station. Network coordinator and router are devices of types FFD (Full Functional Device), end devices are in function RFD (Reduce Functional Device).

Work of the coordinator at the network level is to establish the network, selection of frequency channel that will be used for the network and the possibility of the connection of other modules. It can provide message routing and next services. Only one coordinator can be in the network. The router relays messages from one module to another, allows child modules to connect to it, etc. The router can not be set to the sleep mode as end devices. The main tasks of end device at the network level are sending and receiving messages. If end device does not receive or transmit messages, then it is set to the sleep mode in order to conserve power energy. End device can not relay messages and can not allow other modules to connect to the network through it. Each wireless module in the network has unique identification. MAC address is used for the identification which is 64 bit unique address. Application Jenie Net. in Control Web 5 environment has been created for collection, archiving and presentation of data from wireless modules.

The first wireless network with the name of ATJenie has predefined network topology and number of wireless nodes (modules) with assigned function (figure 3). The tunnel connection is used for connection to the particular nodes and wireless modules are programmed for receiving of AT commands. This network is called as ATJenie network. By the tunnelling, messages are sent to remote nodes with an AT-Jenie command embedded in the payload of messages. AT command is extracted and executed on the remote node (as if it had been generated locally). The remote wireless module sends the response in the form of acknowledgement of execution command after its execution. This method of tunnel connection is implemented on wireless module as a service and modules

have to be to the service connected. The user has a possibility to program and extend possibilities of wireless module for next AT commands for control of sensor board or wireless module's peripherals. The created Jenie Net. application solves the control of all sensor board peripherals.

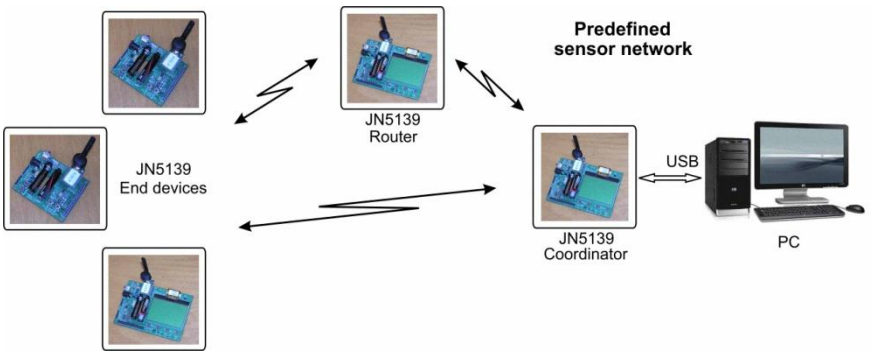

Fig. 3 ATJenie wireless network

First defined wireless network is composed from coordinator of the network that establishes the network, from the router and three end devices. Wireless modules have programmed algorithms for data collection on the question, eventually on cyclic questioning with desired period of measurement. This network can not be next extended, it can be considered as statically. To set wireless module into the network and to do given functions, it has to be initialized first of all. This is possible to do in menu *Inicializace modulu*, whereas the setting of network parameters of modules is done. It means communication channel, PAN ID, network application ID, setting of router function, number of connected stations to module, poll period of end stations on their parents, etc.

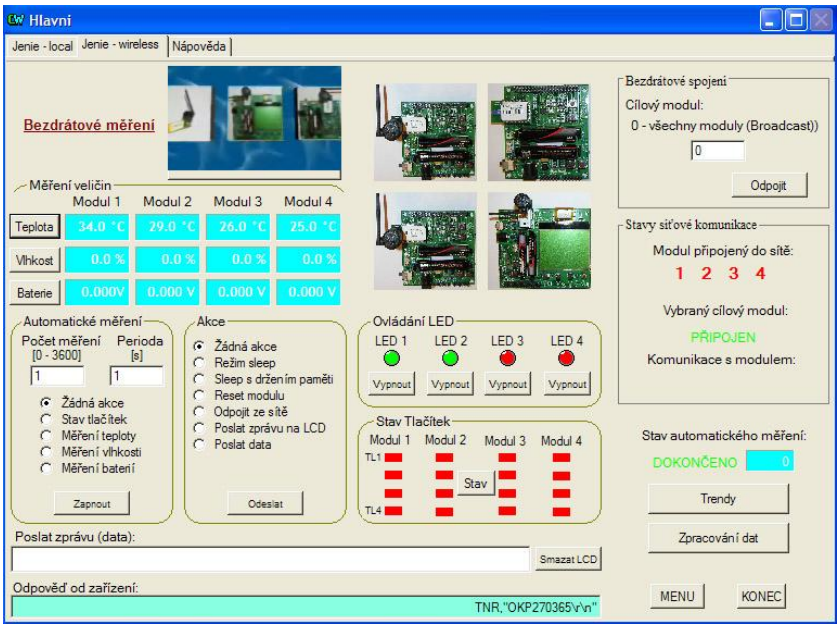

Fig. 4 Application for ATJenie sensor network

This network keeps at disposition control environment Jenie Net. and reference of a choice of the network ATJenie (figure 3). The application offers to us the possibility of connection to particular wireless modules of network. If the connection is done, the number of connected module and its state is displayed. With the help of network coordinator it is possible to connect to particular modules or to send broadcast message when the connection to all modules of the network is done. After connection

it is possible to control from the application ATJenie above mentioned periphery of sensor boards and to measure values from connected sensors (measurement of temperature, lighting, relative humidity and voltage on battery power supply), (figure 4).

Measured data from particular modules it is possible to process further. To do this we can use the reference and subsequently open window ***Zpracování dat*** (figure 5). We can send questions on particular modules in the network to find minimum and maximum values, average values, range and dispersion for measurement of values of temperature, humidity or voltage value on batteries of wireless modules.

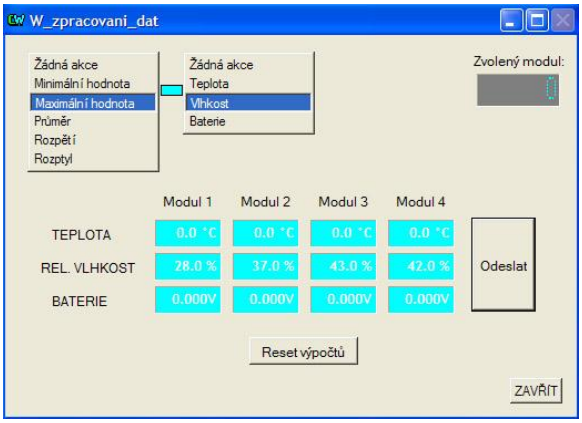

Fig. 5 Data processing from wireless modules

The second designed wireless network is universal and enables automatic connection of new wireless nodes to the network. Each new node is connected to appropriate parent (router or coordinator). Unique MAC address serves for its identification. In case of first network topology is applied so-called bit identification where to the transfer values are added identification characters of wireless module.

At this second network it is concerned created tree network topology where stations create tree structure up to network coordinator. Particular wireless modules in the network have programmed algorithms for automatic initiation of values measurement after activation of wireless module and connection to the network. Wireless module will start to send measured data from sensors with set period of measurement to the central station (coordinator) of the network. User can monitor the modules connection to the network in created application but also to choose the period of measurement for all wireless modules.

Jenie network keeps at disposition created control environment Jenie Net. application in the reference Jenie. The application provides well-arranged table displaying count of wireless stations connected to network coordinator. Each connected module is in the application identified with the help of shorter MAC address. If wireless module connects, it is identified and automatically sends the data through network structure to the coordinator. Whereas values as temperature, relative humidity, voltage on batteries and values from A/D converter are measured. The application also enables to monitor the communication through serial link. In the figure 6 we can see the Jenie application for Jenie network which is controlled through web pages.

Both applications for wireless networks also enable to us to monitor measured values in a form of trends, to save data from particular modules to database files *.MDB and *.DBF, to set end stations to sleep mode (automatically or through remote setting), etc.

End device can go to sleep mode in the case of both wireless networks, it means to the mode with low power consumption of electrical energy. In this case consumption of electric current will reduce about 1 µA at deep sleep mode.

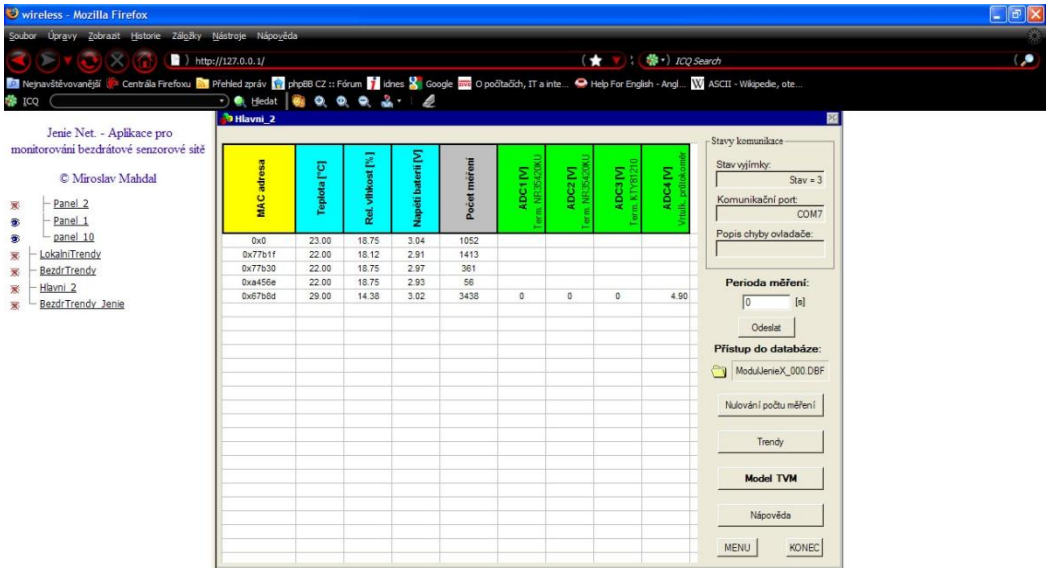

Fig. 6 Application for Jenie sensor network – access through web pages

4 CONCLUSION

Wireless network based on 802.15.4 standard are directly intended for industry area namely above all for measurement of values. Very low power consumption, small proportion, possibility of battery power supply and relative low price are big advantage of wireless stations based on this standard. Created application Jenie Net. containing environment for two types of networks is intended to straight application applying for wireless measurement of values. This application has been created in SCADA/HMI system and enables remote configuration of wireless modules, control of their power consumption and measurement of chosen values.

ACKNOWLEDGEMENT

The presented results have been obtained during the solving o research project SP201030/2010 supported by the Ministry of Education, Youth and Sport of Czech Republic.

REFERENCES

[1] CONTROL WEB. *Electronical help, Control Web 5*. Moravské přístroje [online]. [2010-02-15], Available from: <url: http:// www.mii.cz>.

[2] FARAHANI, S. 2008. *Zigbee wireless networks and transceivers*. Newnes publication, USA. 339 pp. ISBN 978-0-7506-8393-7.

[3] JENNIC USER GUIDES [online]. [2010-02-10], Available from: <URL: http://www.jennic.com/jennic_support/reference_manuals/>.

[4] PUŽMANOVÁ R. *Moderní komunikační sítě od A do Z*. Brno: Computer Press a.s., 2006. 432 s. ISBN 80-251-1278-0.

[5] SMUTNÝ L., MAHDAL M., ŠKUTA J. 2009. Smart sensors with PC connection in wireless networks. Recent advances in computers, pp. 585–587. *Proceedings of 13th WSEAS CSCC Multiconference*, Rhodos, Greece. ISSN 1790-5109.