SMART ENERGY MONITORING SYSTEM BASED ON POWER LINE COMMUNICATION TECHNOLOGY

Martin Rusz
Doctoral Degree Programme (1), FEEC BUT
E-mail: xruszm00@vutbr.cz

Supervised by: Petr Mlynek
E-mail: mlynek@feec.vutbr.cz

Abstract: The aim of this paper is to describe the design of a smart monitoring system based on Power Line Communication technology. As part of the description of technologies and the entire design, technologies commonly used today are described in more detail. The main features of the whole system are mainly reliability, scalability, security. For the purposes of the design, several measurements of different communication technologies were performed. The results of these measurements are important for evaluating the design of the entire system.

Keywords: Monitoring System, Gateway, Power Line Communication, Smart Socket, ZigBee

1 INTRODUCTION

With the growing number of electrical appliances as well as the increasing electricity consumption of households, it is necessary to apply more intelligent systems for monitoring and managing energy consumption. Thanks to these systems, it is possible to increase overall efficiency, reduce electricity consumption and also reduce CO_2 emissions. The European Union has also committed itself to these steps in the Energy Efficient Plan 20-20-20 [1].

Nowadays, concepts such as Smart Buildings, Smart Cities or Industry 4.0 are becoming more and more widespread. These concepts are characterized primarily by the ability to control electrical equipment such as household appliances, heating or air conditioning. Another key feature is the signaling of non-standard events, response to non-standard events and, in advanced systems, also the prediction of possible events [2, 3]. In new buildings this system can be included in the design itself and designed to provide all the necessary functionalities. However, for existing buildings, in most cases it is necessary to install intelligent control systems additionally [4].

The intelligent measurement system, which will be described in this paper, should enable the implementation of all necessary protocols occurring in the Smart Buildings environment and also ensure a sufficient level of security. All the requirements described above are met by the considered Power Line Communication (PLC) technology. Advantage of this technology is the use of the existing electrical network as a transmission medium, which will simplifies the application of the entire system. Throughput, efficiency, packet loss, interference immunity and communication range are the key parameters that need to be determined in the deployment of this technology [5].

2 COMPARISON OF COMMUNICATION TECHNOLOGIES

This section briefly describes the tested Zigbee and PLC technologies. The basic parameters of individual communication technologies will be presented in this part on which the currently available solutions of smart sockets, or entire intelligent control systems, are based. For comparison, the results of measurements will also be presented here, thanks to which it will be possible to evaluate the advantages and disadvantages of individual communication technologies.

2.1 ZigBee

ZigBee is a wireless communication technology provided by the IEEE 802.15.4 standard. It uses the license bands 868 MHz, 902–928 MHz and 2.4 GHz for communication. Depending on the frequency band used, transmission speeds of 20, 40, 250 kbps are then defined. Its main advantages include reliability, simplicity, easy implementation, low energy consumption and affordability. This technology is suitable for building large-scale wireless networks thanks to the use of Ad-Hoc routing, which allows communication between the controlling node network and the terminal device without a direct connection between them. Modem network topologies can be star, tree or mesh. For secure communication is used 128 bit AES encryption [6].

For testing in laboratory conditions was used a simple topology, which can be seen in the figure 1. The topology consists of a configuration PC with Radwin software. The control modem was configured via a USB to RS232 converter. For measurement were selected CDX800 modems using the 869 MHz transmission band with a maximum speed of 24 kbps.

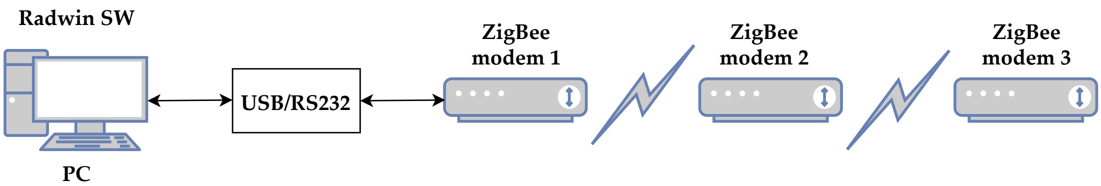

Figure 1: Topology for laboratory ZigBee measurement.

2.2 Power Line Communication

PLC technology uses an electrical distribution network as a transmission communication channel. Communication can take place at the level of low voltage 230 V, 400 V (LV), high voltage 22 kV (HV) or very high voltage 110–220 kV (VHV). The principle of the technology is based on the transmission of a useful signal, which is modulated on the carrier frequency of the electrical network. For this technology, the useful signal has a much higher frequency and lower amplitude than the mains signal. Depending on the bandwidth and use, the technology is divided into two basic types [7]:

- Narrowband PLC (NB-PLC): bandwidth 3–148.5 kHz according to the valid European standard CENELEC, data rate from 10 kbps to 500 kbps, communication range up to several kilometers
- Broadband PLC (BB-PLC): bandwidth 1.8–250 MHz, data rate from several Mbps up to Gbps, communication range up to 300 meters

For the design of communication devices of the smart energy monitoring system was chosen the broadband PLC standard HomePlug AV (HP-AV) on which the used integrated circuit AR7420 is built. The topology, which can be seen in the figure 2, was designed for measurements in the laboratory. The topology consists of several parts:

- Separating transformer - serves to suppress unwanted noise occurring on the power line
- BPL modem - development kit based on integrated circuit AR7420
- Network analyzer - EXFO FTB-1 PRO for measuring transmission parameters
- Noise generator - white noise generator PROMAX PROPOWER-1 (1–50 MHz)

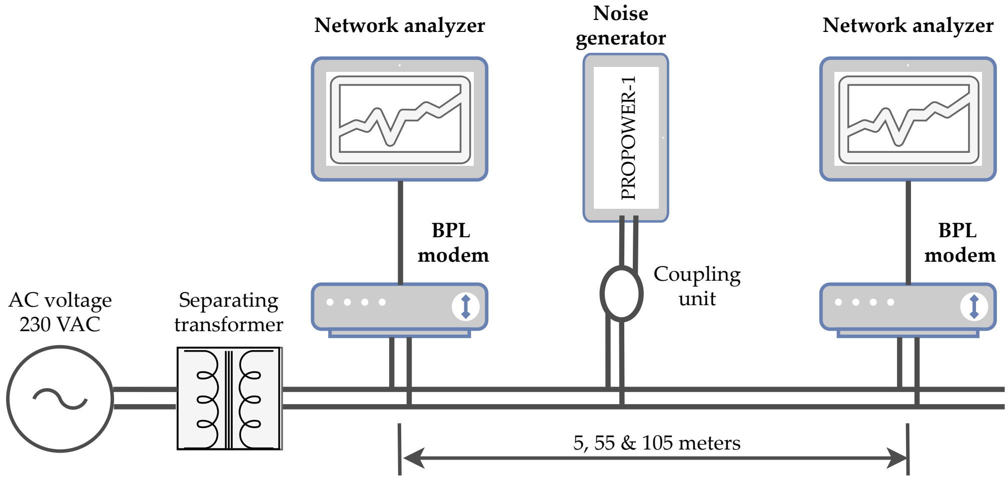

Figure 2: Topology for laboratory PLC measurement.

2.3 COMPARISON AND DISCUSSION

The average measured values of both devices were selected from the performed measurements. Because these are two different technologies, it is difficult to compare them. However, it can be seen from the table 1 that the CDX800 ZigBee modem achieved very low data rates and the total message transmission time was much longer compared to PLC technology. Zigbee systems are now very commercially widespread and focused primarily on signaling, control and measurement in the Smart-Buildings concept environment. Broadband PLCs are a possible alternative to these wireless systems, mainly due to the sufficient range of communication. transmission speeds and delays. Thanks to the sufficient data transmission capacity, they can also be used, for example, for camera systems, connection of terminal equipment to the Internet, building small local networks and other similar application. There is currently no similar commercial solution based on broadband PLC technology.

Table 1: Comparison of ZigBee and Broadband PLC devices.

Device:	Distance [m]:	Data rate:	Round Trip Time [ms]:	Efficiency [%]:
CDX800	75	19.8 kbps	197.67	98.5
AR7420	100	58.2 Mbps	2.289	100

3 DESIGN OF A MONITORING SYSTEM

This section describes each part of smart energy monitoring system. Specifically, the key features of individual devices and their purpose in the design. Figure 3 shows simplified block diagram of the whole system. The whole system consists of several blocks, which represent hierarchically divided elements of the system.

The blue blocks in block diagram represent the smart sockets that make up the lowest layer of the system. Their task is to measure electrical parameters and basic computing operations that do not require powerful computing units. Another important task is the mediation of broadband communication for end devices, such as user PCs. A terminal device that requires broadband communication is connected to the smart socket via an Ethernet interface with an RJ-45 connector. The design of the smart socket is described in more detail in section 4.

The purple part of the diagram shows the communication interface between the smart sockets and the master monitoring center. This part is represented by multi-purpose gates. Up to 16 smart sockets

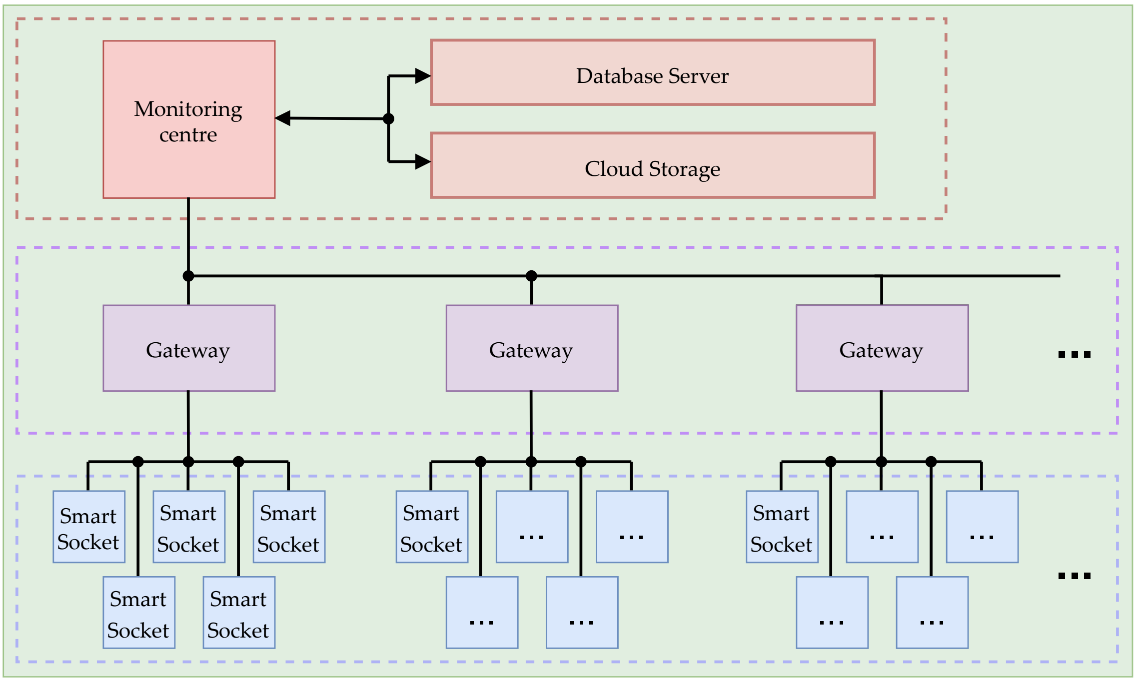

Figure 3: Block diagram of monitoring system.

can be connected to each gateway via BB-PLC. The main task of the gateway is to forward the measured data via wireless or wired interfaces to the superior monitoring system. The gateway can be configured locally and the required data can also be read from it locally from the connected sockets. Multipurpose gateway is described in more detail in section 5.

The top layer of the block diagram is the monitoring center. Accumulates and further processes received data from individual gateways. The parameters and functions of this section depend on the application. The most important task of this part is the implementation of a database system that will be store the measured data and allow the monitoring system to evaluate and respond to network events, power consumption, fault prediction and other functions based on this data.

4 PROTOTYPE OF SMART SOCKET

As part of the development of the entire system, a functional prototype of a smart socket based on BB-PLC technology was designed. The prototype was designed on the basis of the AR7420 integrated circuit, which has a sufficient transmission speed (up to 100 Mbps at the application layer and a communication range of up to 300 m). A communication module from the WisPLC Pro development kit was used for the development. The prototype will be extended by a measuring part, which is needed to measure electrical parameters (voltage, current) and non-electrical quantities (temperature, humidity). The voltage measurement will be realized by a suitably designed voltage divider, the current measurement will be realized by an integrated circuit, which works on the basis of the Hall effect. A switching relay will be implemented for switching appliances, which will provide control of the connected appliances.

5 MULTIPURPOSE GATEWAY

The main task of the multi-purpose gateway is manage the network of connected smart sockets. From the point of view of the system, it is an intermediary between the individual sockets and the superior monitoring center. The gateway will contain a broadband PLC chipset, which will ensure communication with the installed sockets. It will be possible to use a several technologies to transfer information to the superior part of the system. The LTE interface will be used for wireless communication, which will be used mainly in applications with a large distance between the individual elements of the system. For local applications, it will be possible to use the Ethernet interface via the RJ-45 connector.

The multi-purpose gateway will also include an RS485 serial interface for connecting external devices, such as an electricity meter, batteries, PV panels, wallbox chargers. Their task is to measure electrical parameters, switching on/off of appliances and other similar tasks. This interface will also be used for local gateway configuration, firmware update or debugging. For the possibility of remote switching of several independent electrical devices, several controlled relays, so called realy box, will be implemented.

6 CONCLUSION

This paper describes the design of an intelligent measuring system based on broadband PLC technology. This solution responds to the current situation of the need to control and regulate production and consumption behind the point of consumption. Solution presented in the article using PLC is ideal for places where a wireless solution is not possible and installation of new cables is complicated. Based on the measurements and prof of the concept of the prototype, high transmission speeds necessary for the deployment of security and advanced functionalities (surveillance, camera systems, etc.) are achieved. The next step in this work is to put the whole system into test operation, to design a methodology for testing this system and optimization of individual parts.

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