Construction Of An Experimental System For Measuring Data Transmission Delays In The ZigBee Standard

MSc. Maciej Grygiel, *Silesian University of Technlogy*

Abstract

This paper presents the experimental system used to measure the delay of data transmission in a wireless network operating in the ZigBee standard. The article contains a description of the ZigBee protocol. Describes the classes of devices operating in this standard, possible to obtain network topology and its layered structure. Described as IEEE 802.15.4. where ZigBee has been built. Presented measurer of delays, it's parameters, and its principle of action. Presents the results obtained using a prototype of the measuring system and the results of delay measurements for selection of components for the construction of the meter is described.

1. Introduction

The development of wireless technology in recent years has resulted in the creation of many standards for the transmission of information using the public broadcasting spectrum. Experimental measurement system presented in this article, was built in order to identify delays in data transmission network based on the ZigBee standard. The article gives a brief description of the standard, the construction of the measuring system and the results obtained using a simplified version of the measurement system.

2. ZigBee standard

IEEE 802.15.4 and ZigBee wireless communication describes the principles, organized in layers and the creation of user programs. Adherence to these rules allows the construction of small-range wireless network designed for data transmission with low rate. Devices operating in the ZigBee standard are characterized primarily easily make active network connections, low current consumption and resistance to electromagnetic interference generated by other devices. ZigBee standard is designed for use in industrial automation. Short Range Wireless devices are used in construction of intelligent buildings The fullness of the oversight role they are there light sensors, temperature and components of alarm systems. IEEE 802.15.4 document contains a detailed description of the physical layer (PHY) and medium access control layer(MAC) for low rate wireless personal area networks (LR-WPAN). Carrier sensing multiple access protocol is used for the detection of the media and prevent conflicts occurring in the data transmission. It is possible to build a network working in the star configurations, as well as the implementation of peer to peer network. Described in the document physical layer allows for the use of two different frequencies to transmit data. The first one ensure operation in 868/915 MHz band, the second in the 2450 MHz band [1, 2].

The classification of devices is based on the role they play in the network and the range of functionality, which they characterize. In the ZigBee standard, we distinguish three types of devices. These are a coordinator, router and end device.

ZigBee coordinator is a device with full functionality (FFD). It should be understood that such a device can act as any element of the network (coordinator, router, end device). The tasks of the coordinator is to create a new network, synchronize it by sending periodic synchronization frames, making decisions about new devices being connected to the network. It storage address table of devices currently connected to a network.

ZigBee end devices usually have reduced functionality (RFD), which means that they do not have implemented algorithms like the coordinator. Restriction on the ability of equipment to a minimum set of functions allows the use of smaller memory thus reducing production costs and increases battery lifetime. Routers can be used as devices to segment the network. This allows you to expand network coverage over the scope of the coordinator. End devices communicate then with the closest router. Router must be a device with full functionality. It features full time local coordinator, taking over most of the features typical for the network's PAN coordinator [2]. In practice, it is often used the power of the coordinator and routers from an external source as it's radio part is on most of the time. At the same time end devices operates in pulse mode, or give signals only at a certain period of time, thereby prolonging the operating time of battery power source.

The easiest way to configure network devices is the use of star configuration. End devices communicate directly and only with the coordinator. Each new device appearing in the range of the coordinator, can connect to the network. the coordinator determines the annexation of the new device in the network

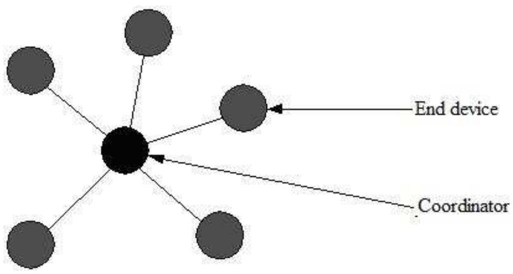

Figure 1. Star configuration [1]

More complex structure of the network configuration is tree configuration, a sample structure is shown in Figure 2. In such a network structure is divided into subnets connected with network elements - routers. Router within the range of acting coordinator can connect to it. End devices located in the network's coverage may be connected to the coordinator or a router depending on the device that gives a stronger signal.

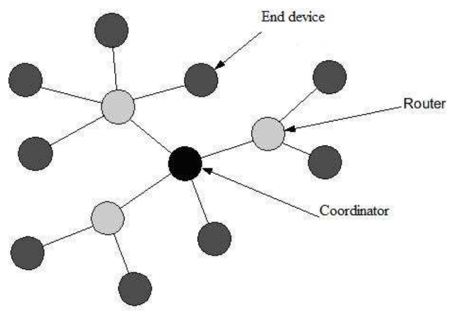

Figure 2 Star configuration [1]

The most complexed is the mesh configuration (Figure 3). Reliability associated with redundant connections are redeemed by the complexity of the network. In this case, the devices in the network form a logical connection made on the basis of selection of the fastest and most reliable way. If one node has been damaged traffic will be redirected through other available nodes. Selection of paths in these networks is carried out based on the routing tables held in memory of routers and coordinators. These include the logical addresses of all adjacent nodes, and information about the distance to each network device, expressed the number of nodes on the way to the target device.

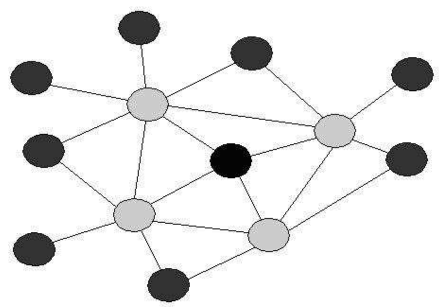

Figure 3. Mesh configuration [1]

Realizing the potential for devices operating in the ZigBee standard operating in the tree or mesh configuration requires the implementation of appropriate software in the device.

The structure of the ZigBee network layer is composed of four layers of communication. The lowest layer is physical layer corresponding to the call through the wireless medium. The second layer is a layer of media access control which provides the physical transmission channels. Higher layers in the ZigBee network model is layer that provides control over the configuration and application layer. ZigBee network layer model shown. (Figure 4)

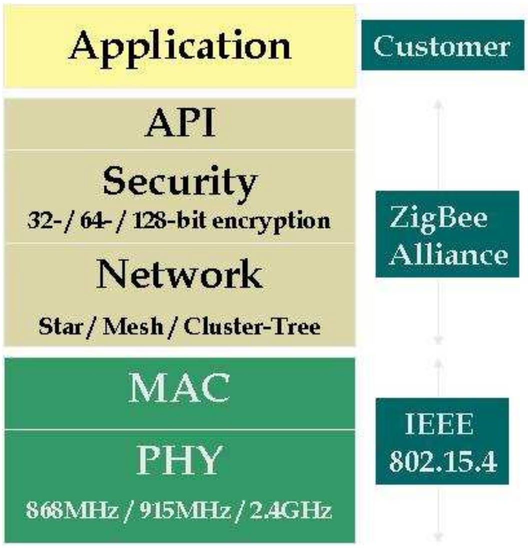

Figure 4. Layered structure of the network operating in the ZigBee [2]

3. Experimental system

In order to measure the delays occurring in data transmission networks based on IEEE 802.15.4 an experimental measuring system has been built. As the devices working in the network applied ZigBee demonstration kits manufactured by Aurel. The test network operates in the 2.4GHz band. Network components are three modules to discharge the functions of coordinators and twelve modules performing the functions either routers or end devices (Figure 5). Components of the network are connected to a measurer using UTP cables to allow serial communication. Serial transmission is used to issue instructions to send data via radio communication as well as measuring the latency of transmission.

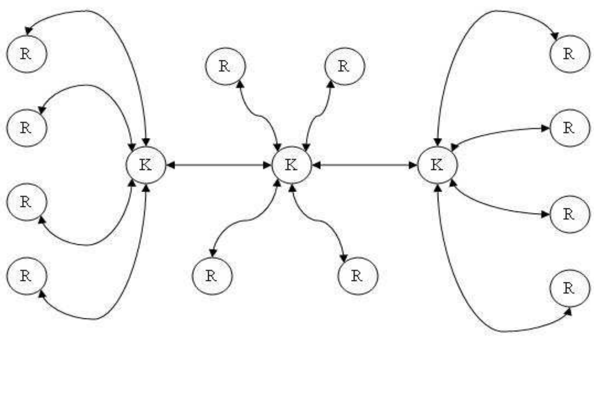

Figure 5. Schematic of the test measurement system in the ZigBee standard. Elements of the system: K - Coordinator, R - Router/End device

The second part of designed experimental measurement system is a measurer of time delays in data transmission. It consists of a Spartan 3 series FPGA device, systems that match parameters of the transmission and a USB interface enabling communication with a PC.

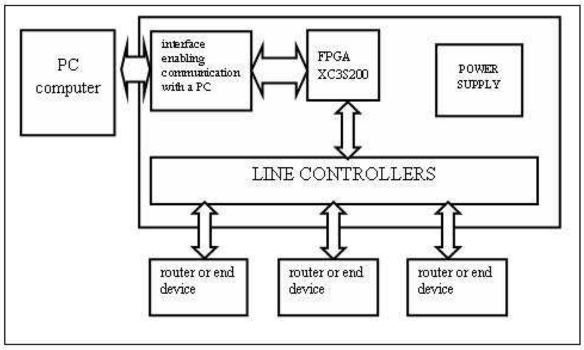

Figure 6. Block diagram of the measurer of delay data transmission in a ZigBee network

In the structure of Spartan 3 has been implemented controllers of serial transmission, binary counters / timers for measuring the transmission delays. In another part of FPGA structure has been implemented picoblaze microprocessor that initiates data transmission by the network elements and then the reads the resulting delay. The results of measurements using the USB connection sends to the PC.

Designed to measurer also provides power for all components of the measurement system, it's synchronization and enables communication with all elements of the system via a serial interface. Application of 32,768 kHz quartz crystal allows to achieve a measurement resolution of delay at 1 / 32 ms. By contrast, the presence of 16-bit counters can obtain maximum measured delay 2000ms.

4. Results

Base for the system described in third chapter measurement system was a prototype measurer described in paper [3] realized in the "Institute of Metrology Electronics and Automatics" for measuring delays in data transmission in ZigBee networks. Diagram used in the work [3] of the measurement system is shown in Figure 7.

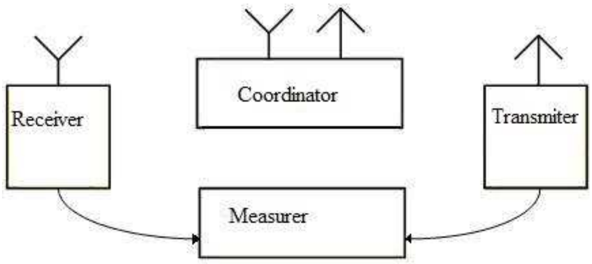

Figure 7. The measurement system used to measure time, the data used in the work [3].

In work [3] 1000 trials has been performed, each with a single transmission time measurement between two end devices, network operating in the star configuration. The average transmission time obtained experimentally was 80 ms. The measurement results are presented graphically in the form of a histogram (Fig. 8). The data were transmitted between two end devices, communicating with each other via the coordinator. Measurement of the average propagation time, and present results graphically on a histogram obtained assuming that the measurement system operated in an environment without external interference, and when sending and receiving devices are from each other slightly apart.

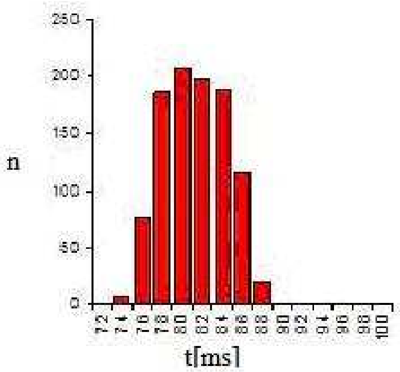

Figure 8 Histogram of results of measurement of time propagation. Measurements performed in an environment devoid of interfering external sources [3]

In order to determine the class of components needed to build the meter described in chapter 3 measurements were made as shown in Fig.9. In this way the minimum possible delay that may occur was determined, and its fluctuations. Measured delay amounted to 30ms and it's fluctuation was 15ms. Quartz resonator of 32.768kHz allowed to perform measurements with a resolution 1/32ms the maximum measured delay 2000ms can be considered, the limit above which it can be concluded that the package was lost and retransmission is required.

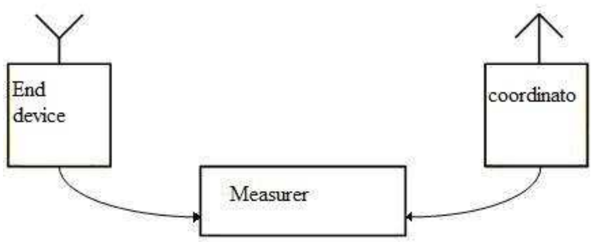

Figure 9. The measurement system used to determine minimum delay and it's fluctuation

Conclusions

The article presents a brief description of IEEE 802.15.4 and uses it the ZigBee wireless network. Presents the distribution of devices operating in this network, the available types of network configuration and operation of standard ZigBee is characterized by a layered model. It shows the way experimental measurement system was built and presents first results of measurements being made. The results to be obtained will be presented graphically on histograms. Histograms will be used to create a probability model of data transmission delay in wireless networks.

Bibliography

1. Sinema Coleri Bergen: ZigBee / IEEE 802.15.4 Summary, September 10, 2004
2. www.zigbee.org - website organization ZigBee Alliance
3. Marcin Onsowicz: Study the effective transmission speed of the ZigBee standard, Master Thesis, Gliwice, Poland, 2007/2008

Authors:

MSc. Maciej Grygiel

Silesian University
of Technology
ul. Akademicka 10
44-100 Gliwice
tel. (032) 2371208
email: *maciej.grygiel@polsl.pl*