Design of Wireless Measurement Device Based on Zigbee Standard

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Abstract – **This paper is presents the design and communication protocol of wireless measurement device based on Zigbee standard. The designed module is part of wireless network of intelligent sensors, which may be used to monitor and control the air parameters in particular area or environment.**

Keywords – **Zigbee, Measurements, Wireless communications.**

I. Introduction

In the last years the wireless standard Zigbee is receiving an increasing popularity on the market. It's offering an extraordinary control, expandability, security, ease-of-use and the ability to use this technology in any country around the world. The underlying benefit is remote control of multiple systems and their flexible management.

Zigbee standard is particularly suitable for developing a wide network of intelligent sensors. In this paper it is presented a one solution for Zigbee wireless network for control and monitor of air parameters. The designed devices monitor temperature, humidity, pressure and air composition. They have compact sizes and are easily installed to almost any places without concerning about wiring hence replacing bulky specialized measurement systems. Flexibility and opportunity for utilizing these devices in different applications is the major advantage. Despite its size it achieves a relatively high accuracy of the sensors which could be used for specific applications. The wireless Zigbee standard provides a high reliability and interference immunity against any narrowband signals and because it's using the standard IEEE 802.15.4 the modules could exchange information with other wireless systems for control and management [4].

The primary application of the wireless measurement devices is for monitoring the air in industry, where working environment is critical for employees or strict requirements are demanded for the manufacturing process. Another use of the modules is for implementing an intelligent sensor network for home control and monitoring, which has increased popularity in the last several years. The implementation of such measurement system of air parameters will provide comfort and security of housekeepers

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II. Design of Wireless Measurement Device

A. Network topology

To develop such wireless measurement system it is crucial to design most effective and secure topology of the network. This specifies the main functions of the designed modules. The IEEE 802.15.4 standard and Zigbee specifications support various topologies of communication networks. Since the main purpose of the modules are to perform measurements via the connected sensors of temperature, humidity, pressure and air composition; and transmit the generated data over the wireless network. The most secure and reliable network of sensors is with Mesh topology (Fig.1) [4]. In this network configuration every module can communicate with all others within its reach which provides a increased reliability to the wireless system and it makes it resistant to any interferences or losses of any node.

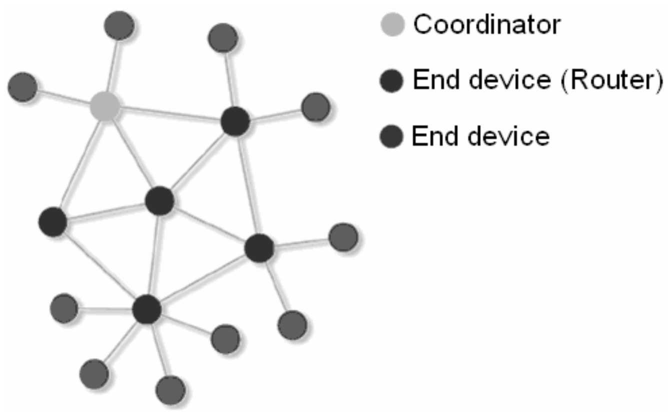

Fig. 1. Wireless measurement network topology

To realize this type of topology two different devices are needed – end device and coordinator. The end device is conducting the measurements and has all the sensors connected. On the other hand the coordinator s' functions are to define and control the wireless network in which it will communicate with end devices. The coordinator device controls and acquires the data from the end devices and retransmits it to a personal computer via serial communication port where data is analyzed and displayed.

B. Block diagram

This paper emphasizes on design of the end device. On fig.2 is shown a block diagram of the end device. It consists of microprocessor, Zigbee communication module, sensors and power supply block. Since the wireless measurement system monitors the air parameters temperature, humidity, pressure and air composition sensors are integrated in this module. To achieve good accuracy analog sensors are used. The Zigbee

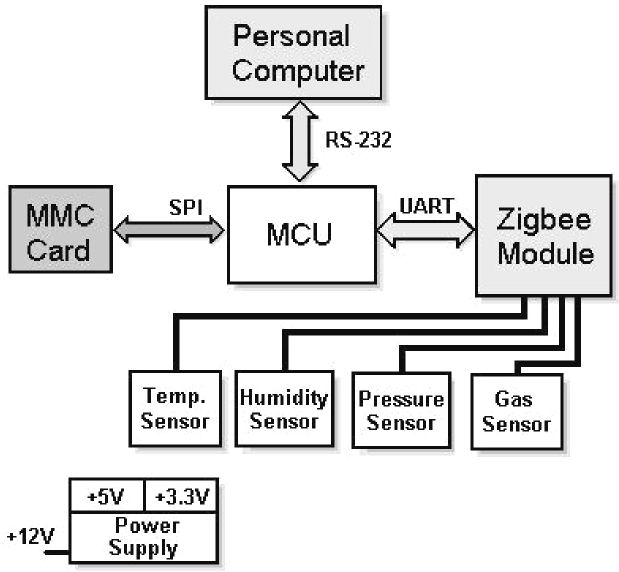

Fig. 2. Block diagram of the measurement device

module has internal analog-to-digital converter (ADC) therefore they are connected directly to the corresponding analog inputs.

Data packetization is performed in the Zigbee module and directly transmitted over the wireless network. The microprocessor is used to configure the Zigbee module, to establish the network association and to control the measurement process. A connection with personal computer is realized for programming and sensor calibration. In scenarios where a communication problem is occurred a MMC memory card could be installed where data could be stored in order to preserve the acquired data.

Sensor accuracy and stability is a major factor of such measurement device. TC1047A is used for temperature sensor, which has a steady DC voltage at its output relative to the measured temperature. The accuracy is ±0.5ºC. To measure the humidity H25V5 module is implemented, which gives good response time and achieves a desirable accuracy of ±4%RH. Pressure sensor is a bridge sensor circuit therefore a differential amplifier is used to increase the signal to levels appropriate for sampling from ADC. This type of sensors is very accurate and error in the measured value could result from the quantization process into the analog-to-digital converter and the used signal amplifier. The accuracy is calculated with the following formula:

$$A = \frac{V_{REF.} ADC_{Err}}{N} . \frac{P_{sens}}{G} \quad (1)$$

Where: A is the needed accuracy; $V_{REF.}$ is the reference voltage of the ADC; N is length of sample word; P_{sens} is the sensor sensitivity and G is the gain of the amplifier.

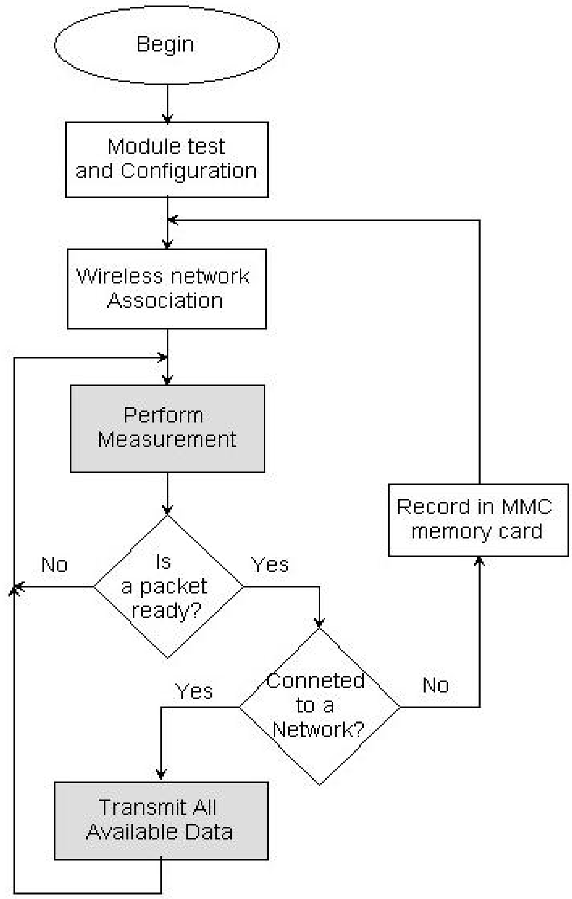

Fig. 3. Algorithm of the measurement device

C. Algorithm of the measurement device

The developed algorithm of the end device in the wireless measurement network is presented on Fig.3. it consists of the following operation steps. At start-up the module performs initial configurations. It includes serial port and SPI initialization in microprocessor, MMC card initialization, Zigbee module test and configuration of its radio and network parameters, sensor initialization, etc.[2]

The next major step from the algorithm is wireless network association. The Zigbee module performs a network scan and initiates the communication with the coordinator device, which collects the data and performs analysis. This step ensures that the transmitted data will be received correctly from the coordinator. After the wireless network association process the device is ready to carry out the measurements from the sensors. It is realized by the Zigbee module as it consecutively acquires samples from each analog channel where a sensor is connected. An adequate data processing is applied to the acquired data. Every sample is transformed into its respective value of the monitored sensor. Furthermore an additional processing is carried out to suppress any additional noise and interferences. The acquired data is collected in packets. If a packet of data is compiled then the device is ready to transmit it over the wireless network. Before that the

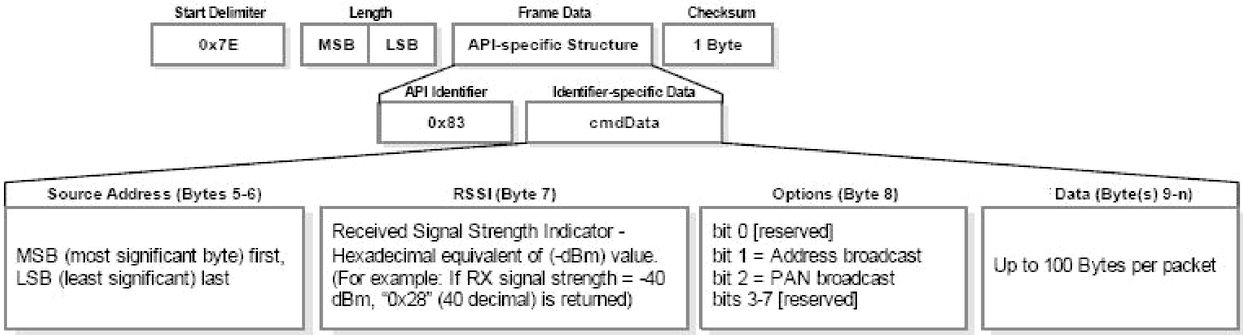

Fig. 4. Algorithm of the measurement device

device assures that it's still associated to the network and after that it forwards the packet of measured data. If the communication with the coordinator is lost the packet is stored in MMC card and a association process is initialized. When the data transmission is accomplished a new data acquisition is performed.

D. Packet description

A packet (Fig.4) which includes data from each sensor is 20 bytes long [3]. It starts with a special packet identifier sequence of 1 byte. It is followed by two bytes which indicate

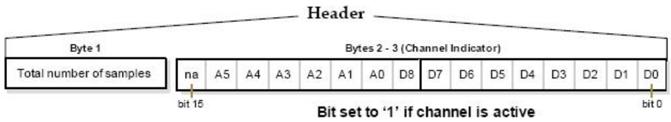

Fig. 5. Sample data header

the length of transmitted data. The next frame is the acquired data from the sensors. It has a specific structure and additional information concerning the radio channel and source device information. The packet finishes with a checksum of the transmitted data. It is calculated by the following formula:

$$Checksum = 0xFF - SUM(Data\ frame) \qquad (3)$$

Where SUM(Data frame) is performed as all bytes from the data frame are added keeping only the lowest 8bits of the result. Then this sum is subtracted from 0xFF resulting in the checksum. Data frame is the part of the packet excluding the packet identifier byte and the two bytes of the packet length.

The data frame includes a API identifier byte, indicating

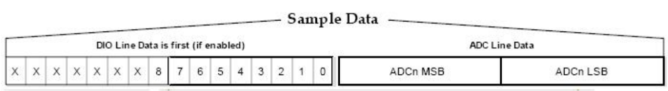

Fig. 6. Sample data structure

what type of information is transmitted. It's followed by two bytes of the source address which is the network address of the Zigbee module. The next byte is RSSI signal level received from the coordinator which indicates the signal strength level in –dBm values. The next byte is optional and it is not used in our application.

The sampled data frame follows. It begins with a header (Fig.5). The first byte of the header defines the number of samples forthcoming. A sample is comprised of input data and the inputs can contain either digital input-output (DIO) channel or analog channel. The last 2 bytes of header (channel indicator define which inputs are active. Each bit presents either digital or analog channel. Sample data follows the header (Fig.6) and the channel indicator frame is used to determine how to read the sample data. If any of the DIO lines are enabled, the first 2 bytes are DIO data and the ADC data follows. ADC channel data is stored as an unsigned 10-bit value right-justified on a 16bit boundary.

E. Data processing

To achieve maximum accuracy and stability of the used sensors different signal processing methods are studied. Considering the fact that it is a wireless measurement device and analog sensors are used, it has to be taken into account the possibility of interference in the analog input signal and additional noises in the analog-to-digital converter. Filtering capacitors are used to suppress any interference however a digital filtering is applied.

A low-pass mean filter is applied. The method used in the data processing is averaging of the last N (for example N=20) samples [1]. The calculations are based on the formula (2):

$$s(n) = \frac{1}{N}\sum_{i=0}^{N-1} s(n-i) \qquad (2)$$

Where s(n) – is the current processed sample; N is the number of averaged samples; The measured parameters change slowly in time, thus the method filters any high frequency noises and at the same time indicates every quick change in these parameters. Maximum sampling rate of 1kS/s is also in favor of this processing method.

III. Measurement Results

The designed wireless measurement device is tested in laboratory environment. The realized data processing and filtering of the input signals are presented on fig.7. On the first diagram no filtering is applied and on the second diagram the designed low-pass filter is introduced. Where N is the number of averaging samples. It can clearly be seen the high frequency noise filtering and at the same time preserving the quick temperature changes.

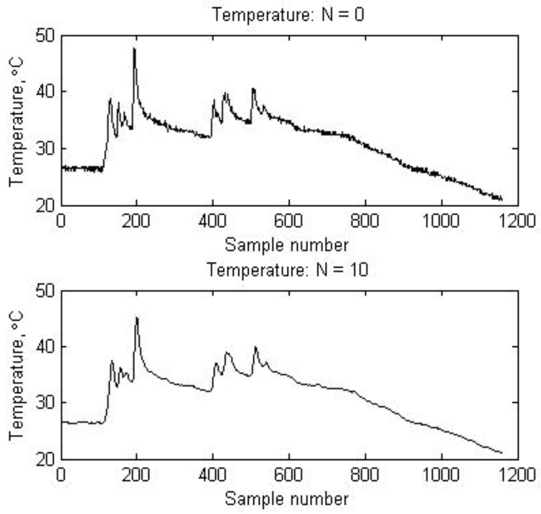

Fig. 7. Low-pass filter application;

A small section of measured data is presented on figure 8. Every chart presents results from the implemented sensors of the wireless measurement device (temperature, humidity and pressure).

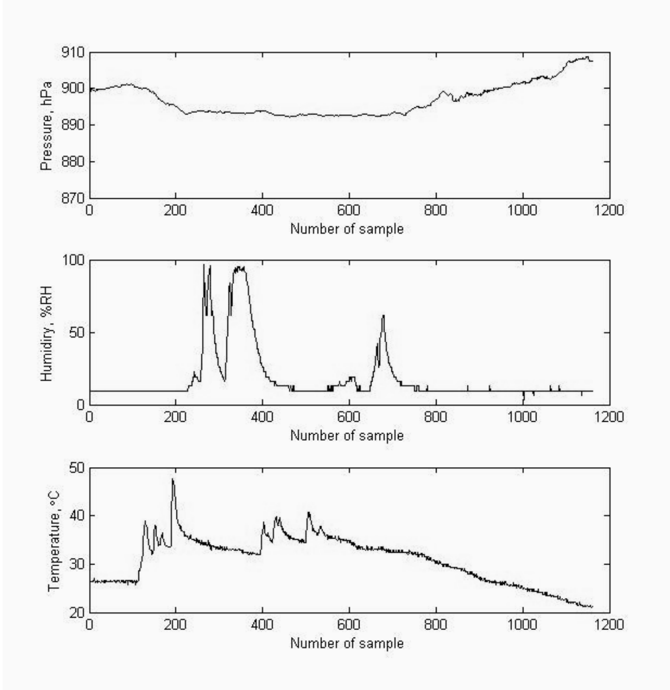

Fig. 8. Measured sensor data;

IV. Conclusion

The designed wireless measurement device is flexible and reliable instrument. Based on the Zigbee standard this module could be easily implemented in a wide wireless network for measurement and control of air parameters. The standard provides reliable radio communication channel, different network topologies and good technical characteristics. The selected measurement sensors have high accuracy and long term stability.

References

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