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The virtual instrument based on the ZigBee network

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***Abstract*-** In this paper, some remarks concerning cable as well as wireless connections in measurement channel are inserted. The demonstration application managing wireless network was shortly described. The main focus of paper is placed in the recognizing of the data acquisition protocols used in demo application for data transfer from wireless network to PC. The implementation of wireless sensor network to the virtual instrument under LabVIEW environment is presented.

I. The data sharing mediums in industrial systems

The data sharing is one of the most essential tasks in technical systems [1,2]. In industrial systems, the commonly used solutions for measurement and control data transmission are based on wire connections. The electrical or more rarely optical signals are carrying the respective information.

In several systems, the transmitted data can have analog as well as digital (numeric) form. On the other side, the information can be carried by means of analog or digital signals. Usually, the standard interfaces are used for transmission of data because of number of advantages connected with the homogenous configuration of cooperating devices. From the point of view of austerity of wire number in communication channel, as well as more simple principles of management of information exchange in system, the serial interfaces are applicable most often.

In many systems the information is obtained from sensors and measurement converters still in form of analog signal and transmitted on the appropriate level of voltage or current. The standard analog serial interfaces are then applied, e.g. current standard 4..20mA, especially at transmission of information in industrial conditions on distance from several for some hundreds meters.

Many among presently offered measurement converters are equipped with analog-to-digital converter (ADC). Its output information is the digital representation of measured analog quantity and it can be transmitted to other elements of systems using analog signals (e.g. HART standard interface) or standard digital interfaces (e.g. RS-485, I^2C, etc.). Similar solutions are applicable at transmission of information to actuators, forcing change of some parameters of controlled object or industrial process.

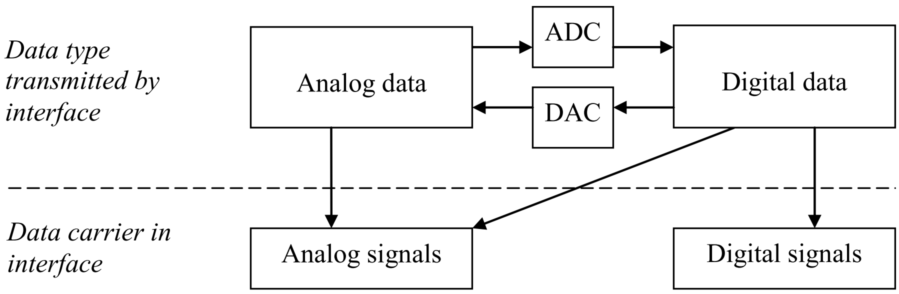

Figure 1. The type of information and its carrying signals in industrial network

From the point of view of specificity of the system (Fig.1), the information obtained from measurement converters or for assigned to actuators, before input to interface, requires often to be converted from analog form to digital one or vice versa.

The cable connections creating communication channels must grant whole a range of requirements related to resistance of signals transmitting information against disturbances and correctness of transmission. In many applications, it is required a special mechanical construction of cable for affirmation of immunity on mechanical factors (tension, vibrations, friction, etc.), particularly, when connections are realized among movable devices.

It is possible to solve considerable part from above described cable connection problems applying wireless technique for data transmission. Similarly, the wireless communication seems to be the reasonable application, when object of measurement or control device is situated in hard available place and when the structure of the cable connections is expensive. In last time, several techniques of wireless exchange of information were developed (e.g. Bluetooth, Wi-Fi, WiMAX ZigBee, GSM, UMTS, etc.). Some of them have found employment with success in distributed measurement and control systems. Additionally, the wireless connection devices comprise usually on board the ADC converters, so the data acquisition becomes more homogeneous. In PC disappears the problem of analog signal carrying any kind of the measurement data.

II. The wireless connections in measurement and control

For expression of specificity of wireless exchange of measurement and control information among devices or technical objects, the term M2M (Machine-to-Machine) is using. The M2M techniques concern the communication of devices on many application surfaces, from multimedia employment to industrial installations. The M2M technology enables an exchange of information among measurement and control devices and computerized information, visualization and data storing systems. Accustoming of system enables an elimination of perplexing limitation in transmission of data related with cable connections. The typical M2M set consists of the telemetric unit and central unit (computer equipped with receiver with proper interface). Data among them are sent wireless way and register on-line or locally.

The technologies of wireless communications, the Bluetooth and the ZigBee, have many common properties. Both are IEEE 802.15 standards "wireless personal-area networks", they act in unlicensed 2.4GHz band (the same as Wi-Fi 802.11b/g).

As first representative of the group of wireless technology was elaborated the Bluetooth (IEEE 802.15.1). It is a functional wire copper equivalent and it try to reconcile two demands: small energy consumption and relatively fast data transmission - to 720kbps – rare transmission (a few times a day) of big portion of information, e.g. among digital devices and PC computer. The ZigBee standard (IEEE 802.15.4) is dedicated to frequent transmission of short messages [3]. Transfer of data proceeds with lowest speed – up to 250 kbps, but in typical implementations it does not exceed 40kbps.

The identification of network devices and their activation from state of sleeping, in the ZigBee technology proceeds a lot faster – an identification occupies near 30ms and activation 15ms, when in the Bluetooth technology - both operations require at least 3s. The refilling of supplying energy in case of the Bluetooth consists in a cyclic recharging of accumulator, while in the ZigBee in typical application one battery ought to be sufficient for whole exploitation cycle of device (or battery replacement every 2 years). The considerable influence on accumulator active time in case of the ZigBee has the fitting of force of signal for distance from transmitter (even to 100m). The Bluetooth keeps the same force of signal for all the time, but its range does not exceed 10m of distance.

The architecture of the Bluetooth is two-layer (the controller and a slave type device dependent on it).

The complete composition of the ZigBee network endowment consists of three devices: Coordinator, Router and End-device. The first of them serves for start-up and management of network, as well as an interface with central unit (PC). Router deals with the network on sub-networks dividing, transferring of packets among the network devices (e.g. from End-device to Coordinator). The End-device is jointed e.g. with measurement converter. It sends to Router the data collected by measurement converter. It can be switched-off for most time. Such manner of work and small energy consumption are the advantages of the system. The End-devices are sleeping by majority of the time. They are excited for several milliseconds only, in order to perform read-out of data from converter (End-device can supply it) or to communicate with other devices in network. The average power consumption of such devices is close to the state of sleeping. The technology passed excellently examination in environments with very low S/N ratio factor.

The MeshNetics is one of the producers of complete units for creation of the ZigBee network [4]. They have designed the ZigBit™ module on the base of ATmega1281V Atmel microcontroller, in the form of assembled and ready-to-use boards – start kit ZigBit Development ZDK MeshBean2 boards.

Every ZDK can work as Coordinator, Router or End-device, what is to select using on-board DIP switches.

The devices are available in three variants distinguishing in the 2,4GHz antenna structure: the board integrated PCB antenna, the external antenna attached to on-board connector or the dual chip antenna integrated into the ZigBit module. Coordinator is connected to PC using R232C or USB interface. Independently on the type of applied interface, in PC operating system the communication port is reported as generic COM port.

The network hardware equipment is distributed along with essential software tools.

The development ZDK board (Fig.2.a), beside other peripheries, gives to the user the several capabilities to connect the measurement sensors or converters as well as the control devices by means of (Fig.2.b):

- ADC converter inputs, range 0..1,5V, 3 channels,
- I^2C interface, max. 30 devices,
- GPIO digital input/output lines, max. 30 lines,
- interrupt inputs, 2 lines.

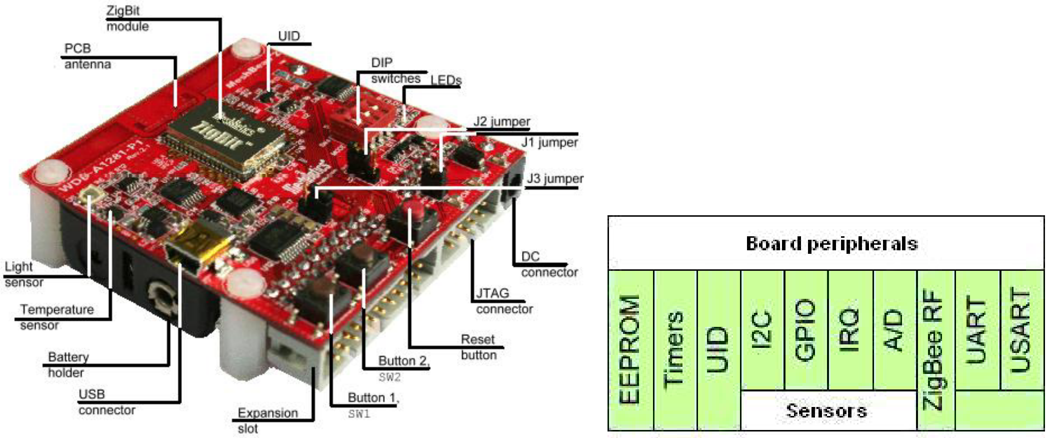

Figure 2. The development ZDK board: a/ the view of board, b/ available interfaces [4]

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III. The firmware software demo application

The producer supports the ZigBit devices with the demonstration WSN (Wireless Sensor Network) Demo application. This application contains the firmware software supporting the functions for Coordinator, Router and End-device. Every ZDK board incorporates two sensors: the temperature sensor LM73CIMK (National Semiconductors) and the light sensor TSL2550T (TAOS) Both sensors are connected in parallel to the I^2C bus. The network Coordinator (0000) collects the data from End-device (003B) and sends it via USB interface to PC. The computer can acquire the data by means of any communication program (e.g. Hyperterminal). The firmware software contains also the WSN Monitor designed for visualization of demo network status.

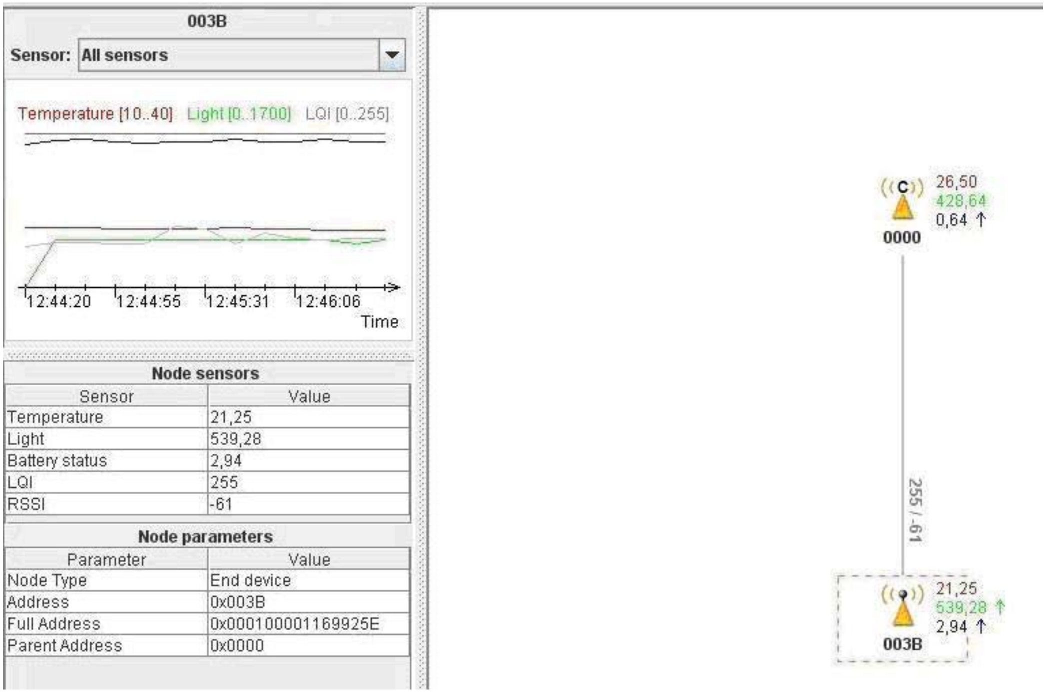

Figure 3. The report of working wireless network obtained with the WSN Monitor

In Fig.3 the mimic panel of the working ZigBee network is shown. The simple network consists of Coordinator and End-device only. On the left side of the picture i.e. the values of temperature and light intensity, obtained on-line from End-device, are reported.
The ZigBee network user can design his own application for actual measurement or control needs. To compile the source file may be used the AVR Studio - professional Integrated Development Environment (IDE) from Atmel, free downloadable development software.

IV. The virtual instrument managing the ZigBee network

The main focus of present work is placed in the recognizing of the data acquisition protocols used in module demo application for data transfer from the wireless network to PC. The considered network consists of End-device and Coordinator (Fig.3) which is connected by means of USB interface to PC. The data send from the Coordinator are collected and processed under LabVIEW environment. The data transferred in on-line captured packets are segregated into words consisting of one or more bytes, taking into account their position in received stream of bits.
The data frame sent from Coordinator (as well as from End-device through the medium of Coordinator and USB interface) to PC contains the information placed in order shown in Table 1.
The verified communication protocol differ in some details from the technical manuals. Some inaccuracy were discovered during the performed experiments (i.e check sum calculation method).

Table 1. MSG_DATA message format (code 0x01) (Message Payload).

Field Number	Field Length, bytes	Field Description
1	2	Header: **0x10 0x02**
2	1	MSG_DATA
3	1	Node type
4	8	IEEE address
5	2	Node short address
6	4	eZeeNet Software version
7	4	WSN channel mask
8	2	PANID
9	1	WSN working channel
10	2	Parent short address
11	1	LQI
12	1	RSSI
13	1	Board type
14	1	Sensor data size
15	12	Sensor data: Battery status, Temperature, Light
16	2	End-foot sequence: **0x10 0x03**
17	1	Check sum: (payload bytes addition modulo 256)

The WSN Monitor data frame consists of 46 bytes. Every multi-byte word (Field) is sent starting from least significant byte. Coordinator sends to PC its own data about every 2 seconds, and the data from End-device (through Coordinator) – about every 12 seconds.
The data receiving and segregation is performed under LabVIEW program. The selected parts of the Front Panel and Block Diagram are shown in Fig.4 and Fig.5. For every received frame the check sum was calculated and compared with the value sent in packet. If the frame is transmitted without errors, there is easy to select the interesting data by implementing the respective algorithm following the example shown in Block Diagram (Fig.5). The green-coloured icons visible at Block Diagram are the simple procedures designed for converting the data from string form to numerical or for calculating some sensors output parameters following the producers technical data [5,6].
Since the data are captured in LabVIEW environment they are ready to use in further processing depending on the user desired application.

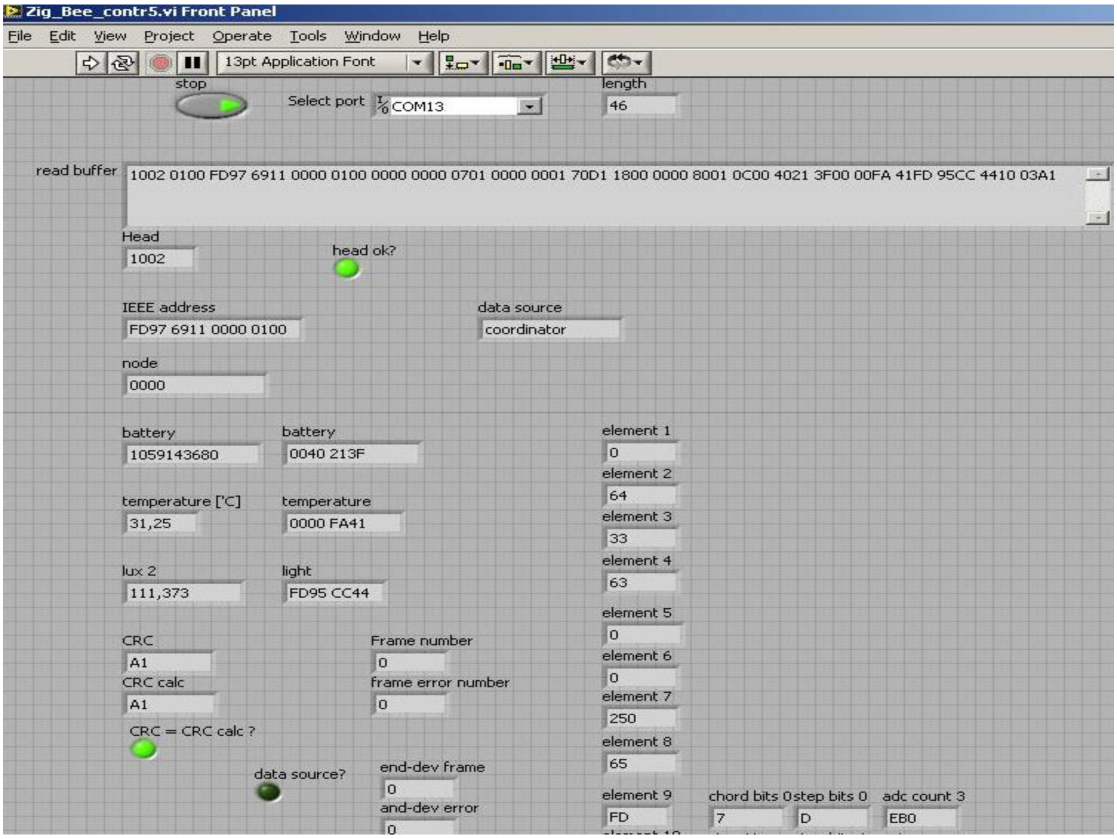

Figure 4. The selected part of Front Panel of program for ZigBee module data capturing and analyzing

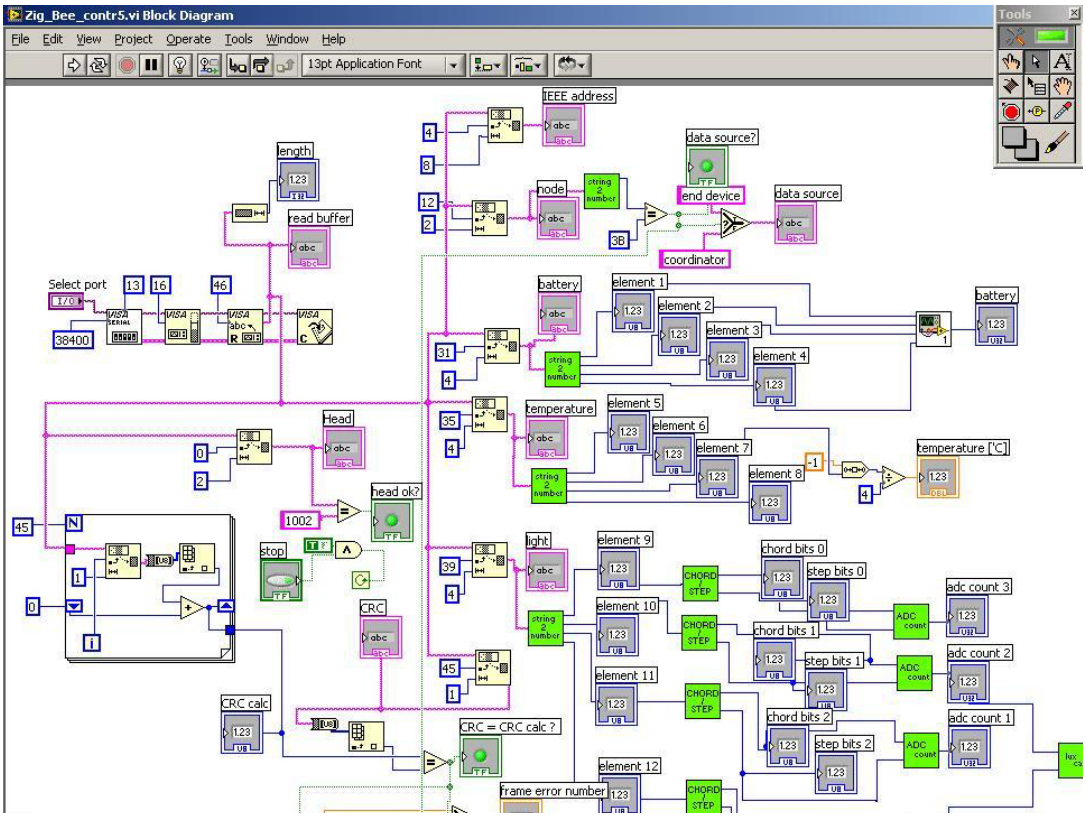

Figure 5. The selected part of Block Diagram of program for ZigBee module data capturing and analyzing

During the data capturing the big number of lost packets transmitted from Coordinator to PC via USB was observed. The especially interesting is the fact, that the ratio of the failed frames to the sent frames, considering the data transmission from Coordinator to PC (via USB interface) is multiple greater than the ratio calculated for frames transmitted from End-device through the medium of Coordinator to PC.
The average value of ratio factor, obtained after many hours of data collecting, for the communication between Coordinator and PC is on the level of 12%, while this factor obtained for End-device to PC (via Coordinator!!!) is below 2%. Such results were obtained during communication of the Coordinator with several computers, desktop as well as laptop type. The standard USB interface data transmission seems to be much worse than the wireless one! First conclusion is that it means the communication algorithm via USB is not elaborated enough correctly. At the moment is very difficult to explain such effects and this phenomena will be the subject of further investigation.
The next effect was observed when Coordinator was switched of from the network. Then the End-device started looking for network, instead normal operation (mostly slipping). After two days, when its battery was discharged because of such mode of operation, any communication with the module was impossible because its Bootloader program was erased from memory.
Taking into account the experiences collected during the communication protocols investigation, the next step will be the project of the user application managing the wireless network configured for cooperation with module external measurement sensors, converters and actuators.

V. Conclusions

In many industrial processes, one of the major problems is the data sharing by cable connections. Especially, moving elements of machines are strongly exposed for mechanical damage of their measurement or control channels.
The producers of the ZigBee wireless network devices equip them with the set of interfaces enabling a connection of miscellaneous measurement sensors and converters.
There is possible to select the adequate converter allowing of the full utilization of capability of the ZigBee network.
It seems to be also interesting the implementation of wireless network as a part of intrinsic safe systems. The elimination of possible damages in cable connections and this way, one of a potential ignition sources, is advantageous in such systems.
There in user application, the special care have to be taken for the correctness of measurement and control data transmission via USB verification algorithms.
Currently, authors lead research over laboratory model of the ZigBee network, acquiring measurement data from several sensors and converters, managed under the LabVIEW environment.

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