Unıversal Wireless Sensor Networks Technology Platform and its Applications

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Abstract. Wireless sensor networks (WSN) are becoming more and more popular due to the growing area of their application. However, finding a single approach to different tasks is rather difficult, as each task has its own peculiarities. In this paper we propose a universal hardware platform as the first step to a quicker development of finished solutions based on WSN. We demonstrate the use of our platform in different types of applications.

1 Introduction

A wireless sensor network [8] is a distributed self-organizing network, consisting of miniature electronic devices, which exchange data through wireless channels. These devices (nodes) do not require special installation and do need to be serviced. The key feature of a sensor network is a possibility of retranslating messages from one node to another, which allows covering large territories without using high-power transmitters.

A common node of a WSN uses the ZigBee standard for wireless data transmission. The ZigBee is an international open standard, which was developed by the ZigBee Alliance. This standard allows using wireless connection with low-power consumption for different applications for monitoring and/or management. The Zigbee supports different network topologies, it has special network functions for self-organization as well as several methods to ensure secure transmission.

The most popular applications for WSN are different monitoring systems (e.g. security monitoring), different management and control systems (climate-control, home automation systems etc.), remote access control and positioning systems (tracking systems).

2 Universal Platform for WSN [1]

A proprietary universal wireless sensor network (WSN) platform was proposed, developed and released by the Wireless Sensor Networks Lab (VEK-21 Ltd.) of the Department of Computer Systems and Networks at Moscow State Institute of Electronics and Mathematics (MIEM) (Fig. 1) because now it’s necessary to use

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similar devices in different application areas. We also can save resources by using our platform because of the universality. It also allows us quickly change priorities of the system, which makes possible using our platform to achieve different goals by working with all popular COTS sensors.

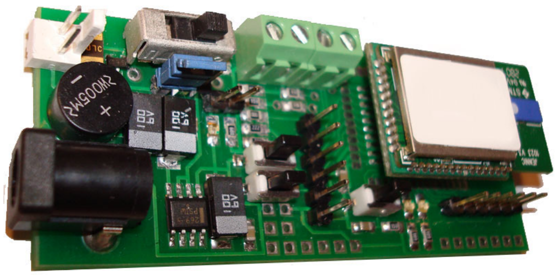


Fig. 1. Universal platform for WSN.

3 Energy Consumption and Lifetime

As sensor network applications depend so much on energy efficiency we want to analyze energy consumption and lifetime of our platform with microcontroller. Typical energy consumption for the sensor node: 37 mA – energy consumption for receiving, 37 mA – energy consumption for sending, 9mA – energy consumption for the CPU while transceiver is off, 0,002 mA – energy consumption in sleep mode. The time which is taken to wake from sleep mode is 15 ms and energy consumption 9mA (from the microcontroller data sheet):

$$9 \times 0{,}015 = 0{,}135 \text{ mAs (milli Ampere seconds).} \quad (1)$$

The microcontroller is running at a clock rate of 16MHz which means that a single cycle takes $1/10^6$ seconds. Let's assume that the average instruction takes 3 clock cycles and that we need 7,000 instruction for the measurement, for data processing and for preparing a packet for transmission over the network. This would result in

$$\frac{7000 \times 3}{16 \times 10^6} = \frac{21}{16 \times 10^3} = 1{,}312 \text{ ms.} \quad (2)$$

The amount of energy consumed at a current of 37mA would be:

$$37 \times \frac{21}{16 \times 10^3} = 0{,}0486 \text{ mAs}. \quad (3)$$

This means that the battery has to supply amount of energy which is equivalent to 1mA for 48.6ms.

And also the time to transfer data from I2C (for instance) is 5 ms with energy consumption – 9mA:

$$9 \times 0{,}005 = 0{,}045 \text{ mAs}. \quad (4)$$

Sending data takes place at a speed of 250,000 bits/s. We assume that our own measurements occupy 32 bytes of memory. A single bit takes 1/250000 seconds to be sent which sums up to:

$$32\ mA \times \frac{32 \times 8\ bits}{250000} s \approx 0{,}033\ mAs\ . \tag{5}$$

Time of calculating and sending took:

$$21/16\ \text{ms} + 1\text{ms}+15\text{ms}+5\text{ms} \approx 22{,}3\text{ms}. \tag{6}$$

This means that the node can sleep for about:

$$1\text{-}0{,}022 = 0{,}978\ \text{s}. \tag{7}$$

The node consumes:

$$0{,}978 \times 0{,}002 \approx 0{,}002\ \text{mAs}. \tag{8}$$

The total amount of energy is:

$$0{,}135+0{,}0486+0{,}045+0{,}033+0{,}002 \approx 0{,}262\text{mAs}. \tag{9}$$

We assume the AA battery delivers about 2300 mAh:

$$\frac{2300mA \times 3600s}{0{,}262} \approx 31{,}6 \times 10^{6}\ s\ \text{(365 days)}. \tag{10}$$

4 Our Projects based on WSN

We used our platform in implementation of some “standard” WSN applications as monitoring systems, SCADA and remote identification systems. Also some “unusual” applications to WSN technology were demonstrated built around proposed platform. These include autonomous system of secured wireless audio transmission and a wireless real-time 3D visualization system (WSN-based Motion Capture application for virtual environment simulation).

Security Monitoring System [3]. Security monitoring system based on WSN, which can work with different security sensors and integrated with GSM, can be used with existent security systems to increase reliability, it’s easier to install this system and it uses cheap data transmission channel than, for instance, Wi-Fi.

It consists of hardware (WSN devices) and special software (for devices and PC), which allows you to control object status through Internet.

Examples of using: private home security systems, offices security system.

Climate Control System (Home automation system) (temperature, illuminance, humidity) [4]. Climate control system based on WSN is a multifunctional system which gives us possibility to work with different electronic devices (air conditioners, light systems etc.) and might be integrated with other systems to increase efficiency of using electricity, water etc.

The main difference of this system from other monitoring applications is the use of special profiles that allow for using diverse devices with diverse algorithms. It also can use GSM channel.

Examples of using: climate control systems, home-automation systems etc.

Remote Identification System. Mobile objects wireless identification.

Fig. 2. Wearable sensor for wireless remote identification system.

We've developed a prototype of the system, which consists of different number of sensors. Each sensor measures power level of radio signal and sets up critical power level. If there is pair of sensors – one of them (base station) always measure power level, other – sends testing data packets. When someone is trying to walk between pair of sensors, one of them receives weak radio signal compare it with critical level, and if power level of the signal is less than critical level it sends interruption information to the central server and turns on alarm system. But if there is someone with special WSN device (Fig. 2) is trying to walk between pair of sensors, our system analyses situation and position of that person with WSN device and if that WSN device is registered at one of the sensors from that pair, system make a decision that there is no interrupt.

Base stations can be easily connected to GSM-channel or Internet.

Examples of using: security systems, special exhibition systems, home-automation systems.

Intellectual System of Wireless Audio Transmission [5]. This system is our first attempt of using WSN in "unusual" way – multimedia transmission. We have developed a prototype of a system, which will provide wireless access to different services using a WSN.

It consists of several base blocks (stations) and portable devices (handsets). A base block can be connected to a public telecoms network (throw special "bridge"), internet (VoIP service) or to a mobile phone. A portable device is a low-power handset using a 10 mW transmitter. Each element of this system is a node of a WSN. Therefore it contains an internal processor, which allows local data processing. For example, when a person talking on the phone listens to his (her) interlocutor, the data from his handset is not transferred thus minimizing the amount of traffic in the WSN.

General features:

- base station translates incoming calls to portable devices;
- portable devices can accept incoming calls, close connection, call a Skype-

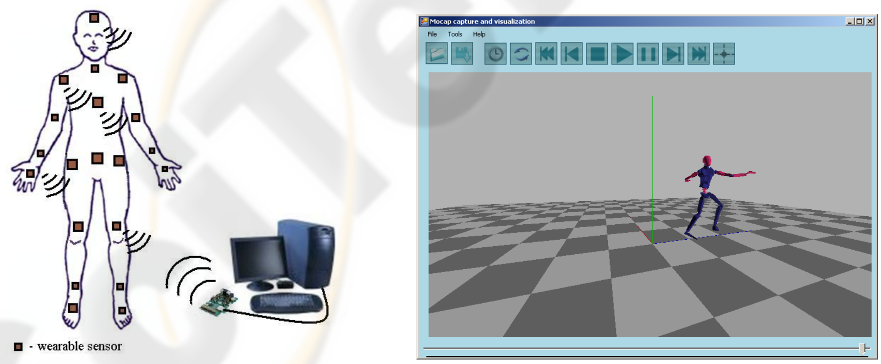
account;

- 400 meters distance between base station and portable devices;
- Internet-radio translation with reasonably good quality – up to 100 meters distance.

Bodynet System [7]. A wireless bodynet system consists of multiple wearable sensors and a central stationary module, each being a node of a sensor network. This system has two main applications – telemedicine and motion capture. The first one has focus on remote health monitoring of people with chronic diseases, patients in hospitals and elderly people. The task is solved with the use of sensors that measure blood pressure, pulse rate and other vital parameters.

A wireless tracking system [2] makes it possible to transform real movements of a person into a virtual 3D environment and visualize them in real-time. This is actually a first completely wireless system, which means that every sensor has a radio transmitter attached to it. In comparison, most existing solutions have a single communication module, which is usually placed in a rucksack, and all the sensors are connected to it with the help of wires. The system hardware consists of many end devices equipped with sensors for capturing acceleration and rotation of a certain part of a human body. A central unit collects all the data and transfers it to the computer, which performs all calculations and visualization. To measure all parameters we use MEMS-based accelerometers and gyroscopes, which are notable for their miniature size, low costs, low energy consumption and high performance. Apart from visualization, our software can also save all captured information for its future analysis in simulation programs, e.g. Autodesk 3ds Max, Maya, Blender.

The main applications for the motion capture system include:
- interface to 3D virtual reality;
- research in human-computer interaction;
- remote control of robots and manipulators with real movements;
- motion capture systems for character animation in films, games or television studios.



a) b)

Fig. 3. Wireless bodynet system.

A combination of different wearable sensors can be used for efficient control of police or fire squads during dangerous operations.

5 Future Work

We're planning to continue our work and we're going to develop:

- real time virtual reality system which will provide all possibilities of computer-human interface interaction;
- full home-automation system;
- sports-monitoring system;
- conveyor monitoring system (getting and analyzing all information about conveyor and environmental influence on it);
- home gaming systems, which will provide real interaction with the game;
- professional motion capture system for movie-making companies.

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