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ENVIRONMENTAL DATA MONITORING USING WIRELESS SENSOR NETWORKS

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ABSTACT: Wirelessly data acquisition from environmental monitoring using wireless sensor networks results in new possibilities and advantages. Main possibilities and features of environmental data monitoring using wireless sensor nodes are described in this paper. Possibilities and key aspects of energy efficient wireless sensor nodes are considered and described. Battery powered wireless sensor network implementation for environmental sensor data acquisition and monitoring is described. Monitoring results of environment data are given and shown.
Keywords: environmental data monitoring; wireless sensor networks; sensor node; energy efficiency; battery powered nodes

1. INTRODUCTION

Wireless sensor network (WSN) is considered as a serious and important, very promising technology in different environment monitoring applications. The measurement and collection of large different environment data using WSN leads to new possibilities in many practical fields and needs, as is food industry production, agriculture, human's life and environment conditions and research and similar. Using set of variety environmental sensors interfaced with small and powerful embedded microcontroller base boards allows remote environment sensing and data collection and processing periodically or on request. Such acquired and processed data from the sensor nodes (SN) are transmitted using low-power wireless technology to a centralized monitoring system.

Implementation of such environment WSN based monitoring system can be realized and used for a specific region or a specific application such as ecology, agriculture, farm, air pollution, climate change, water quality and shortage, forests, etc. [1,2,3,4]. All of these specific and sometimes critical applications can be monitored and researched by using small, inexpensive, low-powered and feature-rich SN in order to develop new strategies and improve human life.

The possibilities, progress and design challenges of using WSN in environment monitoring applications are considered and presented in this paper. The practical implementation of one inexpensive WSN based monitoring system suitable for many different environment monitoring applications, which is based on using Arduino battery powered embedded boards [5], is presented and described.

2. ENVIRONMENT MONITORING USING WIRELESS SENSOR NETWORKS

Many environmental applications can profit from usage of WSN based systems for monitoring and control purposes. Designing and implementing of such remote wireless measurement systems, depending on concrete environmental application, lead to many practical advantages such as: statistical data gathering, decision making, prediction and better response time on negative phenomena, increased productivity, etc.

Spatial large-scale deployment of sensor nodes (SN) enables data acquisition from many different sensor elements, on-board data processing and the data transmission using low-power wireless communication technology [2]. Integrated with different Internet based protocols, processed sensed data can be monitored from a centralized system. In such cases there is no requirement for special designed data loggers on coordinator or sink nodes, which reduce the maintenance, overall costs and on-place data download from data loggers by a human. Besides data sampling and transmission, a WSN for environmental monitoring can also perform other operations such as data aggregation, event detection, control, etc. This advanced operations can be realized using powerful, low-coast and feature-rich smart SN to sense and control many physical parameters in environment [2,4]. The integration with a centralized data storage system could be done through the Internet links, but in case of outdoor environmental monitoring the preferable and most secure way is GSM technology. Such advantages results in the possibility to remotely monitor application and receive information's on special occurred events.

The WSN design for environmental monitoring involves different challenges which should be analyzed in detail, in order to minimize the negative natural impact on the overall WSN. A significant researches show that water and forest monitoring applications on different conditions can influence the wireless signal strength, due to the radio waves reflection from water surface which interfere with direct waves, or wet forest conditions [4]. Another design consideration is the SN placement and the distance between the SN in applications. Long distances between SN could impact on wireless signal strength and therefore increase packet loss and overall SN energy consumption.

The major concern of spatial deployed SN represents the SN power source and the energy consumption. The main focus on energy consumption is on wireless communication (range and natural impacts), data communication rates throughout wide environmental range and sensing optimization [1,4,6]. Data queries such as aggregation queries and data threshold estimation influence on the SN energy consumption, also [1]. Data could be periodically, on event or on request transmitted depending on the application requirements.

In most cases batteries are used as SN power supply, which now have capacity of several thousand mAh. But, in real life environment monitoring application energy management and energy harvesting mechanism should be considered [4,6,7]. Energy management can be for example, established in the communication and data management layer of wireless protocol used, as well as on data processing intensity on microcontroller. Based on environmental application, an energy harvesting mechanism is crucial to charge the battery for powering of SN. Such energy harvester converts solar, mechanical and thermal energy into reusable electrical energy and contains protection circuits to prevent battery over-discharge [6,7]. The extracted and converted source energy could also be sent to the SN directly. A general proposed presentation of SN with energy harvester and management mechanism is show on in Figure1 [7]. As is presented in Figure1, regardless which power supply sources can be exploited in a specific environmental application, a DC-DC converter with a protection circuit is used to control the state of output voltage. This converted voltage is used to charge batteries or forward the controlled output voltage to voltage regulation unit.

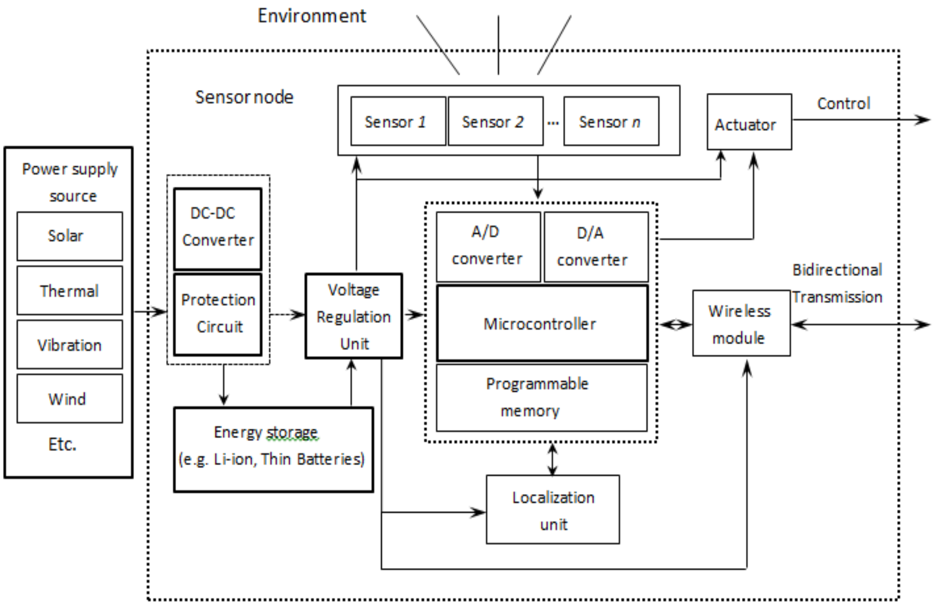


Figure 1. Sensor node with energy management

3. IMPLEMENTATION OF ENVIRONMENT WIRELESS MONITORING APPLICATION

It was designed and implemented one universal inexpensive system for wirelessly environment data monitoring which can be practically utilized for different environment applications. This system is based on application of popular the Arduino Uno boards, interfaced with sensors and wireless module, which acts as SNs [5]. The receiver board is also the Arduino Uno board which has the XBee wireless module directly interfaced with the board [8]. This board acts as coordinator and it is responsible for the PAN (Personal Area Network) network operation, formed during network initialization. The radio modules use the ZigBee protocol for wireless data transmission [9]. Therefore, the board is well suitable for SN implementation as well as other resource and processing intensive applications. In order to reduce energy consumption of the system the radio modules on SNs are configured to change periodically their states between sleep and active mode. The transmission of SN processed data is only realized in active mode, in which radio module operates only for few seconds. In all the SNs are used batteries to power the wireless module, the sensor and the board. In order to achieve the SN autonomous operation, the batteries are charged using solar cells panel and DC-DC converter with a protection circuit.

The designed and implemented WSN system monitors environment temperature, environment humidity and soil-humidity, using appropriate sensors. The sensor nodes measure and gather environment data, aggregate the data and transmit the data to the coordinator node. The coordinator node is connected to computer of PC type that stores the data, presents them to the user and statistically processes the data. The principal block-scheme of the implemented sensor nodes with all the used elements is shown in Figure 2.

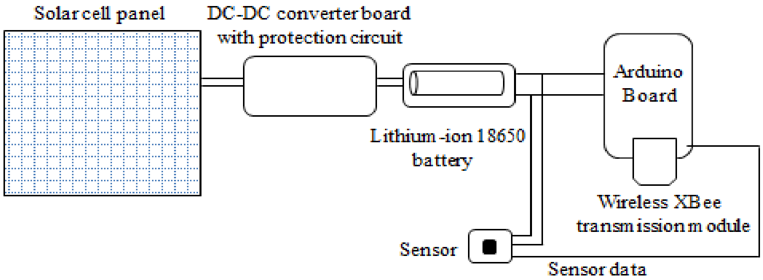


Figure 2. Block-scheme of implemented sensor node

As an example, one SN designed for soil-humidity monitoring is presented in Figure 3. The SN uses Lithium–ion battery to power the wireless module, sensor and Arduino board. In order to extend the SN operation life, the battery is charged by solar cells panel and is using DC-DC converter with a protection circuit.

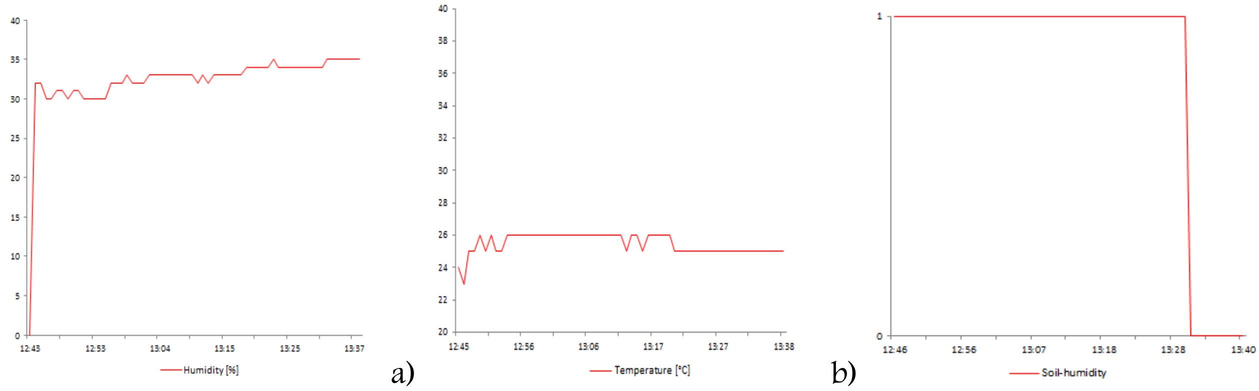
The Figure 3 shows testing of operation of SN for measurement of soil-humidity level. The SN presented in Figure 3 is suitable to measure the soil-humidity level for example for some kind of vegetable production.

Figure 3. Testing of sensor node for soil-humidity monitoring

4. RESULTS OF ENVIRONMENT MONITORING

The SNs in the implemented system were practically placed in a environment to monitor different sensor readings. The readings are processed by the SNs and wirelessly transmitted to the coordinator node using the ZigBee protocol. The transmission is realized periodically.

Results of humidity and temperature monitoring from SNs placed in environment are shown in Figure 4a and Figure 4b. The monitoring results are given in % and °C, for one period of time of monitoring. The soil-humidity sensor interfaced with other SN was placed in the soil and is capable of monitoring the soil humidity state with the soil-humidity threshold. Monitoring results from the soil-humidity SN are shown in Figure 4c. Initially, the humidity level in the soil was low and output state was 1 (high). After a specific time, it was filled in some amount of water in the soil space around the soil-humidity sensor and was achieved appropriate level of soil humidity to trigger change of sensor output to 0 (low), as it is shown in Figure 4c.



a) b) c)

Figure 4. Environment sensor node readings: a) humidity, b) temperature, c) soil-humidity

5. CONCLUSIONS

Integration of WSN in an environment for different applications and projects for environment data monitoring and processing has attracted further development of small and resource-rich SNs. Such WSN integration leads to better understanding of the quality and behavior of monitored environment and enables to make better decisions in various environmental applications and needs.

The proposed and described practical WSN implementation for environment data monitoring is very flexible, inexpensive and suitable for different environment applications which require and use simple battery powered SNs. It is very easy to increase number of SNs to a needed number, to program SNs for use of different sensors, and to program needed data aggregation and processing, depending on concrete application of the WSN. For such battery powered SNs it is recommended to use any possible energy source in the environment to charge the battery to extend the battery replacement period as well as periodical data transmission or on event occurrence. In this practical implementation it was used solar energy generated by the solar cells panel for charging battery. Appropriate methods for reduction of energy consumption in the sensor nodes and in the complete wireless sensor network are also used in the practical implementation, what is significantly reducing total energy consumption.

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