Application of Wireless Sensor Networks in Environmental Monitoring and Agriculture

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Abstract: Background and Aims. **The main aim of this study is to define the possibilities of wireless sensor networks application in agriculture and environmental monitoring in Macedonia, where agriculture is one of the crucial economy development facts. As the environment is basic condition for agriculture development, these two terms are strongly connected. Wireless sensor networks as one of the immerging technologies is fully applicable in those areas, because of cheap implementation and scalability. Environmental monitoring is very essential part of our existence as the world became dangerous place for living. The danger is very hard to be predicted but always the on time reaction can allay the consequences. In fact, in the past years the region of Balkan Peninsula including Macedonia was hit from huge fires resulted with destroying the flora and fauna in many National Parks, human life loss and large material loss. One of the reasons for this situation was the missing of on time information about locations, dimensions and environmental parameters in the fired areas. Also, the precise on time information is one of the key factors for improving agricultural production. Implementation of modern technologies in agriculture in order for its improvement is termed as "Precision Agriculture". As a conclusion, the wireless sensor networks are the future of modern agriculture and environmental monitoring issues.**

Keywords: **wireless sensor networks, precision agriculture, environmental monitoring.**

I. INTRODUCTION

In the past decade we were witnesses of the rapid progress and development in electronics and communication technologies.

This progress was especially experienced in mobile and wireless communication and embedded systems. The recent advances in MEMS technology and modern types of sensors, introduce us in our everlasting dream – ubiquitous, pervasive computing.

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Wireless local area networks (WLANS) are implemented almost everywhere, in our homes, workplaces, our cities and they are modern life reality. Also, the wireless personal area networks (WPANS), provide cable-less communication among devices such as personal computers, printers, PDA's etc.

One of the main reasons for recent progress in wireless communication was the extremely need for mobility. Today, we need freedom in our movements as we are conditional from different types of electronic devices which are tools for execution of daily working duties.

We can sure confirm those well known facts, but naturally one question is here present: What is the future? Where is the way of the next revolution in computing? The right answer of this question was given by the father of ubiquitous computing – Mark Weiser: "Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence". This citation make us to think in a way that next step in communication technology development will be focused in enabling communication abilities to all types of devices. The right term for this performance is "Everything Connected".

Very interesting and challenging field of communication networks – Wireless Sensor Networks (WSN) is rapidly coming of age. The emergence of Wireless Sensor Networks has enabled new classes of application that benefit a large number of areas including environmental monitoring, geology, agriculture, health, retail, military home and emergency management. Wireless Sensor Network is an infrastructure consisted of sensing, measuring, computing and communication elements that give us ability to instrument, observe and finally, react to the events and phenomena in specified environments. The environment can be physical world, biological system or an information technology framework.

There are four basic components in a Wireless Sensor Network: set of distributed and localized sensors, wireless interconnecting network, central point of information clustering and set of computing resources to handle data correlation and mining and event trending. The main technology trend is integration of all this components in single box called mote. On the Figure 1. is illustrated the main architecture of the typical sensing node. This architecture can be expanded by adding additional elements including location finding systems (GPS modules), actuators etc.

The mote includes sensors which are capable of sensing many types of information from the environment including temperature, light, humidity, radiation, the presence of biological organisms, geological features, seismic vibrations etc. These environmental information give us the real picture what happens around us and Wireless Sensor Networks are the right platform to obtain them.

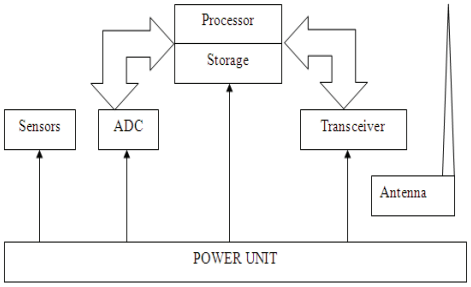

Fig. 1: Typical sensing node.

II. Possibilities for WSN Application in Environmental Monitoring.

Environmental monitoring is one of the crucial interests in many scientific, military and civil areas. The common for all is the need for on time and precise information about environmental parameters.

In this text, we are focused on possibilities of Wireless Sensor Networks applications in environment protection, especially in fire protection of National Parks in Macedonia. The main reason to think in this way is the fact that our region - Balkan Peninsula including Macedonia is often hit by fires in summer period, resulting with large material and nature loss. By the analysis and information provided by the local fire stations in Macedonia, we conclude that the biggest reason for late fire station reaction was the missing of information about locations and intensity of the fire in fired places.

Wireless Sensor Networks are the cheapest and the most effective solution for preventing these types of disasters. One of the fundamental concepts of Wireless Sensor Networks is cost-effective implementation. In fact, all of these problems can be solved by using traditional sensors, wired systems or standard wireless protocols, but the solution will be extremely expensive. Wireless Sensor Networks design is based on using low-power and cheap elements, which can be deployed with high density over the area of interest. Some informal sources says that in Macedonia in the past years the material loss from fires was about 70-80 million Euros. This amount is more than enough to cover the main National Parks with multi-modal wireless sensing motes, which are capable to detect, localize and alarm presence of fire in critical areas. These motes are small-size and cost-effective. Current sensor systems based on Bluetooth technology cost about 10$, but Bluetooth is very limited as a transmission technology in terms of bandwidth and distance.

On Figure 2. is shown the miniature sensor mote – MacroMote, developed at UC-Berkeley (Courtesy of UC-Berkeley). The size of the mote is approximately size of one coin.

The first fundamental concept of Wireless Sensor Networks is the self-organization capability and system scalability. For Wireless Sensor Networks to become truly ubiquitous a number of challenges must be overcome [1]: limited functional capabilities, including problems of size, power factors, node costs, environmental factors, transmission channel factors, topology management complexity and node distribution, standards versus proprietary solutions, and scalability.

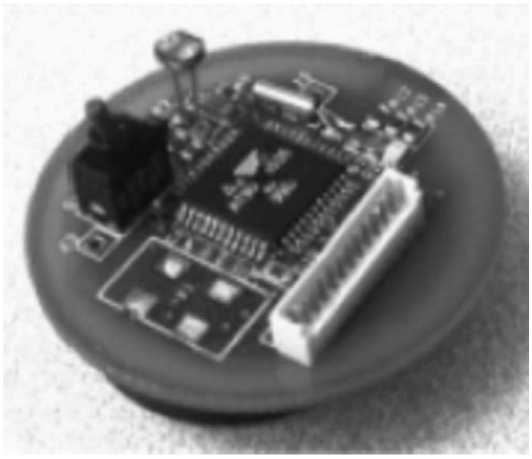
Fig. 2: Berkeley MacroMote

All of these elements must be taken in advance before we start thinking about the system's design. When we think about high distributed and high dense implementation of Wireless Sensor Networks over a critical wooden forest, the first question is how many types of sensors we need for effective fire detection? This question has physical nature and it is strongly connected with the fire phenomena. There are few sensible products of the fire presence: smoke (CO), increased air and soil temperature, light, and decreased humidity. For high reliable and stable system all of these factors should be taken. The presence of all of these elements with defined values, which depends from environmental conditions, can be adequate reason to think about fire presence. Also the system can be extended with low-resolution imagers for taking the image from the critical area.

One of the main constraints about Wireless Sensors Networks is power consumption issue. The sensor node lifetime is in strong dependency with battery life. Distributed wireless sensor nodes have limited power sources based on AA alkaline cells or Li-AA cells. Replenishment of power source in many cases is almost impossible. The function of as sensor node in the observed sensor field is to detect defined events, perform local data processing and then transmit raw or processed data. Therefore power consumption issue can be allocated in three functional domains: sensing, communication and data processing each of which requires optimization.

Deploying and managing high number of nodes, in example for fire detection purposes 100-200 nodes/km^2, requires special techniques. Beside that many wireless protocols are designed to have ad hoc capabilities, they are not suitable for using in the field of Wireless Sensor Networks. As we said in above text, Bluetooth technology is very limited for using as transmission technology in bandwidth and distance boundaries. Sensor nodes based on Bluetooth are still expensive if we assume that we design high distributed and high dense network.

The IEEE 802.15.4 standard has been adopted by the ZigBee Alliance for wireless personal area network

technology. The alliance is association of hundreds of members around the world, working together to enable a reliable and cost-effective networking of wireless devices for monitoring and control, based on an open global standard. There are three categories of logical devices in the ZigBee standard: Network Coordinator (FFD – Full Function Device), Router (FFD) and End Device (RFD - Reduced Function Device). The network coordinator is responsible for network parameters and configuration, router for linking the different components, and the end device contains just enough functionality to communicate with its parent node: router or coordinator. In the fire detection WSN application one of the most important issue is the network topology. Based on the logical devices defined in ZigBee protocol, the network topology can be organized in one of three possible topologies: star, mesh (peer-to-peer), and cluster three. On Figure 3. these types of topologies are illustrated.

The star network topology is organized with single coordinator and support up to 65.536 devices. This topology is useful when the wireless sensor network is distributed in small distance area. In the case of fire detection application this topology will be not applicable because we expect to cover bigger wooden forest area. For this purpose the ideal will be mesh or cluster-tree topology. The mesh configuration implemented in the fire detection system will allow path formations from any source device to any destination device.

In example if the area of interest is about 10 km^2, we expect implementation of thousands sensor nodes. One of the main principles in this design is to realize capabilities for communication among all of the nodes in the network.

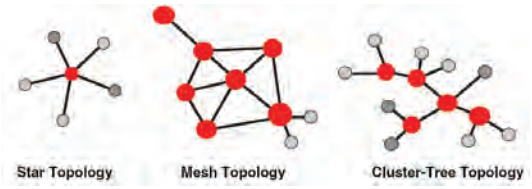

Fig. 3: ZigBee Network Topologies

The main interests are physical parameters: temperature, smoke presence (CO), humidity and light intensity, or more precisely changes in their values. All of the sensors nodes (end RFD devices) should alarm the parent FFD device (router or coordinator) about significant changes in the values of parameters. The algorithm for making decision for fire presence alarming, is based on the predict that if a sensor node registered rapid changing or increasing temperature and CO presence, and light, but decreasing humidity the panic procedure should be activated. The panic procedure should request parameter comparing among the sensor nodes. FFD devices in this situation are collectors of data about parameter's conditions in the end devices that they cover. Also additional devices equipped with low-resolution cameras needs to be activated to get real-time images of the critical area. Special software applications are needed for processing the data and final decision making. Thru the ZigBee gateways information can be send to the fire station servers where fire alarm will be realized. The system in the fire station will provide information to fire station staff about location and intensity of the fire. Localization can be realized by GPS systems integration in the sensor nodes. Sure this will increase the power consumption, but GPS system can be implemented in few sensor nodes that we will equip with additional power sources and alternative - renewable power sources. Then with implementation of localizing algorithms the localization can be achieved.

Wireless Sensor Networks in the area of environmental monitoring today are unique solution which provides cheap implementation and scalability. Self-organization capability of the Wireless Sensor Networks is one of the crucial techniques which promising explosive development and innovations in the new network technologies. Expanding the network with new motes (nodes) is allowed by not changing the network topology and system's architecture.

II. Possibilities for WSN Applications in Precision Agriculture

In the past few years new trends have emerged in agricultural sector. Thanks to development in the field of Wireless Sensor Networks as well as miniaturization of the sensor boards, precision agriculture started emerging. Precision agriculture is focused on providing the means for observing, assessing and controlling agricultural practices. It covers a wide range of agricultural concerns from daily guide management through horticulture to field crop production. Also precision agriculture today includes pre and post-production aspects of agricultural enterprises.

The main aspect of precision agriculture is focused on site-specific crop management. This includes different aspects such as monitoring soil, crop and climate in the field; generalizing the results to a complete parcel; providing decision support system for delivering insight into possible treatments.

Wireless Sensor Network is a promising data mining solution of precision agriculture. These technology implementations will provide real time monitor to the plants. The main physical parameters as air temperature, soil water content and nutrition concentrations will be very easy to gather and process with the final result – right treatment. The real time information of the fields will provide a solid base for farmers to adjust strategies at any time.

In the past few years, great attention was focused in smart irrigation systems. The main reason for that is the emerging need for water management and equally distributed soil moisture. Because the current wired systems, integrated in the field to provide information about these parameters, are very expensive, wireless sensor networks are completely ideal solution for this purpose. Implementations of wireless sensor networks in agriculture will make the modern farming completely different than current trend. Even there are some precision agriculture systems based on current wired and wireless technologies, the farmers are still in doubt about that is right investment. The cost price is the main reason for that skepticism.

Wireless sensor network are just on of the main parts in precision agriculture systems. The concept of precision agriculture is implementation of technology that will provide

help in decision making. Precision agriculture is not only monitoring oriented. In the following text we will explain how we understand the ideal precision agriculture system: wireless sensors nodes highly distributed in the field and central data processing point where all information gathered from sensor motes are processed. This should include special designed software which should inform the farmer about the critical agricultural parameters and with integrated algorithms for best productivity to advice the farmer about next strategy which will be increase the productivity of the field. In the development of this system agriculture scientists, information technology scientists and chemistry scientist should be consulted.

In our interviews with farmers in our region about their strategies for productivity we realized that they have habitat actions in the different period in the year, without any research about the need for that action. This situation makes them to waste money and resources for unnecessary activities. Sometimes they are not sure about the need for watering which goes to non- effective water management. Wireless sensor motes buried in different depth in the soil will provide real image about soil moisture. Based on those information and dependent from the culture in the field computer should advise the farmer about the need for watering. Also the possibility for farmer's system connection with weather forecast stations will improve the water management. If the data gathered from weather station indicate that next day will rain, the soil moisture and soil chemical structure is expected to be changed. In this situation the system should advise the farmer about the next actions for best results.

Information about individual conditions can be networked with global systems of organizations which care about country's and world's agriculture strategy.

Wireless sensor network will change our life style. With this development speed and possibilities for application almost everywhere, this technology is very attractive for research. We encourage, especially the technical universities in our region, to include this technology in their syllabus.

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