Deployment of a WSN Testbed for an Emergency Scenario

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Abstract — Wireless sensor networks are one of the most rapidly developing technologies with a wide range of applications. The functionality and behavior of the sensor networks are often investigated through a testbed setup. The testbeds are used for a proof of concept and for exploiting the possibilities of the technology. This paper presents elaboration of the testbed foreseen for emergency/disaster recovery scenario based on wireless sensor networks.

***Keywords* — applications, RFID, testbed, usage scenario, wireless sensor networks**

I. INTRODUCTION

WIRELESS sensor networks (WSNs) are a new, fertile technology and a hot topic within the network research community. Variety of possible applications makes them attractive for research and deployment, such as telemedicine, environmental monitoring, home applications and control, security and surveillance, traffic monitoring and agricultural applications [1]. The integration of WSN with RFID (Radio Frequency Identification) and their deployment into a global IT and communication systems, makes these technologies building blocks for the future Internet of Things [2, 3].

WSNs are aggregates of sensor and sink nodes into sophisticated sensing, computational and communication infrastructures. A typical network configuration consists of many tiny, battery-powered *sensors* working unattended and transmitting their observation values to some processing or control center, the so-called *sink* node, which serves as a user interface. Taking into account that the sensor nodes have limited energy and processing capability, it is a challenging issue to design protocols and models for these networks, especially if there is a requirement for practical implementation.

Even the sensor networks are usually composed of numerous static nodes spread randomly in a certain area, mobility of the nodes (sensors or sinks) can be introduced to reflect numerous real scenarios and to provide performances improvement (e.g. coverage, detection time, connectivity, energy consumption or network lifetime) [4-7].

Laboratories that are concerned in WSN research use testbeds as a platform to develop new concepts, including algorithms, protocols and applications. Testbeds (accomplishing hardware and software requirements) allow for rigorous, transparent and replicable testing of scientific theories, computational tools, and other new technologies [8].

Institute of Telecommunication at FEEIT (Faculty of Electrical Engineering and Information Technologies) – Skopje, Macedonia, aims to build a WSN testbed to develop emergency/disaster recovery applications. The plan for the testbed setup consists of two phases. In the first phase, the testbed will be implemented in the FEEIT's premises for an indoor scenario; while at the second phase it will be used for the outdoor settings. The planned testbed will additionally apply RFID system for the selected application realization. The objective is to employ the benefits of the technologies with practical testbed setup and initiating specific and novel research in the area.

This paper will refer to the practical aspects before the actual testbed deployment, meaning elaboration of the usage scenario that would be implemented by the testbed and selection of appropriate hardware and software resources.

The paper is organized as follows. Section II briefly presents the state-in-the-art in WSNs. Section III describes the usage scenarios for WSN implementation at the FEEIT's premises. The last Section IV concludes the paper presenting the future work towards the testbed deployment.

II. STATE-OF-THE-ART IN WSN RESEARCH

The importance of WSNs is highlighted by a number of initiated research projects, established laboratories worldwide and the range of possible applications. This section presents the state-of-the-art in WSN research topics and projects, providing short introduction of the different WSN equipment.

Sensor networks attract interest of international research community and are supported by European Framework Programs (FP6, FP7), NATO, US NSF, DARPA, etc. Among the biggest ongoing projects can be enumerated the FP7 SENSEI [9] and the NSF projects in the Network

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Research Lab at UCLA [10].

Topics that are of highest interest among research community concern issues like energy efficiency, routing and MAC (Medium Access Control) protocols, node's localization and self-configuration, cooperative communication and mobility [11]. Considering mobility as an important issue in the current network concepts, reference [5] provides good overview and classification of the mobility models.

Many commercially products are available on the market: Lynx technologies, various ZigBee and Bluetooth kits, as well as Java supported nodes. The most important WSN equipment relevant for the testbed setup includes Crossbow Berkeley Motes [12], Sun SPOTs (Small Programmable Object Technology) [13], BTnodes [14], SHIMMER [15], Sensinode [16] and Sentilla [17]. It is out of scope for the paper to gain more into technical characteristic of the specific nodes, and more information can be found in the provided references.

III. Usage Scenario

We are witnessing the time in which emergency situations, such as natural disasters, fires, floods and earthquakes take human lives daily and cause enormous financial damages. That is the motivation why a number of WSN applications, which refer to the issue of human lives protection, health and property of the citizens under emergency situations, can be employed.

Our goal is to make a solution for WSN implementation and a testbed for this purpose. The testbed will focus on three main usage scenarios: for fire detection, earthquake detection and usage of RFID for disaster recovery and for making the FEEITs' premises "smart building". The three scenarios are chosen to show the duality of the concept to have a system for emergency situations and a separate system that will function under "normal" circumstances ("smart building" solution) [18].

The design of such testbed would provide flexible and low-cost sensing mechanism, which is expected to reduce eventual casualties. The system will be used to monitor the key environmental variables (temperature, light, humidity, vibration, etc.), to provide accurate and fast information in a case of emergency and to help for fast discovery of eventual victims. Also the RFID system will make the premises "smart building" (additionally allowing the professors presents to be announced in the monitor to prevent their unnecessary disturbance).

The following subsection A presents the common scenario for WSN and RFID implementation at the FEET's premises and the scenario synopsis is given in the subsection B. The subsection C gives hardware and software requirements for the usage scenario implementation. The last subsection D explains the testbed setup presenting some possible drawbacks.

A. *General scenario for emergency/disaster recovery*

Figure 1 depicts the plan for wireless sensor network implementation within the Telecommunication institute's premises. The whole system consists of: 19 wireless modules, 2 gateways, 4 WiFi compatible wireless cameras, 2 servers (PCs), 2 RFID readers, 1 monitor (connected to the server at the entrance of the institute), dialing system and alarm device (with loud-speaker and alarm light). All of the premises are equipped with at least one wireless sensor module, every one with temperature and vibration sensor and some of them with additional CO (carbon monoxide) sensors.

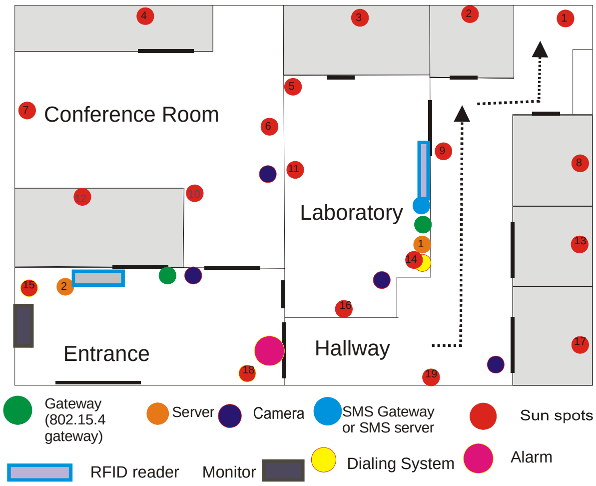

Fig. 1. Scheme of WSN and RFID implementation plan at the FEEIT's premises.

The gateways are located in the central positioned laboratory and at the entrance. This provides good clustering for energy saving and at the same time is a good way to provide back up in a case of a gateway failure.

The RFID readers are used to identify the employees according their badge holder IDs with an active RFID tag, to verify their presence and their relative location. That result is shown on the monitor. The wireless senor modules have a palette of onboard sensors (e.g., temperature, light, humidity and acceleration), which can detect a number of emergency situations, like fires and earthquakes. The WiFi compatible cameras are used to confirm the fire emergency situation, and also can be used for surveillance purposes.

The system is self-healing (because of the multi-hoping feature of the wireless nodes) and power independent. Larger components have their own alternate power supplies (batteries), and as a result the system can be on-line for a longer period of time.

B. *Scenario synopsis*

Scenario synopsis is presented in the following text. When a person enters the Institute's premises, the RFID reader at the entrance registers him/her (the RFID tag), and displays on the monitor that the person has arrived and is available/not available. When this person passes by the second RFID reader, his/hers tag is detected, thus, his location is now known (relatively).

If a case of an earthquake or fire detected by any one or any group of the sensors, the information has to be confirmed. If it is an earthquake, it has to be detected by no less than 3 most distant sensors. If a fire is detected, it has to be confirmed with the help of the WiFi cameras by an authorized person (guard).

In both cases, after the detection of the emergency, an alarm signal sounds off, the main power is turned off and the dialing device informs the people in charge and the emergency services about the situation. During the alarm, the whole system is still on-line (with the provided UPS - Uninterruptible Power Supply device), and the RFID readers count the people who are leaving the building. If one or more tags are detected in the building, in the alarm message sent to the emergency services the number of those tags is included like a possible casualty count.

C. Hardware and software requirements

Scenario description under A provides enumeration of the required hardware for its realization. We have chosen to use modules mainly from Sun Microsystems, since their characteristics are desirable for our research and educational needs. This subsection includes more detailed information for the Sun SPOTs (Fig. 2), as a selected sensor's platform and description of the SPOTs' hardware and software features [13].

Fig. 2. Sun SPOT

Sun SPOT's may be the easiest system to get up and running and to program. The basic characteristic which made Sun SPOT modules attractive is that they are fully Java capable which makes application development less complex than programming in for example TinyOS (used for Berkley motes). Sun SPOT is an open source platform based on Java VM (Virtual Machine) called "Squawk". The Squawk VM is a small JavaTM virtual machine written mostly in Java that runs without an operating system on a wireless sensor platform.

Each SPOT module consists of a battery, processor board and sensor board. The Table 1 presents its main features.

Regarding the programming part of the scenario, it will be based on J2ME and Java API for the Sun SPOTs. Base station application is also based on J2ME and Java API for the Sun SPOTs, while server application is J2SE compatible. Sun SPOT software includes an emulator capable of running Sun SPOT software just the way the physical Sun SPOT does – either for testing or when a real Sun SPOT is not available.

TABLE 1: SUN SPOT'S FEATURES.

Framework	Sun Java Squawk VM
Programming language	Java
Battery	720 mAh lithium-ion
CPU	180 MHz 32 bit ARM920T
Memory	512K RAM/4M Flash
Radio	2.4 GHz IEEE 802.15.4 compliant CC2420 transceiver
Embedded sensors	- 3-axis accelerometer - Temperature sensor - Light sensor - 8 three-colour LEDs - 2 momentary swiches - 6 analog inputs readable by an ADC - 5 general purpose I/O pins - 4 high current output pins

SPOTs have several disadvantages that can product drawbacks. First of all, some practical measurements show that the transmission range of the SPOTs cannot be more than 15m indoors. This can cause some problems taking into account walls between premises. Then, SPOTs exploit a lot of battery for communication which makes them unsuitable for larger deployments and outdoor scenarios. Another problem is that the embedded sensors are not accurate enough, so for the precise results some additional sensors might be required.

Being aware of the fact that there would be more problems for solving, the initial plan is to obtain more resources than needed, in order to be prepared for possibility of nodes failure or other hardware harms.

The FEEIT's team investigates possibilities for online environmental parameters monitoring. For that purpose, the team has initialized a creation of a web interface (http://prosense.00freeweb.com/), which is still under construction.

After the actual testebed setup, we plan to integrate it into the global sensor's platform – webDust [19]. It is a generic and modular application environment for developing applications for WSNs and for networks' monitoring on a Google map, developed at Research and Academic Computer Technology Institute (CTI) in Greece.

D. Testbed setup

This subsection presents the testbed setup, including brief explanation of the nodes' duty cycle, neighbors and routes discovery, with the last part referring to the network organization.

Sun SPOT nodes can be in three modes of operation: run, idle and deep-sleep. The nodes will be in sleep or idle mode a number of times longer than being awake, thus providing network increased lifetime through improved power efficiency. When sleep - the nodes can be awaken only from the smoke detector (in a case when higher level of smoke is detected) or when the time period for sleeping expires. When the node wakes up it floods beacons and with their acknowledgement learns for the other nodes that are awake and for the neighbor nodes. This is the way the node makes a routing table for how to transfer the information to the sink. This table is kept only when the mote is awake and is not changing during that time. More than 50% of the nodes will be awake at any time, thus providing accurate measurements and a proper detection of possible threats.

Testbed organization is planned to be as follows. The two SPOT gateways are connected via USB with the servers, and the servers are connected via Ethernet cable with WiFi routers/access points, to achieve a connection with the WiFi compatible cameras. The dialing system is connected to one of the servers, so that it can be reprogrammed remotely if it is necessary, and the alarm is connected to one of the SPOTs. One of the RFID readers is connected to one of the servers via Ethernet cable (WiFi router/access point), and the monitor is connected to the same server via standard monitor cable.

IV. Conclusion and Future Work

The paper provides elaboration of the WSN testbed that should be used as a platform to develop emergency/disaster recovery applications at the FEEIT's premises. There are plenty of other possible use cases, and therefore the research infrastructure is planned to be generic enough to enable their realization in the future. Furthermore, there are many possible sensors platform that can be used, but the equipment was chosen since it responds to the specific usage scenarios requirements, is handy for research and education and is presented in accordance with the constant market observation and current trends in WSN applications development. Possible drawbacks of the selection can be discussed after the concrete deployment.

The actual testbed setup is initiated with obtaining the specific equipment and followed by programming the nodes and connecting them into the integrated WSN network. The planed second phase of the testbed will be upgraded into the outdoor large scale setup.

The testbed will be used for validation of research results, developing novel concepts, and projects which can establish FEEIT as a potential "Region of knowledge".

Acknowledgment

This paper has been supported by the project ProSense (Promote, Mobilize, Reinforce and Integrate Wireless Sensor Networking Research and Researchers: Towards Pervasive Networking of WBS and the EU), EU-FP7-Cooperation/Support Action in the REGPOT-2007-3-01, March 1, 2008 – February 28, 2010 [20].

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