WSN based Railway Secure Transport

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Abstract – **The paper describes a demo platform which utilizes wireless sensor network for increasing the safety and comfort in the railway transport, particularly on the train. The platform is composed of several analog sensors (e.g. temperature, humidity and motion), Sun SPOT modules and various wireless transmision devices. GUI and web page are designed for real time and remote monitoring of the environmental conditions in the wagons. The characteristics environment for wireless data transfer requires specific and resistant solution (i.e. transceivers for the wireless transfer), and for that reason the demo platform implements varios wireless devices which are tested and compared. The measurement results for the delay and packet losses from these modems are analyzed and the most appropriate solutions for the practical demo realization are proposed.**

Keywords – **demo application, railway transport, wireless data transfer, WSN**

I. Introduction

WIRELESS sensor networks (WSNs) are collection of autonomous devices with computational, sensing and wireless communication capabilities. In the recent years the fields like environmental studies, medicine, agriculture, industry, military etc. have manifested a high level of distinctive trend for the support of complex processes with various sensor data. Some of the standard applications incorporate monitoring weather conditions and environmental contamination, ventilation inspection, as well as inspection of building's heating and cooling systems, reading electricity counters, gas or water consumption, then monitoring of the patient's vital functions, monitoring the traffic and drivers' behavior, etc.

This paper describes a WSN demo platform for providing safety and comfort in the railway traffic with attractive for wireless networking researchers mainly because of the specific environment for the data transfer. The environment is very noisy, full of interference and the train construction is made of steel that disturbs wireless data transfer. Lots of applications are developed, e.g. monitoring the bridges that are critical part of the railway infrastructure, then monitoring the wheels' temperature for preventing accidents as a result of malformations on the wheel profile, detection of trains' presence inside the tunnels, etc. Also there are some attempts for sensors' implementation on the train, i.e. inside the wagons in order to prevent accidents and provide appropriate control [1 - 4].

In most of these applications the transfer of the data to an acquisition center is over wire, mainly because that assures reliable data transfer in noisy environments. This was additional motivation for the demo platform - to find appropriate replacement of wired with wireless technology and at the same time to provide reliable data transfer in a scenario of WSN based railway secure transport.

The paper is organized as follows. Section II describes the envisioned scenario for providing comfort and safety in passengers and fright train wagons. The realized system configuration is decribed in Section III and the software part of the application is presented in Section IV. The performed measurements in experimental conditions are presented in Section V and Section VI concludes the paper.

II. Scenario Description

The demo implementation conserns train control, i.e. passengers and fright train protection.

The usage scenario for providing comfort and safety in passengers' trains foresees deployment of different sensors inside the wagons to monitor the passengers and the vital parameters for their comfort and safety. The idea of the system is monitoring and preventing emergency situations and deviant acts from other passengers inside the railway cars. Various analog sensors are implemented inside the train. The sensor system includes sensors for monitoring environmental

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parameters like temperature, humidity or light (for inspection of heating and cooling system, automatic control of lights, preventing possible fire, etc.), as well as for measuring high-level sounds (for preventing deviant acts).

In the freight trains, sensors are implemented inside the containers for monitoring the freight and the containers condition, thus providing effective and in time prevention activities. The goal is to prevent the freight cars to be damaged. Different sensors measuring temperature, humidity, light, acceleration, etc. are deployed inside the container; they monitor the specific parameters predefined for the proper transport of the particular shipment, and prevent transport irregularities causing shipment damages.

The collected data from the sensors positioned in the wagons (in both scenarios) is processed and transferred wirelessly to the acquisition center. This center can be placed inside the train (in a locomotive cab for example), or outside the train. The data is stored in a data base from where the results are extracted and presented on a Graphical User Interface (GUI). The GUI displays the sensor results and also appropriate messages if some actions need to be taken (e.g., turn on the light).

The following section describes the system configuration, while the application is described in Section IV.

III. System Configuration

The system architecture comprises two main parts: a wireless sensor network and data acquisition network (see Fug. 1). The sensor network is implemented inside the wagons and is consisted of different analog sensors and Sun SPOT modules. The acquisition network serves to transfer the collected data from the WSN to a remote data base. The acquisition center can be placed inside the train (e.g. in a locomotive cab), near the train or in a distant database.

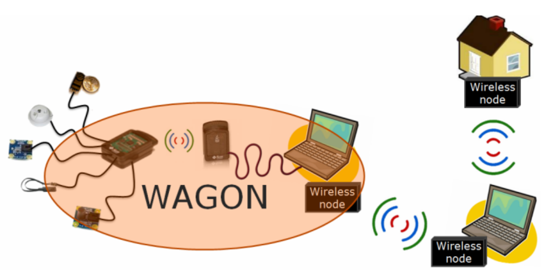

Fig. 1. System architecture

The wireless sensor unit (Sun SPOT) connects various analog sensors which sense different parameters and transmits the gained values to the Base Station (BS). The BS collects the sensor data into a local host, which retransmits them through an attached wireless device to the distant machine. The various analog sensors of interest are temperature, humidity, smoke, motion, light and sound. These sensors give analog values related to the measured phenomenon, which are then collected by the Sun SPOTs, A/D converted and sent over ZigBee to the Sun SPOT BS.

The acquisition part is composed of wireless transmission devices which are used to transfer the sensor data. These devices are a replacement of the traditional wired RS-232 connections, and are considered in order to obtain more flexible solutions and to achieve the possibility for transferring the gained data outside the train. To achieve this goal, 3 different wireless modems are tested and used: HPS120 (which works on Bluetooth), XBee-PRO rf modems (ZigBee) and Avisaro (WLAN) [5, 6, 7]. The delay and the packet losses of each device are measured and compared (see Section V) in order to evaluate the performances of the different devices/technologies.

After the description of the system configuration, the following section elaborates the application with the software parts for its realization.

IV. Software Applications

According to the presented system architecture, appropriate software applications are developed and integrated into a joint application. The software platform is JAVA and the two main parts of the scenario are the sensor nodes' algorithms and the JAVA host applications.

A. Sensor node algorithms

Sun SPOTs are small, programmable objects which support JAVA programming language. In the proposed system, the Sun SPOTs are used to collect the sensor data from different analog sensors and to transfer them to the BS. The analog sensors are connected to the analog Sun SPOT's pins where with appropriate algorithm that information is extracted, represented in appropriate manner and then sent over ZigBee.

The data from the sensors needs to be calibrated first, since the Sun SPOTs receive it as a voltage level between 0 and 1024. Thus, the algorithms for the Sun SPOTs are developed for extraction, calibration and combination of the data from the analog sensors. Different values' thresholds are defined and when some of the thresholds are exceeded proper messages are sent and displayed on the GUI and different activates are undertaken for increasing the comfort and the safety in the wagons.

B. JAVA host applications

The function of the host applications is to enable, or open the PC's serial ports for sending/receiving data over them through different wireless devices attached to the serial RS-232 port. The same applications are used for the delay measurements. For this purpose the applications comprise a part which adds time stamps on the end of the sent and the received data stream.

Host applications are used on the server's side for enabling the serial port to receive data strings. One of the modems is connected on server's side for receiving the data which is then stored in MySQL data base. The results are represented on a GUI which is visable on a web page. The results from the GUI can be monitored from the locomotive driver, as well from a remote control center. Beside the current value of each sensor, the GUI displays messages when some actions need to be taken.

V. Measurements and Results

This section presents the measurements for the delay and packet losses probability of the different devices/technologies used for the wireless data transfer.

A. Delay measurements

Two JAVA host applications are used on two distanced PCs to perform the delay measurements. Each PC is connected with a wireless modem and a host application is started on each machine. The first PC resends the data stream received from the Sun SPOT BS after adding a time stamp at the end of the string. The second PC after receiving the string forwards it to the first PC, where a new time stamp is added. The described method is depicted in Fig. 2.

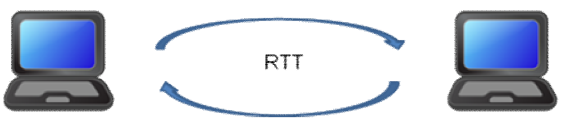

Fig. 2. Method for delay measurement in the wireless data transfer

Absolute value of the difference between the two time values, or the RTT (Round Trip Time), divided with two presents the approximate time delay, equation (1).

$$Delay = \left| \frac{RTT}{2} \right| \tag{1}$$

B. Packet losses probability

The packet losses are calculated with the same applications. The coefficient of packet losses is computed in percents [%] and is calculated with the equation (2)

$$Packet_{losses} = \left(1 - \frac{received}{sent} \right) * 100 \tag{2}$$

where *received/sent* refers to the number of successfully received and sent packets respectively.

C. Experimental results

The delay measurements are performed on an application level, where the values presented in the following graphs contain the processing delay inducted from the two PCs. The values are obtained with a sequence of measurements, where the delay is calculated as an average value of the gained results.

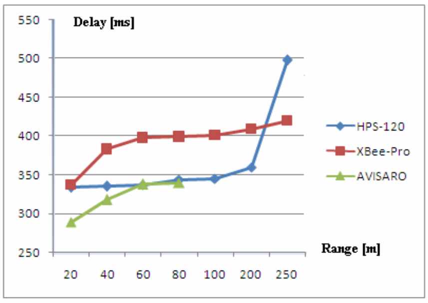

Fig. 3. Results for delay in still state

Fig. 3 presents the results of the measured delay in still state in Line Of Sight (LOS) conditions. The measurements depict how the delay depends of the distance and the type of the RF modems.

The graphs show that Avisaro (WLAN) has the smallest delay, but also has the shortest data transfer range. HPS120 and XBee-PRO have similar characteristics for shorter ranges, but HPS120 has extremely bigger delay for a range over 200 meters.

The measurements were also performed in a moving state and on distance of about 80 meters (by using a car). The results of the delay dependence of the vehicle speed with different devices are presented in Fig. 4.

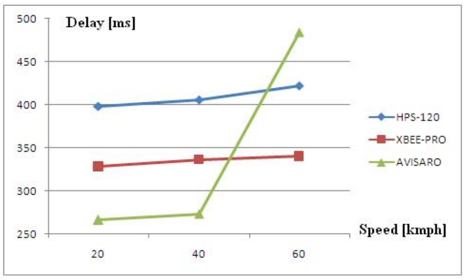

Fig. 4. Results for delay in moving state

These results show similar features with the previous ones (which were made in still state). HPS120 and XBee-PRO have linear characteristic for different speeds, but XBee-PRO has smaller delay. Avisaro gives the smallest delay for speeds up to 40 kmph, but for higher speeds it gives an extreme delay.

Table 1 presents results for the packet losses calculated in a still state. HPS 120 and XBee-PRO do not have any packet loses for ranges up to 200 meters, but for the higher ranges they have similar values. Avisaro has short range of coverage and for example in a range of 100 meters has 100% packet loses.

Table 1: Packet losses calculated in still state

Modems	***HPS 120***	***XBee-PRO***	***Avisaro***
Distance [m]	***Still***		
	Packet lost [%]	***Packet lost [%]***	***Packet lost [%]***
20	0	0	0
40	0	0	0
60	0	0	0
80	0	0	94
100	0	0	/
200	20	23	/
250	73	79	/

The results show that a combination of these devices can provide desired performances: for the wireless data transfer inside the train (from the wagons to the locomotive cab), Xbee-PRO can be the most suitable solution because of the longest ranges it can achieve; the data transfer from the acquisition center in the train to some ground station can be performed with Avisaro, since the train can spend only a short time passing through the station and the data should be sent quickly and with a smalest delay (here we assume that the train will approach the station with a speed smaler than 40 kmph).

VI. Conclusion

The paper elaborates on the developed demo platform for WSN secure based railway transport. To complete the scenario realization, testing the equipment in more realistic circumstances needs to be performed. Therefore, the different wireless replacements for the RS-232 modems should be compared in order to derive realistic perception of the technology which is the most appropriate in the specific environment.

The experimental results in non-real environmental conditions show that Xbee-PRO is appropriate for transferring the sensor data to the data center in the locomotive cab, while Avisaro can be used to transfer the data to an acguisition center placed out of the train.

Further evaluation of the demo platform requires measurements and testing on a real train and under real circumstances.

Acknowledgment

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