# Application of Wireless Sensor Networks to the Automobile

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***Abstract* — Some applications of Wireless sensor networks (WSNs) to the automobile are identified, and the use of MICAz motes operating at 2.4GHz is considered together with TinyOS support. These WSNs are being conceived in order to measure, process and supply to the user diverse types of information during an automobile journey. Examples are acceleration and fuel consumption, identification of incorrect tire pressure, verification of illumination, and evaluation of the vital signals of the driver. A survey on WSNs concepts is presented, and the wireless sensor network itself (transmitter/receiver/control board) is developed. Aspects of the definition of the architecture and the choice/implementation of the protocols are identified. Security aspects are also addressed, and solutions are proposed.**

## I. INTRODUCTION

Nowadays, in the context of Computer, Electromechanical or Telecommunications Engineering, one of the fields with the strongest expansion is the one of Wireless Sensor Networks (WSNs), with several applications in industry, atmosphere monitoring, and defence, among others. Besides instrumentation concepts, WSNs involve aspects of wireless communications, and of networks architectures and protocols. WSN is a term used to describe an emerging class of embedded communication products that provide redundant, fault-tolerant wireless connections between sensors, actuators and controllers.

Due to technological innovations in the area of wireless communications, digital electronics, and personal micro-electromechanical systems a revolution is occurring in the area of measurement with remote wireless sensors [1]. In particular, WSNs are characterised by a high amount of sensor nodes with multi-hop communication capabilities. These tiny sensors can be spread inside the environment to be monitored or close to it, and, differently from traditional sensor networks, the positions of each node are not pre-determined. Indeed, they are set randomly as wireless sensors can be dropped onto places with difficult access from helicopters or airplanes [2], Fig. 1.

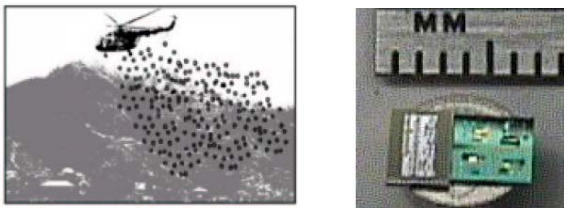


Fig. 1. Deployment of a Wireless Sensor Network from a helicopter, and example of the typical dimensions of sensors.

The application of wireless sensors networks to the automobile constitutes a challenge and was faced as an endeavour; we conceived a wireless sensor system capable to collect, process and supply several types of technical information (to the user) during an automobile journey. Examples are acceleration and fuel consumption, identification of wrong tire pressure values, acknowledgment of illumination failures (turn lights, brake lights, front lights, and registers plate lights), and determination of the vital signals of the driver. We chose Crossbow MICAz sensors operating at 2.4GHz (IEEE 802.15.4), and supported by TinyOS. The concepts and the wireless sensor network itself (transmitter/receiver/ interface board) are explained, and aspects of the architecture, and of the implementation of the protocols itself are established. Security aspects are also addressed, and the power consumption issues are discussed.

In Section II some characteristics and applications used in industry, security services, and military environment are discussed. In Section III routing protocols are briefly discussed, security aspects are presented, and security imperfections are identified. Besides, energy consumption issues are addressed. Section IV presents the various components, e.g., flow, tire pressure, light, acceleration, temperature, heart beat frequency, and blood pressure sensors. Finally, conclusions are presented in Section V.

## II. CHARACTERISTICS AND APPLICATIONS

At the University of California, Berkeley, an open code operative system was developed for WSNs with the support of Intel, called TinyOS, which demands little memory (about 8 Kb). As an example of application for TinyOS, it is a worth noting that it is already being used by Crossbow to trace automobile parts in industrial environment [1].

### *A. Safety applications*

One of the applications sought for domestic use falls in the area of safety. The distribution of temperature and movement sensors, along the house allows the detection of fires and intrusions. Besides, it can supervise and control children's and elderly people's movements in the house [1].

### *B. Industrial applications*

WSNs can be designed and implemented by taking the specificities of each type of industry into account, and several applications can be identified in this framework. WSNs are capable to monitor the quality of the air, and the temperature of a building or on an oven. Besides, it controls the produced goods, the complex machinery set, and the conditions of the production system of a certain or a group of factories [1].

### C. Military applications

Nowadays, military applications of wireless sensors are quite common, mainly because it is difficult to deploy a communication infrastructure in the theatre of operation, e.g., battle field. The installation of a centralised infrastructure, apart from being time consuming, would become a vulnerable solution because the destruction of the central node would totally put an end to the entire network [1].

## III. Routing, Security and Energy Aspects

There are several protocols in the context of TinyOS. As an example the TinyOS Beaconing is a protocol used in Mica Motes wireless sensor nodes of the University of Berkeley, and operates within networks with restricted hardware [3]. The protocol periodically builds the Minimum Spanning Tree starting from the Base Station. The Base Station propagates the message (beacon call) that is spread through the network with the objective of creating the routing tree. As it is a simple and general protocol, its performance is lower than the one of protocols developed for specific applications.

In terms of security, spoofing is the attempt to change or repeat the direction of information by a malicious node [4]. As a consequence, the information may enter into a loop, and the information will never arrive to the sink, as it will continuously be routed through the same set of nodes, causing wasting energy (to send and to receive data).

TinySec is the TinyOS cryptography layer, and offers authenticity, integrity and confidence [4]. Actually, TinySec just offers the cryptography of symmetrical keys, and the secret key is distributed in the procedures of programming sensor nodes. The algorithm to produce messages can be any symmetrical one (that can be implemented in TinyOS).

In TinySec there are three operation modes: *SendMsgCRC*, *SendMsg*, *SendMsgEncryptAndAuth*; it can operate both in TOSSIM, in the MICA, and in the MICA2 platforms but, until the moment, it is not yet prepared to work with MICAz.

An architecture typically used in WSNs is the Mica Motes of Crossbow one [5]. Among its components, the one with the highest energy consumption is the flash memory. However, in spite of the high consumption of energy during the writing and reading cycles, the use of the memory flash is not essential for link maintenance in the constitution of a WSN.

Hence, from the essential hardware components needed, the transmitter is the largest energy consumer one. Even when it is in the sleeping or idle modes, the transmitter wastes energy.

## IV. Hardware Components

For the transmission and processing of the signals we have selected the MICAz ZigBee (MPR2400) from Crossbow. This module uses a ATMega 128L in order to collect the data from the network, and to program MICAz motes. Its communication range is aprox. 30m non-line-of-sight and aprox. 100m line-of-sight. The MIB510 interface board was connected to a computer by using the serial port, and the MICAz MTS310 sensor node was then used to connect the sensors that are not on the board via the Digi-Key H2163-ND connector, Fig. 2.

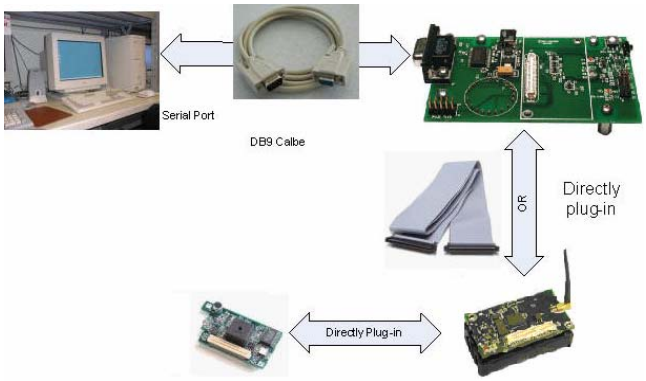


Fig. 2. MIB510 Interface board and related components.

### A. Flow sensor

We chose a flow sensor with the technical, economical, and weight specifications closest to the requirements. The choice was the RS 508-270, which allows to measuring a wide range of flows, from 0.05 to 10 [l/min]. However, its sensibility is not enough to measure small values of fuel flow as those involved in the low fuel consumption cars from Shell ECO-MARATHON, the scenario we used as an initial motivation to our work, i.e., ~0.0054 [l/min]. Even though, they are useful in the context of competition cars with higher fuel consumption flows, and we adopted this second view here. A scenario can be two or three cars of the same team, and a central node in the team box; each car can serve as a relay for the other nodes.

As the output of the flow sensor is proportional to frequency, we used the frequency to voltage converter LM2917N whose output varies 1 V for each variation of 67Hz in frequency. We had to select the *nodeId* related to the sensor of light because of TinyDB functioning, which uses the terminal from the sensor of light for data acquisition when MICAz is connected to the MTS310 sensorial board.

### B. Tires pressure sensor

The pressure sensor included in tire pressure reader *Sensor Monza 2 in 1*, is the one that was used. As the sensor does not have any identification it was not possible to find its datasheet. However, the sensor has four terminals, which indicates that its internal circuit should be a Wheatstone bridge. To have access to the output of this sensor it is thus necessary to measure the voltage in each of its four terminals, in two different cases: sensor reading the ambient pressure, and sensor under pressure (close to the limit is the ideal). We had to remove the pressure sensor from the *Monza 2 in 1* kit in order to connect it to the MICAz. To monitoring the pressure value we used TinyDB, and the sensor node

executes the *TinyDBApp* program, available in the directory /opt/tinyos-1.x/apps/TinyDBApp.

Fig. 3 represents the scheme of the amplifier used between the MICAz and the sensor.

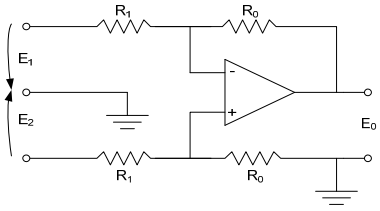


Fig. 3. Differential amplifier for the pressure sensor.

$E_0$ is the output voltage of the amplifier circuit, and is connected to the input of MICAz; $E_1$ is a reference voltage of 0.2 V, which is used to calibrate the sensor; $E_2$ is the voltage at the output of the pressure sensor; $R_1$=1500, and $R_0$=10kΩ.

### *C. Light Sensor*

To verify the state of the automobile lights, a light sensor has been used close to each lamp. In our case, we opted for the light sensor already included into the MTS310 sensorial board, Fig. 4. To collect data from this sensor, the mote is programmed with *OscilloscopRF* application, while being placed onto the zone to be monitored.

Another node running the *TosBase* application is placed on the interface board connected to the computer. The programming board is switched off while the nodes are switched on. To generate the executable files one has to type

cd /opt/tinyos-1.x/apps/OscilloscopeRF; make micaz

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To send the generated files to the motes, the *MoteConfig* executable file can be used, or alternatively the following command can be used

MIB510=/dev/ttyS0 make micaz install

To compile the Java directory one has to type

cd /opt/tinyos-1.x/tools/java;make

For every new session we need to select the frequency of the through the serial port connection (which is 57600 Hz for MICAz and MICA2, and 19200 Hz for MICA and MICA2DOT) by typing the following command line (example for 57600 Hz)

export MOTECOM=serial@COM1:57600

The received data can be easily visualised by typing:

java net.tinyos.oscope.oscilloscope

Then, we can watch lively the variation of the light brightness on the photo-voltaic sensor of the mote, Fig. 5, and it allows to knowing how the state of lamp is.

### *D. Acceleration sensor*

The acceleration sensor is incorporated into the MTS310 board of sensors. The signal acquisition is performed by using TinyDB but, as the *TinyDBApp* programme is very slow, in the future, this aspect should be improved.

### *E. Temperature sensor*

The temperature sensor should be installed in contact with the driver's body in order to monitor his/her temperature. As the sensorial board already has a built-in temperature sensor, it is considered that this sensor serves our initial objectives. The data of this sensor is read by TinyDB.

### *F. Heart frequency and arterial pressure*

The equipment selected to measure the heart frequency and the blood pressure (diastolic and systolic) is the prototype for testing and monitoring the biomedical signals developed in the Department of Computer Science of University of Beira Interior, by Prof. Pedro Araújo and his student Pedro Ussman, Fig. 6.

Fig. 4. Placement of the light sensor on MTS310.

Fig. 5. Graphical representation of the light intensity in the mote obtained by using the *OscilloscopeRF* application.

This prototype uses an inner tube that is placed under pressure. During its emptying process the pressure is measured through a sensor. This signal is amplified, Fig. 6, and sent to the computer that runs the software to interpret the signal while extracting the blood pressure and the heart beating frequency values.

The monitor of arterial pressure is formed by a motor that insufflates air into the inner tube, by a Metrodyn MPS-1001 pressure sensor, by an inductor, and escape valves for the inner tube (fast and slow ones). The connections from the circuit amplifier to the MICAz are the following:

- White wire - analogue signal of the absolute pressure, and it is connected to the terminal 42 of the MICAz;
- Green wire - analogue output signal of the relative pressure, and it is connected to the terminal 42 of another MICAz;

- Yellow/blue wire - digital output signal to turn the motor that inflate the arm brace on/off, and it is connected directly to a relay that is commanded by the terminal 9 of MICAz;
- White/blue wire - digital output signal that closes/opens the valve, and connects to the relay that is commanded by the terminal 10 of MICAz.

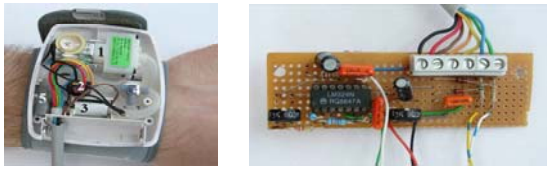

Fig. 6. Arterial pressure monitoring prototype placed at the human pulse, and circuit for signal amplification.

These processes were controlled by running the *SimpleLedCmd* application, followed by the execution of the following MICAz command

java net.tinyos.tools.BcastInject <parameter>

where the parameter can have the following values: *led_on* - closes the valve; *led_off* - opens the valve; *led_A_on* - activates the pump; *led_A_off* - turns the pump off.

TinyDB is a query processing system for extracting information from a network of TinyOS sensors. It is only necessary to specify the required data and the rate at which it should be collected and the TinyDB will perform all the necessary operations to pick up, aggregate and display the data on a PC.

In our work, TinyDB was used for reading data from external sensors attached to the sensorial board, e.g., from the flow meter, the tires pressure sensor, and the blood pressure sensor. In these cases, we used the Digi-Key H2163-ND connector. By consulting the datasheet of the sensorial board, it is possible to verify how internal sensors are connected, as well as to know how to read some information, Fig. 7. In this work, the option was to connect the external sensors to terminals 42 and 51 (Ground), corresponding to the light sensor in the sensorial board.

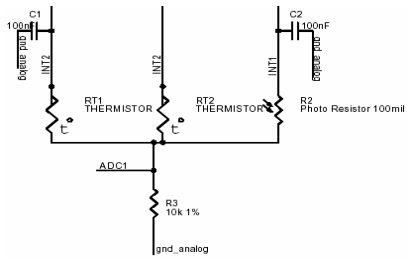


Fig. 7. Connections for temperature and light sensors [6].

## V. CONCLUSIONS

This work addressed the conception of a WSN capable of measuring, process and supply to the user diverse types of information during an automobile journey. Examples are acceleration and fuel consumption, identification of incorrect tire pressure, verification of illumination, and evaluation of the vital signals of the driver. Besides a survey on the concepts, the wireless sensor network itself (transmitter/ receiver/control board) was developed, and aspects of the architecture and protocols were addressed. Security aspects were also identified, and the difficulties and solutions were discussed. Competition cars in a controlled environment is a good scenario (for experimental work) but the evolutions in this field promise a lot in the automobile industry, e.g., for cooperation among cars for road safety purposes.

## ACKNOWLEDGMENTS

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