Application of ZigBee and Bluetooth to Urban Ambient Monitoring and Guidance

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Abstract - **This work focuses on development of a prototype for a Wireless Sensor Network (WSN) that monitors various environmental parameters of interest in urban areas based on ZigBee protocol. This through a small device that can be placed anywhere in a city. First it is studied the operation of ZigBee protocol. Second it was chosen and tested a ZigBee module and sensors from the market. Then it was developed a module that monitors: Humidity, Temperature, Light, Carbon Monoxide, Carbon Dioxide and Oxygen. These data are measured and sent periodically to a base station connected to a computer. These data are stored and processed for presentation on the Internet. Yet to demonstrate the capabilities of the network, each node is equipped with Bluetooth, so that passersby where the scope of the network with their actual cell-phone can get information of the environmental quality on that area like joggers, and also guide passerby like tourists.**

Keywords-component; ZigBee; Bluetooth; Sensors; Localization; Low power

I. INTRODUCTION

Given the growing interest on the population life quality, it's important to monitor environmental parameters, especially in urban areas. Currently, monitoring is done through large and expensive devices, which are not always connected to their control center and are in a small number for the coverage area. To connect ambient monitoring to a wireless network creates new possibilities [1]. Projects for wireless air monitoring have been developed in the last years e.g. [2]. Specially based on ZigBee technology due to its low power consumption and low cost [3]. This work purpose is to develop a complete prototype of a small node for WSN with high integration of sensors with low power consumption and low cost, and to give a step further on networks integration adding Bluetooth interface.

II. WIRELESS AMBIENT MONITORING SYSTEM

A. Sensors

Sensors where chosen from market, giving especially attention to the small size, low power and reasonably priced.

The CO2 sensor is the C20 solid-state sensor produced by Gas Sensing Solutions (GSS), which detects the concentration of CO2 by measuring absorption of infrared light [4]. This technology delivers high speed (startup of 2 s), sunlight immunity, accuracy and especially low power consumption (< 100mW). The C20 is a sensor provided in a complete module, fully factory calibrated, which already includes the processing of measured data (conversion and linearization), providing the measured value via UART.

The CO sensor used is the TGS5042 from Figaro. It is a battery operable electrochemical sensor that offers a current output that varies linearly with the CO concentration in air [5]. Manufacturer indicates the calibration data. To monitor CO, is necessary to convert sensor current output to voltage, and then can be read by the microcontroller ADC. Sensor offset correction and temperature compensation table is carried out by the microcontroller.

The Oxygen sensor is KE-25, a unique galvanic cell type oxygen sensor produced by Figaro [6]. The sensor does not require external power supply, but due to small scale of voltage it is used an OP-Amp to amplify the sensor output.

For temperature and humidity it is used the SHT15, which is a dual sensor in a single chip produced by Sensirion [7]. It is largely used on WSN due to its low power consumption and tiny size. It comes calibrated from factory, and gives a digital output. The interface is similar to I2C but not standard. So is needed to embed the protocol on the microcontroller program.

For light sensing it is used two photodiodes from Hamamatsu, S1087 and S1087-01 to measure Photosynthetic Active Radiation and Total Solar Radiation respectively [8]. Again due to small current output an OP-Amp circuit is used to convert the signal to a proportional voltage.

B. ZigBee

ZigBee technology, is vastly used on similar applications, since it has the characteristics suitable to route sensor readings periodically to a center base station wirelessly and still with low power consumption.

The variable dynamic topology (peer-to-peer, star, cluster-tree or mesh) [9] simplifies the placement of the nodes for ambient monitoring on an urban area.

For the ZigBee module the XBEE from DIGI is used since it works within the ZigBee protocol, it's low cost, low power and especially easy of use. The XBEE offers a simple UART interface to the application, being one of the main merits that the developer need not to be an expert in ZigBee technology and can therefore only work on the application.

The XBEE module is commercialized in two versions: XBEE OEM and XBEE PRO, differentiated specially by the sensitivity level and output level. They offer an indoor/urban RF range of up to 40m and 100m respectively. On-line of sight they can reach the 120m and 1,6km respectively [10].

To establish a ZigBee network, is necessary to program the XBEE's with the appropriate firmware and identify two type of ZigBee devices: the network controller – Coordinator; and the Routers/End Devices, since the difference between Routers and End Devices is made on to be always active for Routers and sleeping whenever not transmitting on End Devices. The hardware interface is completed with the connection of one digital I/O pin from the microcontroller to the XBEE sleep pin.

Since the nodes will be stationary on urban buildings it is proposed the cluster-tree topology as the best choice, since it is possible to define who will be the End Device and who will act as a router, requesting different power levels supply. The topology is showed in the system architecture on Fig. 1.

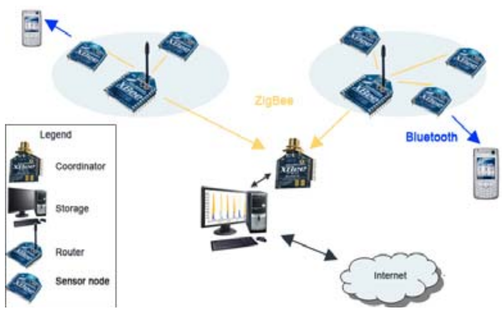

Figure 1. Wireless Ambient Monitoring System architecture

C. *Wireless sensor node prototype*

The wireless sensor board was developed using a small 8bit microcontroller, ATmega324 that is low power and low cost [11]. For the design was considered the power source, so was added a power circuitry consisting on DC-DC converters to simplify the limitations on power source voltage. The microcontroller controls the shutdown on the power circuitry for the CO_2 sensor since it does not have that feature. The node architecture is shown on Fig. 2. To complete the module, a small display, button and LED were added to provide direct access to module data. The assembled circuit is shown in Fig. 3.

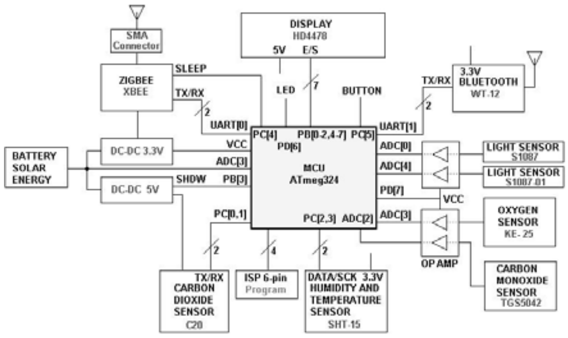

Figure 2. Wireless sensor node architecture

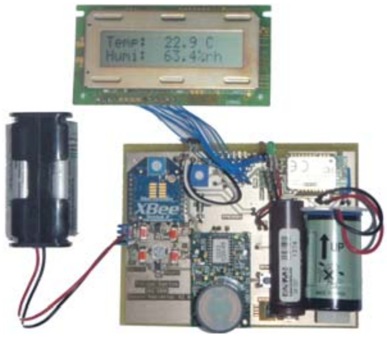

Figure 3. Wireless sensor prototype board

The wireless sensor node is programmed to acquire sensor data, wrap it in to a ZigBee message addressed to the coordinator and send it through the XBEE every minute. It also has registered the GPS position and street name for Bluetooth purpose.

D. *Bluetooth interface*

The wireless sensor node is equipped with Bluetooth module GIGA WT-11, that is a class 1 device, offering an RF range of up to 300 meters [12]. It exhibits small size, transparent functionality and low power consumption. The node is programmed to answer at Bluetooth requests, with node location (GPS coordinates), Street name and last measured sensor data.

A small Java ME application was developed for cell-phone since it is one of the most present languages on cell phones [13]. The application starts showing a preloaded map of the area, and begins to search for wireless sensor nodes. The first node found is inquired. And after data is received, the map is marked and centered on the position of the node, the sensors values and the street name are also presented. After 10 seconds starts searching and inquire again. Cell-phone interfaces are shown on Fig. 4.

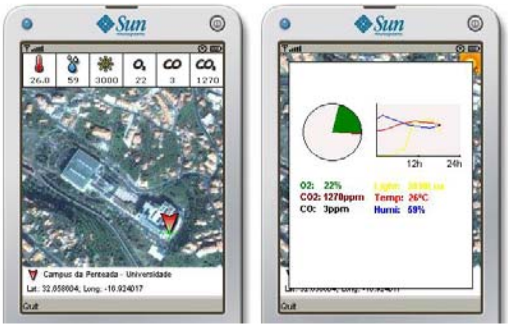

Figure 4. Cell-phone bluetooth application

A second module was built to test the Bluetooth application transition. The two wireless sensor modules were placed on a building wall with a distance of 100 meters. And tests were made walking between them with the cell-phone application running. The results showed that at normal walking speed the application changed from one node information to the other after some seconds (< 30s). But at higher speed's (like running) some times only one node was discovered.

E. Web Interface

The XBEE coordinator is connected to a central computer and receives each message sent from the End Devices. The computer has a small Java application always running to receive and store every message to a MySQL database. A web page was developed to show the ambient monitored parameters through Internet in real-time, using graphics for better perception, as it is shown in Fig. 5.

Figure 5. System web page interface

III. Results

The module was placed near a Window of the Laboratory of the university during the full month of July 2009.

Every sensor responds in general in correspondence to their description. The light sensor responds in accordance to light variance, as shown on the web page on Fig. 5.

Temperature and Humidity sensor exhibits good quality data, as shown on Fig. 6.

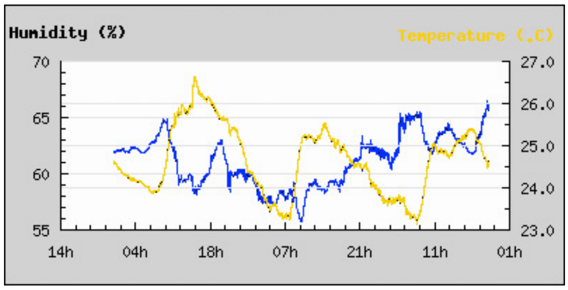

Figure 6. Temperature and humidity response for 3 days

O_2 sensor exhibits a stable line around 21%, and CO sensor only registers values above 10ppm, but responds fast with the proximity of a lighter, as shown on Fig. 7.

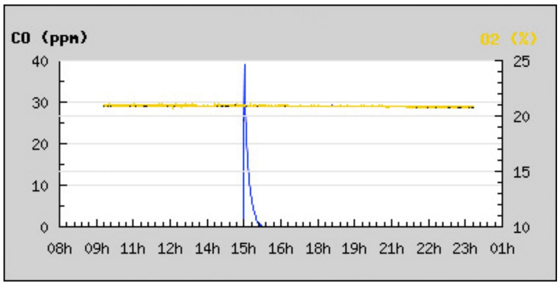

Figure 7. O_2 and CO sensor response for 1 day

For the CO_2 a low pass filter of 8 seconds was used but still on low level of Dioxide Carbon it responds noisy, as shown on Fig. 8. Is yet to be decided if the filter should be increased, since it will request more ON time, thus contributing to a major consumption.

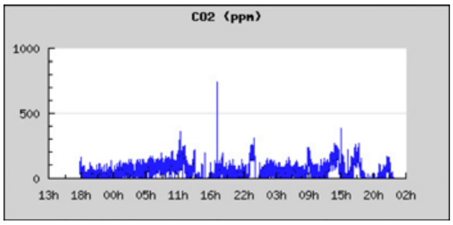

Figure 8. CO_2 sensor response for 2 days

One of the main goals was to obtain low power consumption. This was limited due to CO_2 sensor power requirements and continuous Bluetooth operation. Although with intelligent power management, putting to sleep every component when not needed, was possible to increase the duration of a pair of batteries (2xAA 2500mAh) from 22 hours when all components active to 7 full days, as showed on Fig. 9.

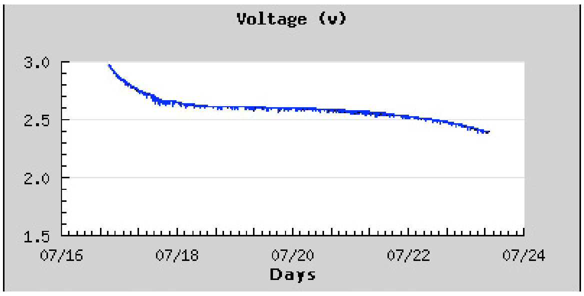

Figure 9. Battery voltage discharge

The size of the prototype is relative small, and can even be reduced. Having in mind the operational temperature and humidity range of every component, this prototype exhibits the specifications indicated on Tab. 1.

TABLE I. WIRELESS MODULE SPECIFICATIONS

Parameter	**Values**	
	Values	***Observation***
Current consumption	Avg. < 15mA Max. < 180mA	@ 2.6 V
Humidity Range	10% to 90%	Limited by O2 sensor
Temperature Range	5ºC to 40ºC	Limited by O2 sensor
Size	144 x 89 x 45mm	Including protection box
Input voltage	1.3 to 3.3V	

IV. CONCLUSION

This work describes implementation of a prototype for an urban ambient monitoring system. This work demonstrated that ZigBee technology combined with the current sensory technology, allows the creation of modules with a high level of integration of features, while being of low power consumption and small size.

It is demonstrated that using Bluetooth gives people instant access of important data. Therefore placing some of these modules in the city creates diverse possibilities of information to present to people. This work is a middle step to ubiquitous networks.

The project is still in development. Future work will be: Improve box impermeability; Build more modules to form an complete network and place them in urban area for test the network and sensors in the long term; Add solar panels to some of the nodes to become energy independent; And add system functionality to alter Bluetooth information, directly from central computer.

ACKNOWLEDGMENT (HEADING 5)

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