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 is performed 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 the Internet. 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 passersby 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. The connection of a ambient monitoring to a wireless network creates new possibilities [1]. Projects for wireless air monitoring have been developed in the last years [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. This integration can contribute for a better citizen’s life. For example, was proved that polluted areas with gases like CO decrease the athlete’s performance [4]. With this interface joggers can check on their phone the present air conditions, changing their route for less polluted areas. It is an opportunity to use the ZigBee network to transport small amounts of information to passersby. For example information of some event near the monitoring place.

II. WIRELESS AMBIENT MONITORING SYSTEM

In this section we will present the components that, with their characteristics, made the possibility to achieve our purposes of relatively small size and low power module for monitoring environmental parameters.

A. Sensors

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

The CO 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 [5]. 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 [6]. Manufacturer indicates the calibration data. To monitor CO, it 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 [7]. 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 [8]. It is a battery operable sensor that is 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 [9].
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) [10] 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 is 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 [11].

To establish a ZigBee network, it is necessary to program the XBEE’s with the appropriate firmware and identify two types of ZigBee devices: the network controller – Coordinator; and the Routers/End Devices, since the difference between Routers and End Devices is to be always active for Routers and sleeping whenever not transmitting for 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.

C. Wireless sensor node prototype

The wireless sensor board was developed using a small 8bit microcontroller, ATmega324 that is low power and low cost [12]. 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 CO2 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.

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 [13]. 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 [14]. 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 node position. The sensors values and the street name are also presented. After 10 seconds starts searching and inquire again. Cell-phone interfaces are shown in Fig. 4.
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.

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 Fig. 6. The light registers the luminance near a windows, and in a particular hour of the morning receives direct sunlight.
One of the main goals was to obtain low power consumption. This was limited due to the CO\(_2\) sensor power requirements and to 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 in Fig. 9.

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>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current consumption</td>
<td>Avg. &lt; 15mA</td>
<td>Max. &lt; 180mA</td>
</tr>
<tr>
<td></td>
<td>@ 2.6 V</td>
<td></td>
</tr>
<tr>
<td>Humidity Range</td>
<td>10% to 90%</td>
<td>Limited by O2 sensor</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>5ºC to 40ºC</td>
<td>Limited by O2 sensor</td>
</tr>
<tr>
<td>Size</td>
<td>144 x 89 x 45mm</td>
<td>Including protection box</td>
</tr>
<tr>
<td>Input voltage</td>
<td>1.3 to 3.3V</td>
<td></td>
</tr>
</tbody>
</table>

IV. CONCLUSION

This work describes the 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 to 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.

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REFERENCES

[12] ATmega324P, Datasheet, ATMEL.