Using WSN and Mobile Apps for Home and Office Ambient Monitoring and Control

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ABSTRACT
This paper presents a complex system (hardware and software) that is used to monitor and control some ambient parameters (temperature, humidity, light intensity, etc.). Monitoring parameters are temperature, humidity and light intensity. The system provides remote and automated control of local devices that can be used to assure the security or to increase the comfort indicator of the air.

Author Keywords
Sensors; air quality; monitoring; wireless communication; mobile applications.

ACM Classification Keywords
C.2.1. Computer-communication networks: Wireless communication.

General Terms
Experimentation.

INTRODUCTION
Wireless connectivity of more home appliances was a target for many years [10]. Temperature and light control for each room, status of the doors and windows and even monitoring of the domestic applications as washing machine, refrigerator and air conditioning provide many benefits to many home or office building owners [1]. Since the global trend is to build homes more economical in terms of energy, it eliminates the traditional heating, ventilation, lighting because the costs are very high. In new buildings such systems can be easily implemented at a low price given the low energy consumption of wireless sensors. One system based on standard 812.15.4 – ZigBee [9] can provide fire detection, security and access control as well as monitoring of environmental parameters. There are now security surveillance systems [2, 7], home automation [6], smart home systems [8] based on wireless sensors and ZigBee technologies. Some recent and important attention has been paid to Mobile Devices as terminal for users and some interesting applications have been developed [5, 9].

Even if there are over 10 years since the appearance of the wireless modules that allow networks of wireless sensors (Wireless Sensor Networks - WSN) the presented application tend to be innovative by extending mobility, surveillance and command being done through a dedicated application for mobile devices like a smartphone or tablet. It shows a connection of new software and hardware technologies, not older than a few years, thereby achieving a solution of the future supervisory and safety living or working spaces.

SYSTEM ARCHITECTURE
The presented system (see Figure 1) has two main features: displaying the information measured in real time and the possibility to control remotely multiple actuators in order to maintain the optimum intervals for the monitored parameters. The optimum intervals are related to low and high values for each measured parameter. Recent technological solutions are used for both hardware and software elements. As communication standards used there are: ZigBee, RS232, web protocols, for saving data a MySQL database was used and as mobile devices operating system Android was chosen.

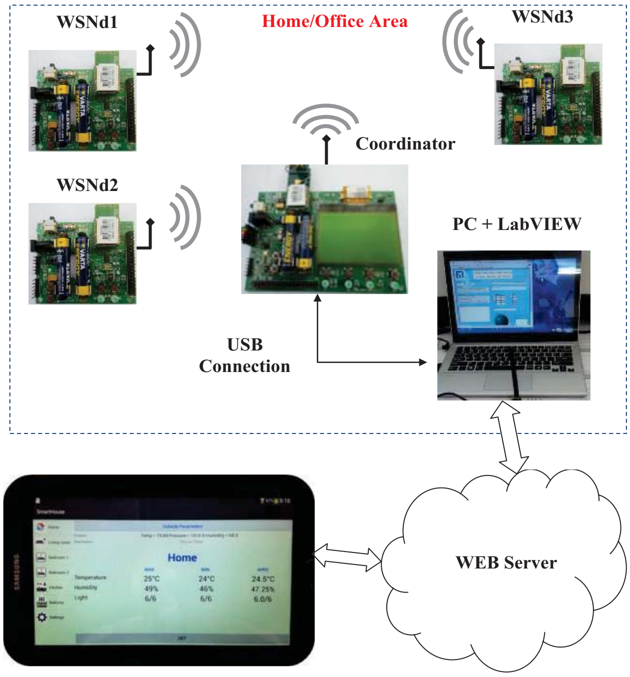

Figure 1. System architecture.

The values of monitored parameters are retrieved using wireless modules. These modules are arranged in space monitored at various points, without any restriction. They are powered by batteries that provide autonomy to several months. The information of all measurement nodes is centralized by another measurement node that acts as coordinator of the network. It allocates addresses to other modules and centralizes data. The data is sent from the coordinator node to a computer connected to the Internet using a USB-RS232 serial protocol. The data read from the measurement nodes is saved in a database that is located on a server. The data can then be accessed by mobile devices through a native Android applications, which in addition to displaying the current parameters also offers other functionality (text-to-speech, sending e-mail, command of physical devices, etc.).

HARDWARE RESOURCES

In order to obtain a physical system easy to design, program and that can allow quick re-dimension a series of modules which construction method is suitable for such applications were chosen. Being based on the ZigBee standard and containing all the elements necessary for measurement, analogue-to-digital conversion, acquisition and transmission of information, JN5148 family circuits are ideal for prototyping of wireless monitoring systems.

Wireless Modules

The presented system contains five measurement nodes but can be extended as required up to 256 nodes. All communication modules work on the same microcontroller (JN5148), small differences being due to attached peripherals [4]. From this point of view the system comprises a coordinator and four measurement nodes. Features of communication modules are:

- Compatibility with IEEE 802.15.4, ZigBee PRO JenNet and the 2.4GHz;
- Current consumption in standby mode (with timer active) 2.6µA;
- Up to 1km and 4km away from outdoor communication (depending on the antenna used);
- Current consumption in transmission: 15mA;
- Current consumption data reception: 17.5mA;
- Voltage: 2.3-3.6V.

Measurement Nodes

Figure 2 presents an image with a measurement node. This module is a stable platform that allows rapid application testing and development. Radio Frequency (RF) transceiver is on a smaller board which allows it to be moved on another board after programming. A measurement module has the following features:

- 2 configurable LEDs and an LED for checking power supply;
- 2 configurable push-buttons and 3 buttons with predefined functions (ON-OFF, RESET, PROGRAM);
- Temperature/Humidity sensor;
- Light sensor;
- Serial EEPROM Memory;
- Two UART interfaces (Universal Asynchronous Receiver / Transmitter) used for communication and for programming the circuit;
- A set of pins extension for addition of other sensors or actuators.

The Coordinator

This module is similar with the measurement node, with the addition of some components that allow easy interfacing with a human operator (Figure 3). These components are:

- 2 configurable LEDs (totally 4);
- 2 configurable push-buttons (totally 4);
- a 128x64 pixels LCD.

Sensors types

The proposed system is based on the use of three types of sensors: temperature, humidity and light intensity. The first two are integrated into a single physical circuit. The system can be improved by adding more types of sensors given the complexity of initial data acquisition interfaces.

Temperature and Humidity Sensor

Each monitoring module is equipped with a temperature and humidity sensor type SHT11 (Sensirion). This is a single-chip sensor for temperature and relative humidity. The conversion can be scheduled on 8, 12 or 14 bits, and the measurement range is between 0-100% humidity and 85°C and -40°C temperature.

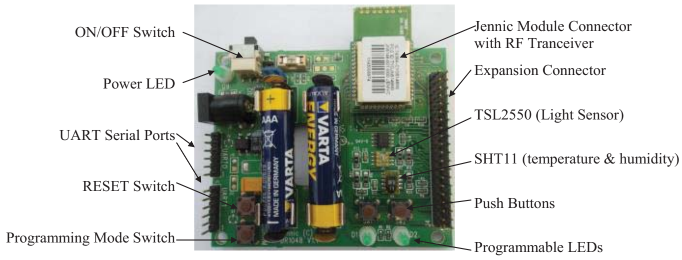

Figure 2. Measurement node.

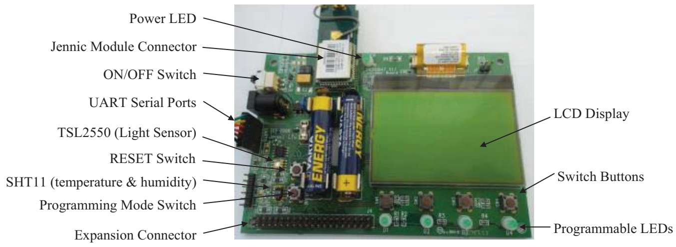

Figure 3. The WSN coordinator.

Light Intensity Sensor

The module contains a light intensity sensor type TSL2550. This is a digital sensor with a 2-wire SMBus serial interface. It combines two photodiodes and an AD converter into a single integrated circuit and can be used to determine a dynamic range of 12 bits for luminous intensity, which is very close to the human eye.

SOFTWARE TECHNOLOGIES

The software part of the system can be divided in four parts:

- wireless measurement nodes programming;

- interface between WSN and the database;
- server side services used for uploading, recording and providing measurement data;
- Android app used by user to interact with the system (this part will be presented in the next section).

Wireless measurement nodes programming

Eclipse IDE (Integrated Development Environment) with a Jennic SDK (Software Development Kit) was used to configure the wireless measurement nodes and the coordinator. The following steps are performed in order to establish the wireless communication protocol:

Initialization Protocol: physical levels and 802.15.4 MAC protocol must be initialized in each device on the network;

Network coordinator initialization: each network must have a fixed coordinator device. Initialization of the coordinator is the first step to take in the idea of building a WSN.

Set PAN identification and address: immediately after initialization coordinator chooses a unique identifier for the network. This identifier can be fixed before or coordinator can automatically choose an ID by "listening" to other networks in the neighborhood so as not to be the same identifier in two different networks. Scanning networks is made possible in several frequency bands. It is usually preferred choice of frequency bands and then only scans for other networks available that band which is selected by the ID.

Selecting the frequency band for transmission: coordinator must choose a frequency channel for communications within the network. This channel can be selected from a scan of Energy Detection. This scan determines which channel is "quietest" (has less traffic).

Starting the network: the network is turned on. Once it is initialized devices are expected to connect to the network.

Recording modules on the network: from the moment devices may require network connections. In order to connect to the network device must first be initialized after which it must find a coordinator. To find a coordinator, the device performs Active Channel Scan devices. This involves sending connection requests on all available frequency channels. When a coordinator receives such a request responds to signal the existence of a network channel.

Interface between WSN and the database

Wireless sensor network coordinator is connected to a computer using a PC USB serial interface. JN5148 wireless system contains a USB-RS232 interface cable used for both programming and circuits for data communication between PC and modules. In order to upload data from the WSN to a database on a server a Virtual Instrument (VI) was developed using LabView. The VI has the following tasks: read data from USB serial interface, transmission of data to the database by accessing a web page, reading the values for control equipment from the database and sending control data through the USB when it is required to control the equipment.

The Front Panel of this VI is presented in Figure 4.

Server side services

An http server with php support and mysql database service was used to store the measurement and configuration data. The WSN side is connected to the database using an ODBC connection as LabView resource. When a client service needs to read measurement data or to write some data for system's actuators, php scripts are called. The php scripts are used for GET and SET operations. JavaScript Object Notation (JSON) was used to intermediate data between server side and the mobile App.

USER INTERFACE OF THE SYSTEM

A user interface was developed using official Android Studio IDE. The application was tested in a Genymotion emulated device and a Samsung Galaxy II tablet.

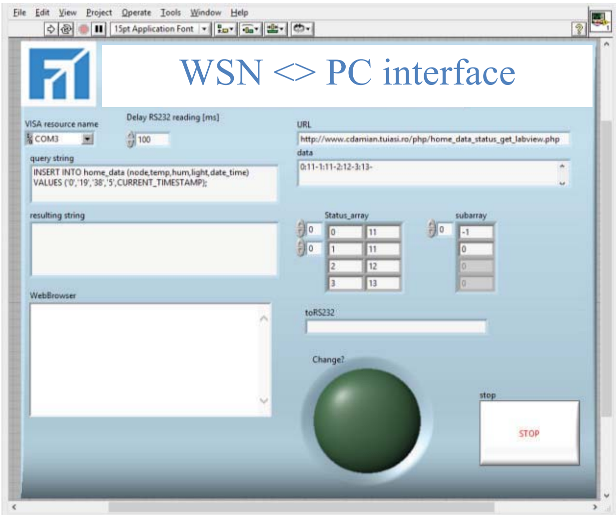

Figure 4. Front Panel of the VI used to communicate between WSN and a network PC.

The application is based on the following tasks (background or foreground):

- reading data from a database;
- display parameters based on the location selected;
- calculation and display some statistic values;
- configuring global settings;
- Text To Speech – TTS function;
- send e-mails;
- setting the values for the actuators.

To achieve the above requirements, the application is based on complex programming technologies: Android fragments, native operating system TTS engine, e-mail sending, volley library for connection to the server, etc.

The Android application (Figure 5) is described regarding its functionality. Application screen is divided vertically into two parts; the left representing a menu that allows the selection of the right side content.

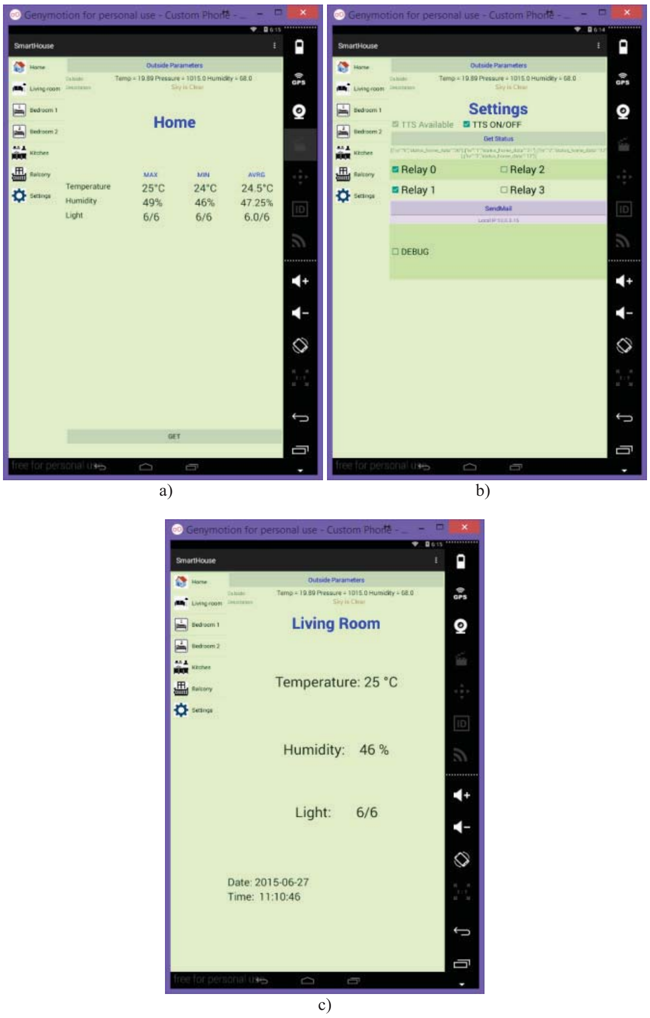

Figure 5. Mobile application's display types: a) main window, b) settings screen, c) a specific room screen.

The menu side is designed using ListAdapter and contains entries:

Home: allows to select the main window of the application;

Room1, Room2, …, RoomN: a list of locations;

Settings: displays configuration snippet.

CONCLUSION

The paper presents a hardware system and a mobile application that can be used to monitor and control a series of parameters from a home or office building. The system uses five ZigBee modules (four measurement nodes and one coordinator) that send data to a server using a local PC. The data is displayed on a mobile device using a dedicated Android application [3].

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