Smart Home Automation System Using Wi-Fi Low Power Devices

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***Abstract*—Home automation is gaining popularity nowadays. A smart home automation system is based on ensuring security and making user life easier. It contains a large number of sensors which can control or monitor objects distributed in three-dimensional space. The sensors can be specialized in measuring temperature, humidity, pressure, light, noise, dust air, and so on.**

In this paper, a solution to transform a normal house in a smart house while reducing the energy consumption is proposed. This can be realized with the help of wireless sensor networks and of the LabVIEW™ graphical programming environment, which use the NI LabVIEW™ Statechart Module for collecting data from sensors.

Keywords*— *Home automation, NI Statechart Module, Tag4M

I. Introduction

Day by day, the technology is becoming an increasingly important part of our everyday life. Using new technology, everything at home can be automatically controlled. Thus, home automation becomes much more popular nowadays.

In 1984, the National Association of Home Builders (NAHB) introduced the ”smart house” concept. The researches and developments in this field continued over the years, but to actually automate a building is still a quite expensive job. [1] This leads to the question: ”If it is expensive, why home automation?”.

First, home automation brings interoperability: the temperature can be set to a certain value according to certain conditions, lighting can be turned on, off or may be dimmed based on daylight. Second, home automation implies remote access, such as monitoring the house using a laptop or even the own cell phone. Third, a smart home automation system should have the possibility to be extended or reduced when needed. Therefore, it can bring expandability and also energy savings [2]. Nowadays, one of the hottest topics in media is related to energy conservation. Automation systems can help the energy savings by, for example, turning off the electronic devices automatically when they are not in use.

A house which is equipped with such a system offers much more comfort, flexibility, elegance, security, but most important, reduced maintenance costs through the optimization of the consumption of electricity and heat. For example, some of this smart houses can include simple things like turning the sprinkler at some time during the day or detecting thieves in the middle of the night; others are more advanced and employ sensors for detecting the presence of a person in a room, used to adjust the ambient light, to control the temperature or the music volume depending on various factors.

A field which encompasses all facilities of a smart home is ”domotic”. The domotic term was coined in 1984 by the journalist Bruno de Latour [3]. It is a combination of technologies and services that improve the life in the areas of safety, comfort and technical management, resulting in a complete system. Things can happen automatically, as they are necessary or as they are scheduled by the users. However, the user does not lose the control over the house, manual operation being available also [4].

Typically, domotic systems need to collect data from various sensors and make things such as light and temperature to automatically adjust. Moreover, using these sensors, many tasks can be accomplished, such as, controlling curtains and windows without human intervention, opening, locking or unlocking the garage gate, controlling the climate inside the house, providing the corresponding light in each room, starting the sprinkler when the soil is too dry and so on.

However, the concept of home automation gets increasingly louder on the market, being a relatively new concept which draws attention to researchers. This leads to new technologies that can perform home automation functions. Therefore, a system used to automate a house through wireless environment will be presented in the paper.

The pattern of the proposed system is illustrated in Fig. 1 ((a) presents the inside view of the house and (b) the outside view of the house). As it can be seen in the figures, the hardware components are distributed inside and also outside of the house. The system can be used to control the temperature and the light, to monitor the smoke, the humidity and the pressure and also to ensure security in a house.

The paper is structured as follows. In section 2, the home automation systems overview is described. Section 3 illus-

All the authors have the same scientific contributions to this paper.

(a) Outside view

(b) Inside view

Figure 1. Home automation - pattern

trates the system architecture. The hardware and software implementation is presented in section 4. Section 5 shows a few experiments for measuring the temperature and also the quantity of smoke in the air. Finally, section 6 submits the concluding remarks for this article.

II. Overview

The concept of "smart house" was implemented in time, in the most civilized countries of the modern world. The current home automation systems use different technologies and standards, such as ZigBee™, Bluetooth™ and X10™.

Bluetooth technology is used in home automation where there exists hardly no infrastructure to interconnect intelligent appliances. ZigBee might be a better solution than Bluetooth sometimes because it is a protocol more targeted toward home automation applications. ZigBee devices are not widely used these days, but in the future ZigBee chips in normal houses may exist. This can lead to an easier morning life for users because the alarm clock could communicate wireless with the coffeemaker, ordering: "Strong coffee, please!". [5]

Choosing a better technology might depends on what you want to do, sometimes being a better idea to choose ZigBee instead of Bluetooth. Even if the ZigBee transfer speed is lower in comparison with Bluetooth, it consumes a lot less energy (1-2 years on 2 AA batteries is expectable).

X10 is a standard for communication among electronic devices used for home automation, but it has an important drawback: it is very slow [6].

Another standard, which is said to be "the Worldwide Standard for Home and Building Control" is KNX. It is much more suitable for smart houses because it is the only global standard for home and building control with a single, manufacturer independent design and commissioning tool (ETS), a complete set of supported communication media (TP, PL, RF and IP) and a complete set of supported configuration modes (system and easy mode) [7].

Compared to these technologies, Wi-Fi wireless LAN adapters are much more powerful, data transmission rates reaching about 54Mbps. As a conclusion, the Wi-Fis strengths are the bandwidth and flexibility, while the ZigBee offers low cost and low power. Therefore, an easier way for home automation, which employs a very low power Wi-Fi device, is proposed ("a universal remote control"). By using it, the user can control the light, the temperature and also the alarm system in a building. Moreover, the dust air density can be detected and the humidity and pressure can be monitored.

For data acquisition, the Tag4M system is used [8]. In comparison with the other technologies, the Tag4M does not require infrastructure, providing communication security and relatively little interference with other networks. It offers a relatively low cost, allows the creation of networks which contain a large number of nodes and it provides communication security with relatively little interference with other networks. Besides, ZigBee uses the 2.4 GHz band for the communication between devices. In buildings with Wi-Fi, both networks can fail due to the interferences because 2.4 GHz band is commonly used by both networks [6].

For the implementation part the NI LabVIEW Statechart Module was used [9]. It can be used as a programming model for applications with a high-level design. LabVIEW Statecharts are especially useful for programming event-response applications, such as complicated interfaces and advanced state machines used to implement dynamic systems [10]. The use of this module involves creating a chart for each proposed objective as it is presented in chapter 4.

III. Home automation system architecture

From the user point of view, by using a universal remote, the alarm, the light and temperature in all rooms can be controlled and monitored. The remote may possess the option to monitor the house humidity, pressure and dust air in order to inform, for example, the fire or gas leaks age occurrence. The development of such an automation system requires combining several techniques and tools.

First, the system needs information about the status of the lights, temperature, humidity, pressure, amount of smoke, doors and house windows. Obtaining this information requires several types of sensors. Data collection from sensors must be performed at different periods of time. If the temperature differences from one minute to another are insignificant, but if they are not read by the alarm system for a minute, serious consequences could occur. Also, the temperature control should be possible in each room, so that the user can set different temperatures in different rooms. The lights in each room can be individually operated from the remote control.

All these options combined with a friendly graphical interface can be easily understood and use by the user.

Therefore, a system which can:

- control the alarm system (When an unwanted event occurs the alarm is turned on and during this time the doors and windows are secured. Also, if the user has activated the alarm, the unexpected occurrence of an event will start the buzzer.)
- control the room temperature (The temperature is kept within the user settings. The value read from the temperature sensor is saved in a global variable and it is compared with the maximum and minimum value set by the user for that room. Depending on the result of the comparison, a "heating" or "cooling" signal is transmitted. The signal

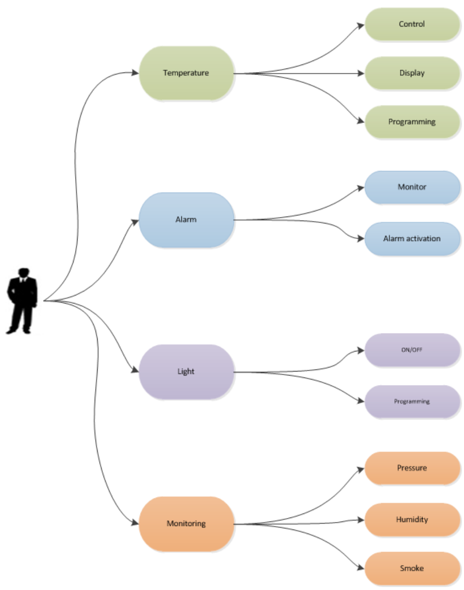

Figure 2. Menu diagram

shall operate the heating that will heat a resistance or the cooling fan that will cool the room.)

- control the room lighting (The lighting can be turned on, turned off or dimmed based on the daylight.)
- monitor the smoke in the rooms (When the quantity of smoke exceeds a certain threshold, the fire alarm will be turned on.)
- monitor the humidity and pressure in the rooms

is proposed.

The diagram menu of the system looks as in the Fig. 2.

The system is designed so that the user can set the temperature and lighting in advance. This is very efficient in winter when the temperature during the day can be set slightly lower, with the possibility to be modified with, for example, 1 hour before a certain time. The user needs only to input the date and time when the change should produce and the limits within which to maintain the desired temperature. The same actions have to be performed for setting the lighting: only the date and time when the event occurs should be specified.

IV. Implementation

The system was developed using a Tag4M devices as the hardware part and the NI LabVIEW Statechart Module as the software part. [10]

A. Hardware devices

A building can be monitored using devices for temperature, humidity, light, pressure, dust air and magnetic sensors [20].

In the application presented herein, the utilized sensors are: the HIH-5030 humidity sensor [17], the TC1046VNB temperature sensor [18], the MP3H6115A6U pressure sensor [16], the SQ-SEN-200 shock sensor, the magnetic sensor (Reed relay) and the LX1792 light sensor [19].

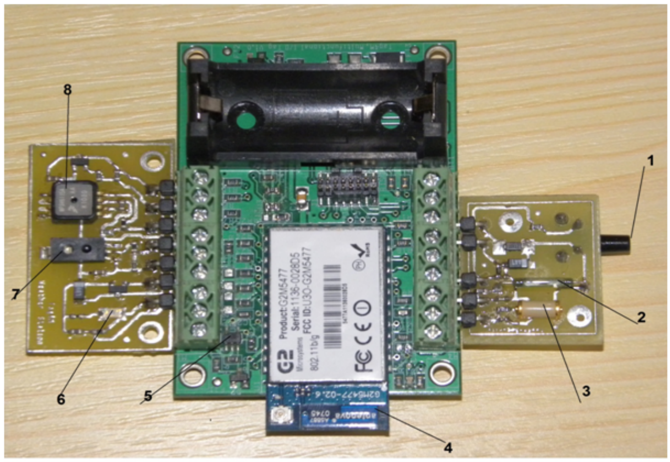

Figure 3. Tag4M device used for security

1) The Tag4M device used for security: The device used for security is presented in Fig. 3.

The doors are monitored using tilt sensors, as shown in the Fig. 3 with *1*. When the door opens, the sensor will be on and the sensor's signal can be collected. The windows are monitored using magnetic (Reed relay) and shock sensors, numbered in the Fig. 3 with *2* and *3*. The tilt sensors are mounted inside the window. When the window opens, the magnetic sensor will meet the magnetic field created by the magnet and it will emit a signal. The shock sensor is attached to the other window. When sudden movements or strikes occur, the signals will be send in order to activate the fire alarm which announces a possible housebreaking. This sensors are used mainly for security specific applications.

The Tag4M, illustrated on our figure with *4*, is used for measurements. The temperature sensor (*5* in Fig. 3), reads the room temperature value at the time when the application runs. The light sensor (*6* in Fig. 3), measures room light intensity. When the value exceeds some certain thresholds, the room light will turn on/off or will be dimmed automatically. The pressure and humidity sensors (*7* and *8* in Fig. 3) take the pressure data in the room in order to inform the user.

2) The Tag4M device used for temperature control: The device used to control the temperature is illustrated in the Fig. 4.

On the figure, *1* represents the power supply jack and *2* represents the buzzer which is used in the security menu. When the alarm is on and an undesirable element appears, the buzzer will notify the user through a beep. The number *3* illustrates the heater (implemented with a 25W power resistor). This is used for temperature control, namely, the user imposes a maximum and minimum temperature and this resistor will warm up according to the current temperature in the room. With *4* the LED is represented (a power LED model PHL20W-WJ4 which gives about 20-25 lm with 1W power consumption). This LED can be turn on or off using the remote control or it can be scheduled to light turn on at a certain hour. The ventilator (*5* in the figure) is used to control the temperature and it can cool the room if the temperature read from the sensor is greater than the desired temperature. *6* indicates the tag4M which controls these elements.

3) The device used to detect smoke: It is presented in Fig. 5.

The smoke sensor, GP2Y1010AU0F produced by Sharp, is used for monitoring the room smoke quantity. The sensor data are collected and they are used in order to inform regarding a possible fire in the building. Every tag has a unique MAC for identification within the network. This tag MAC is 0012B80028D5.

B. Software implementation

The implementation was carried out using the LabVIEW^{TM} software. LabVIEW^{TM} is the National Instruments Corporation trademark. Fig. 6 represents the main menu of the implementation in LabVIEW^{TM}. It contains two graphics: the first one is used for fire detection, which shows the room smoke quantity, and the second one is used for indicating the status of the sensors used for the security.

For processing sensors data, Statecharts are used. Fig. 7 presents the statechart for the temperature, which has five states: wait alarm on, controller, heating, cooling, wait off and twelve transitions that connect states. This diagram consists also of thirteen transitions linking these states. The system will stay in the waiting state until the user will choose to adjust the temperature by setting a minimum and a maximum value. The *Heating* and *Cooling* states contain LabVIEW^{TM} code used for comparing the temperature read from the sensor with the values set by the user. If the temperature is lower than the minimum desired temperature, then the *Heating* state becomes active and the resistance heating will be activated in order to warm the room. If the room temperature is greater that the maximum desired temperature, the cooling fan will start to cool the room.

Fig. 8 presents the alarm statechart. It informs the user regarding the door and window states, and also the smoke quantity levels.

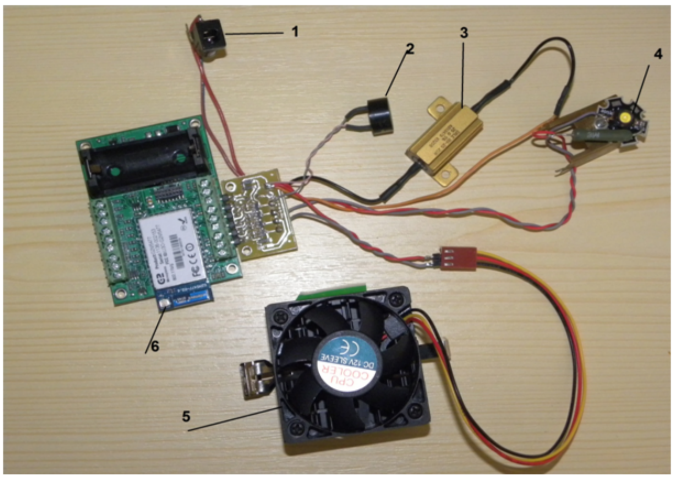

Figure 4. Tag4M device used for temperature control

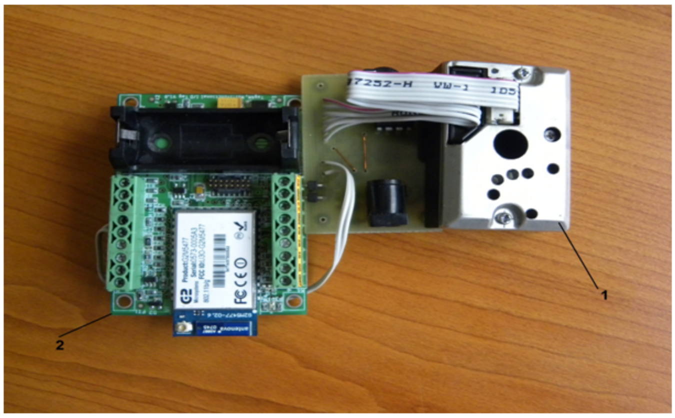

Figure 5. Tag4M device used to detect smoke

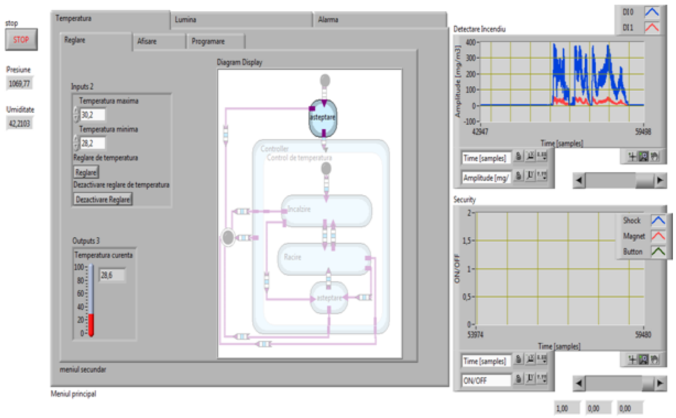

Figure 6. Main menu

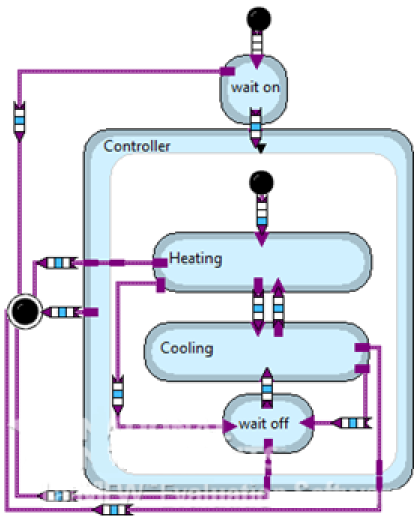

Figure 7. Statechart for the temperature

V. Experiments

In this section, a few experiments employing the sensors will be presented.

Fig. 9 presents the room temperature. When the room

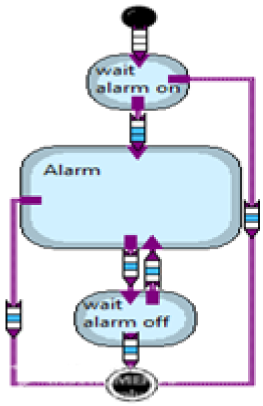

Figure 8. Statechart for the alarm

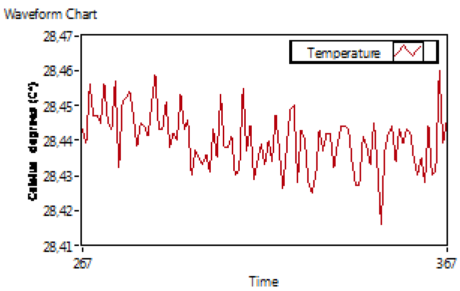

Figure 9. The temperature graph

temperature is lower than the temperature set by the user, data will be transmitted to the tag and the resistance will begin to warm up in order to rise up the temperature. In the heating state, the temperature graph is shown in Fig. 10. It can be seen that the temperature rises when the resistance began to heat up.

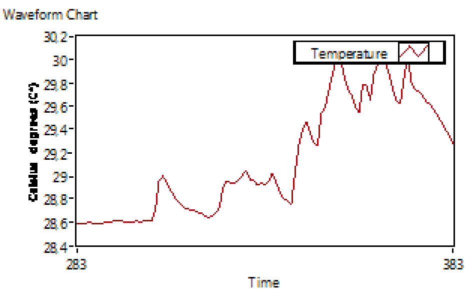

Figure 10. The temperature when the heating state is on

Fig. 11 illustrates the normal situation when the security elements are not activated. The shock sensor stays in state 1 until a perturbation appears.

When the button is pressed or when a perturbation exists, the status of the elements changes as it is presented in the Fig. 12.

The smoke detection in a room is presented in the Fig. 13 and Fig. 14. The initial state, when smoke does not exist in

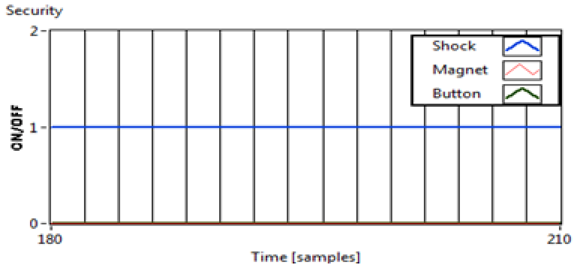

Figure 11. The inactive states of the security elements

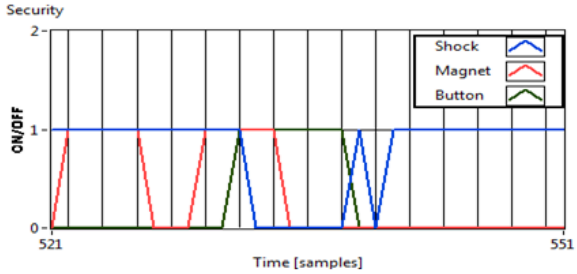

Figure 12. The active states of the security elements

the room, is presented in Fig. 13.

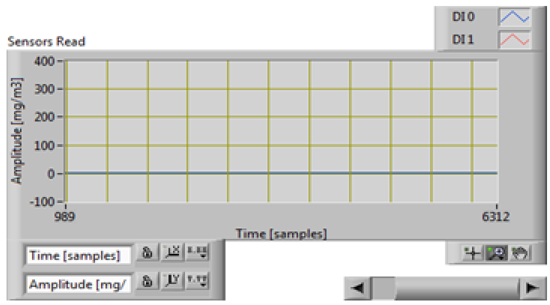

Figure 13. Smoke sensor in the initial state

When a measurable quantity of smoke appears in a room, the graph changes, as it can be seen in Fig. 14.

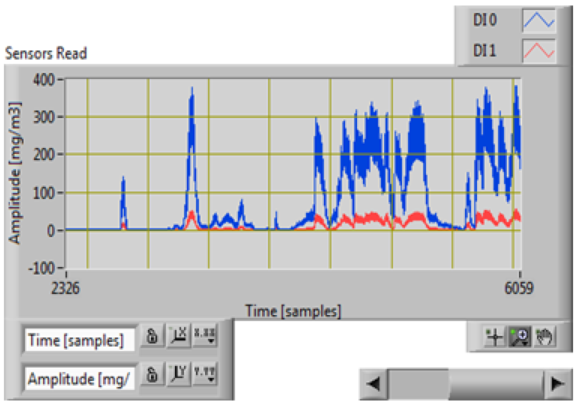

Figure 14. Smoke sensor detecting smoke in a room

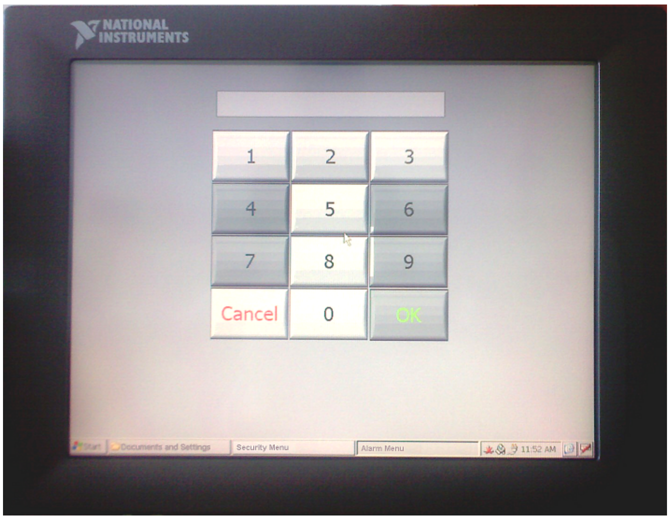

Figure 15. TPC Alarm Menu

One of the main advantages of the system is that it is very effective in detecting fine particles like the ones in the cigarette smoke. In addition, it can distinguish smoke from house dust by the pulse pattern of the output voltage. The dust air is correlated to the temperature and humidity variation, so cigarette smoke does not activate the fire alarm, preventing in this way false detections.

The application is running on a PC connected to the Internet. It receives data from the Tags and feeds them in a Pachube stream [23]. Pachube is a data infrastructure site for the Internet of Things and allows devices to feed data on demand or periodically at predefined (by the client) time intervals. Pachube enables setting triggers, and when the set value exceeds the limits, it can send alarms through SMS. Therefore, the data may be easily viewed from any location as long as the user has a mobile Internet connection.

In order to develop a friendly-user interface, the system is implemented using the National Instruments Touch Panel Computer (TPC) as shown in the Fig. 15. For example, in the case in which an alarm occurs, on the TPC display will appear a numerical keyboard with two buttons, *accept* and *cancel*, will appear. The buzzer will also start, and it will not stop till the moment when the correct PIN is introduced.

VI. Conclusion

In this paper, the way in which LabVIEW Statecharts can be used in order to realize a monitoring and control system is presented. This solution offers a reliable, low cost and low power consuming solution for data acquisition, during long periods of time, which can be used for home automation. The sensor extensions developed can be used for solving real life problems. The work presented in this paper emphasizes the advantages of using the Tag4M Wi-Fi Tag in wireless measurement applications.

Some possible aspects of home automation which make us not forget that the need for new automated systems is very high and the degree of integration increases from year to year are presented. Therefore, more and more functions will be included into fewer and smaller systems that can perform several functions in parallel. Automation is inevitable, especially because it can be a determining factor in energy, time or in housing space efficiency.

This system can be extended by introducing the possibility to inform the user and also the security company by SMS when housebreaking is detected. Another future research idea is the possibility to record remote settings using a browser.

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