Modular Framework for Smart Home Applications

Javier Blesa, Pedro Malagón, Álvaro Araujo,
José M. Moya, Juan Carlos Vallejo, Juan-Mariano de Goyeneche,
Elena Romero, Daniel Villanueva, and Octavio Nieto-Taladriz

Universidad Politécnica de Madrid, Dpto. Ingeniería Electrónica,
ETSI de Telecomunicación, Ciudad Universitaria s/n, 28040 Madrid, Spain

Abstract. In this paper we present the design of a low cost system which automatically controls the air conditioning equipments of a home. The sensors and controllers distributed use Zigbee, a protocol for wireless personal area networks, to communicate themselves. The aim of our design is to facilitate the development of complex smart homes applications, emphasizing the modularity of the system. This kind of applications is a great advantage for the end user, especially in the case of people with disabilities, who couldn't interact with home's electronic equipment.

Keywords: Wireless personal area network, low consumption, domotic, ZigBeeTM, ambient intelligence, air conditioning.

1 Introduction

Home automation (also called Domotic) is the incorporation of a simple technology to the home equipment that allows a simple, energy-efficient, safe and comfortable management of the different electronic components and systems that we have at home. Some practical implementations of home automation are, for example, fire detection, sense the presence of a person, lighting control, etc.

One of the most interesting fields is helping people with disabilities to improve their quality of life by making easier their interaction with home's systems or other possible smart home applications, such as patient monitoring [1]. For example, a person in a wheelchair may have trouble reaching the thermostat, or a physically handicapped person can not use the remote control to turn on the air conditioning. If we could give them new interfaces or a new system that wouldn't require user intervention, then the improvement of their quality of life would be considerable.

Nowadays, home systems frexibility is not enough to adapt to different kind of users, taking into account the principles announced in [2]. Homes haven't sensors, which increase the information about the environment that system have to take decissions. Moreover, homes usually have just one human-machine interface, such as a light switch, a thermostat or a remote control. Our proposal is an easy-to-install system, adaptable to the user and to the designer of more complex applications in a smart home.

S. Omatu et al. (Eds.): IWANN 2009, Part II, LNCS 5518, pp. 695–701, 2009.

We have chosen a wireless personal area network protocol, Zigbee [3], because it adjusts perfectly our restrictions for adapting an existing home equipment to our system: flexibility, easy installation, cost-effective, etc.

2 System Design

The system we have designed and implemented provides the base for a fast adaptation of an existing system to a complex smart home application over a wireless network. This system will provide with all the advantages of a smart application to end users. So, we need to arhieve these requirements [4]:

- To be an advantage. Firstly, we consider that this design methodology should provide a clear advantage for end users. Hence, automatic control, to reduce the human-machine interaction. When end user has given their preferences, the system is the only responsible of the control.
- Dynamism and adaptability. As another added functionality, the system can control different zones of the house independently. This is useful, for example, when we want a different temperature in our bedroom and our living room, or at work, if each worker has different preferences about lighting, even in the same room. That is, the system can be more adaptative with user preferences.
- Low consumption. This requirement has been taken into consideration too. The nodes of the wireless network do not need to change batteries often, another advantage for the end user.
- Scalable. The system should be able to control the equipment of a regular house and the systems of a great company, taking into account the different number of equipments, users and space covered.
- Modular. The system architecture should be modular to facilitate the addition of new services to the smart home application. In this way, we could use this architecture for different home automation applications.
- Security. We need an additional security to be more resistant against external attacks, failures in the system, and intrusions.

Among all the protocols that can be used for home automation applications we have chosen ZigBee, because it includes key features to accomplish our requirements [5].

ZigBee is an open global standard providing wireless networking based on the IEEE 802.15.4 [6] standard and taking full advantage of a powerful physical radio this standard specifies. It is well suited for a wide range of building automation, industrial, medical and residential control and monitoring applications. For each one of these areas ZigBee provides a standard profile that specifies domains applications. Within this profile are, for example, the device descriptions that are required for an application.

In this project we have designed and fabricated our own ZigBee nodes, using a PIC18J4620, distributed for Microchip and designed to low power-consumption.

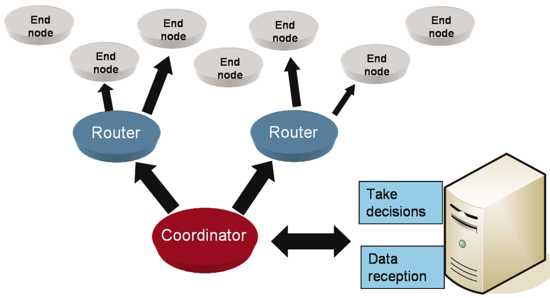

Fig. 1. Model architecture

This micro communicates via SPI port with the radio module MRF24J40, Microchip componet too, that uses a PCB antenna for communication with other nodes and exchanging control information and receiving or transmitting data in the 2.4 GHz band. Both PIC18J4620 and MRF24J40 go to sleep state when they haven't any task. Flexibility has been one of the major facts taken into account for the design of this node, so it can adapt to any kind of application and profile, due to its general purpose input/output port and its communication port (with I2C, SPI and UART).

Figure 1 shows the architecture of a generic application. We need two kind of devices: end devices (with sensors and actuators) and routers which are connected to main power and help to connect the end devices to the servers. In the server we have two applications running: the data receiver, which stores the data in a file with XML format, and the the decision maker, which reads the data and sends the relevant actions.

3 Implementation as an Example: Air Conditioning Control System

For the air conditioning control has been proposed scheme in figure 2. There is a coordinator network, which is responsible for creating and managing the network, end nodes equipped with temperature sensors and infrared actuators and, finally, a PC that will act as a server.

It's necessary at least one final node for each air conditioning if we want to control different zones independently. It could be some nodes in each zone to have better reliability in the temperature measures.

The node fabricated is the main block but, besides, the node has a MCP9801 temperature sensor, that sends the measures through I2C bus to the microcontroller, and an actuator, formed by a LED and transistor in an emitter common configuration, that sends infrared signals encoded to the air conditioning. Finally, there is the power block, which is formed by two AA batteries and a step-up converter form 1.5V to 3,3V, the voltage supply that the radio and microcontroller need to their right operation.

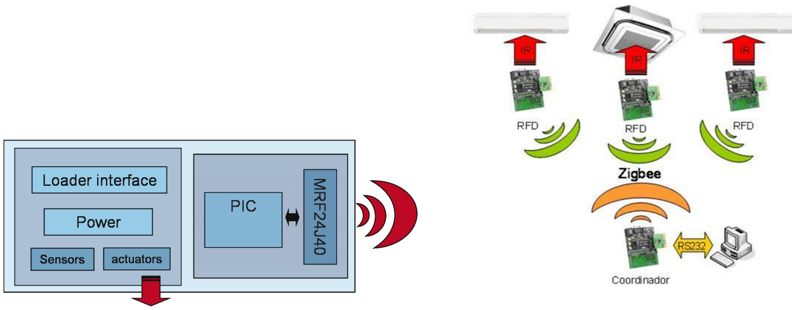

Fig. 2. Air conditioning node

The design software can be divided in three points: first the user profile, second the ZigBee applications and, in last place, the server applications.

Each ZigBee application must have a user profile, which includes the following information:

- A user identifier.
- A set of devices required in the application area.
- Specification of which clusters are required by which devices.
- Specific functional description for each device.

In particular, in our application, we have temperature sensor devices, and air conditioning controller device. As an example of a cluster, we can say that air conditioning device have a temperature cluster, a mode cluster, a power cluster, etc. In the next figure you can see a schematic design that explains our profile.

Two different applications have been developed: one for the coordinator network and other for end nodes. The applications have been developed with the free ZigBee stack provided by Microchip.

Coordinator's functions are to create the network, to manage it, to provide access to new nodes, to control security, to collect data from the final nodes and retransmitted it to the server and send instructions to end nodes for air conditioning equipment.

The functions of end nodes are to join to the network and, from that moment, to send temperature measures to the coordinator periodically and to receive instructions. The sending data is periodically because, in this way, the node can sleep between sending and sending and reduce consumption. This is very important especially in end nodes that can be spread by household and not have an external power source.

So, the flow of the application is:

- When the ZigBee coordinator turns on create a new network and wait until some end node ask for joining.
- An end node turns on, scan all the channels and if it finds a network send a request for joining.

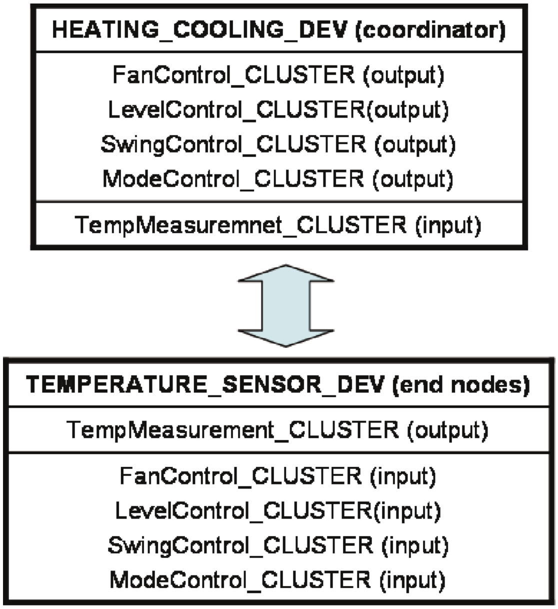

Fig. 3. Clusters used for air conditioning

- The coordinator could accept o deny this request. If request was accepted the coordinator sends the network key to the end node.
- After that, the end node transmits periodically the temperature and request data from the coordinator. The period between two measures is cofigurable. In our example, the end nodes send the temperature each 5 seconds.

The server is responsible for managing the temperature data and make decisions about air-conditioning equipment. Server communicates with ZigBee network through the coordinator with RS232 interface.

Temperature data are stored in a file system in which each directory corresponds to a network node. Thus, anyone can easily make a correspondence between home's areas and directories. Furthermore, it has been included a web interface where there are available the temperature measurements in XML format.

Periodically, a server application accesses the stored data and user preferences. Using this information, the server decides what action to perform on the air conditioning. For example, if we want a temperature of 23 degrees and the measures indicates that, in fact, 28 degrees, the server should turn on the air at 21 degrees to cool down the room.

The rules to control the temperature in the room are:

- We have different sensors associated to a particular zone of the room. Each zone is independent.

- The server application reads last five measures of all sensors associates to a zone and calculates the average. Server application reads the optimal temperature set by the user, too.
- The fixed temperature is proportional to the difference between the average and the optimal temperature.
- Some special rules could be imposed. For example, if a user directly set a temperature then the automatic control switch off, and if there are nobody in the room the automatic control switch off too.

3.1 Results

At this point we present the results obtained after the implementation of our application. According to this results, it's possible to obtain conclusions about different aspects of the system.

Consumption . The main block of hardware has the expected consume. In sleep state the microcontroller and radio module consumes 40 microamperes and 45 milliamps receiving or transmitting. But the power block increase this consumes because low performance of the regulator in low currents.

Range . Our nodes have a range of 20 meters, enough to cover a great room. Moreover, it could be possible to use a coaxial antenna to increase the range.

Speed . We have measured the main times of the applications:

- Time to create the net since coordinator turn on: 1,011s.
- Time to joining nectwork since end node turn on: 0,544s.
- Time between temperature sendings: 5s (configurable).

4 Conclusions

During this project we have developed a modular easy-to-install air conditioning system adaptable to the user preferences over a ZigBee wireless protocol for Smart homes. The system allows to abstract end user for the complexity of the system and it makes the use of their electronic components easier.

We have achieved our goal in several different system features: low power consumption, security, low cost, support for a large number of nodes, etc. In addition, the design and the integration of new applications or a new device it's quite simple for the developer.

We continue working in this project, developing new sensors to take more context information, such as presence sensor, light sensor, etc. and new interfaces such as USB and integrating this application with a real-time operating system. This would be useful for applications that require time restrictions.

References

1. Jiménez-Fernández, S., Araujo-Pinto, Á., Cobo-Sánchez de Rojas, A., del Pozo-Guerrero, F., Nieto-Taladriz, O., de Toledo-Heras, P., Moya-Fernández, J.: PERSEIA: a biomedical wireless sensor network to support healthcare delivery for the elderly and chronically ill. In: Proceedings of the 28th IEEE EMBS Annual International Conference, pp. 2064–2066 (2006)
2. Davidoff, S., Lee, M.K., Yiu, C., Zimmerman, J., Dey, A.K.: Principles of smart home control. In: Dourish, P., Friday, A. (eds.) UbiComp 2006. LNCS, vol. 4206, pp. 19–34. Springer, Heidelberg (2006)
3. Chase, B.: ZigBee Alliance Tutorial. ZigBee Alliance
4. Kumar, D.V.: Smart wireless network for reliable, low cost, low power solutions. Technical report. Spring Computing Technologies Pvt. Ltd.
5. Osipov, M.: Home automation with zigbee. Technical report, Siemens Corporate Technology, St.Petersburg
6. IEEE: IEEE Standard 802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specications for Low-Rate Wireless Personal Area Networks (LR-WPANs) (October 2003)