SMART HOME APPLICATIONS FOR DISABLED PEOPLE BY USING WIRELESS SENSOR NETWORK

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SMART HOME APPLICATIONS FOR DISABLED PEOPLE BY USING WIRELESS SENSOR NETWORK

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ABSTRACT

SMART HOME APPLICATIONS FOR DISABLED PEOPLE BY USING WIRELESS SENSOR NETWORK

Smart homes are no longer design concepts of the future. They are being built now, and they are having a direct impact on the lifestyles of people living in them. The aim of smart home systems is to create an environment that is aware of the activities taking place within it. Beside the healthy people, disabled people also need such systems to make their life easier. Because they encounter with a lot of difficulties in their everyday life especially when they are at home.

In this engineering project in order to make disabled people's life easier some smart home applications are designed for different kinds of disabilities. Firstly, automatic door control system is developed. Secondly, gas detection system is developed. Finally warning system is improved for disabled people.

The focus of this project is on the integration of wireless sensor network (WSN) in smart homes and applications of this system. Tmote Sky wireless sensor nodes are programmed and used to carry out actuations. Hardware and software requirements are designed and developed. Then whole system is tested in real life and obtained successful results.

ÖZET

ENGELLİ İNSANLAR İÇİN AKILLI EV UYGULAMALARI

Akıllı evler artık geleceğin tasarım kavramları arasında olmaktan çıkmıştır. Günümüzde akıllı evler inşa edilmekte ve içinde yaşayan insanların yaşam tarzlarını doğrudan etkilemektedir. Akıllı ev sistemlerinin amacı, içinde oluşan ektivitelerin farkında olan bir ortam yaratmaktır. Sağlıklı insanların yanında engelli insanlar da günlük hayatlarını kolaylaştırmak için bu sistemlere ihtiyaç duymaktadırlar. Çünkü engelli insanlar özellikle evde bulundukları zamanlarda bir çok zorluklarla karşılaşmaktadırlar.

Bu mühendislik projesinde, engelli insanların hayatlarını kolaylaştırmak hedeflenmiş ve farklı engel türleri için bazı akıllı ev uygulamaları tasarlanmıştır. İlk olarak otomatik kapı kontrol sistemi geliştirilmiştir. İkincisi, gaz algılama sistemi geliştirilmiştir. Son olarak engelli insanlar için uyarı sistemi geliştirilmiştir.

Bu projede akıllı ev sistemleri ve uygulamaları ile Kablosuz Sensor Ağlarının (WSN) entegre edilmesi odaklanmıştır. Uygulamaları yürütmek için Tmote Sky kablosuz sensörler programlanmış ve kullanılmıştır. İhtiyaç olan donanım ve yazılım gereksinimleri tasarlanmış ve geliştirilmiştir. Bütün sistem gerçek hayatta test edilmiş ve başarılı sonuçlar elde edilmiştir.

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LIST OF SYMBOLS / ABBREVIATIONS

WSN	Wireless Sensor Network
RFID	Radio Frequency Identification
RSSI	Radio Signal Strength Indicator
PIR	Passive Infrared Sensor
GUI	Graphical User Interface

1. INTRODUCTION

1.1. Wireless Sensor Network

The rapid development in the fields of microelectronics, communication/networks and other related technologies enabled us to develop various kinds of wireless sensors. These sensor nodes are consisted of spatially distributed devices using sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants at different locations. They are capable of doing actuation, communication and computation while enabling us to sense and measure the data more efficiently and accurately independent from wire. [1]

Wireless sensor network (WSN) can be described as a collection of these low power sensor nodes which are connected wirelessly. It is a network system that enables to communicate sensor nodes between each other.

Figure 1.1 A WSN Node

Each sensor node is capable of only a limited amount of processing and power. But when they are coordinated with other nodes in the network, they have the ability to communicate, measure and actuate in great detail.

With the help of combination of these nodes, ad-hoc networks can be created. For example, the nodes can be distributed to an environment and wireless ad-hoc networks can

be formed. These distributed and formed nodes constitute a sensor network system as shown in Figure 1.2.

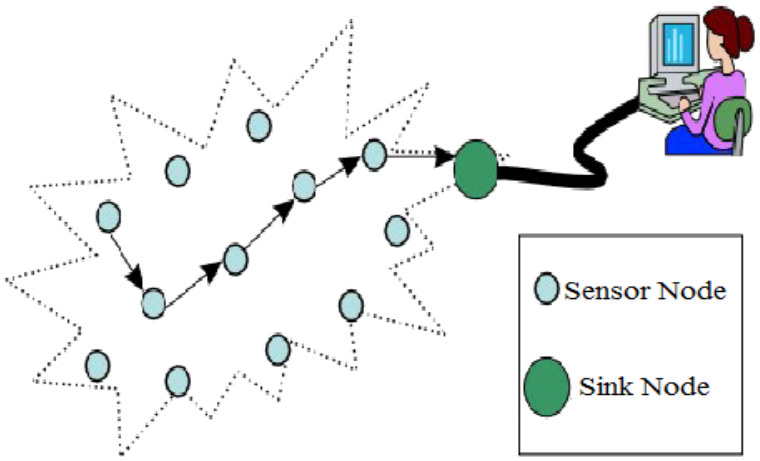

Figure 1.2 Wireless Sensor Network

A sensor network provides easy access to information from anywhere at every time. This functionality is achieved by collecting, processing, analyzing and spreading data. So that, wireless sensor network plays an important role in creating smart environments effectively.

WSN provides the capability of revolutionary detection over a wide range of different applications. Because the sensor networks have features such as:

- Reliability
- Accuracy
- Flexibility
- Cost efficiency
- Ease of Installation

Tilak et al. [2] stated that intelligent sensors may serve prudential supervision and collect information from machine crashes, earthquakes, floods and even about terrorist attacks. Sensor network makes possible,

- Information gathering
- Information processing
- Environment monitoring for a variety of civilian and military applications.

Because of the features outlined above and usage of wide area, Wireless sensor network seems to be an important part of present and future applications.

1.2. Smart Home Systems

Smart homes are no longer design concepts of the future. They are being built now, and they are having a direct impact on the lifestyles of people living in them. Intelligently designed and operated buildings yield dramatic increases in worker productivity, energy cost savings and administrative savings.

"Smart Home" is the term commonly used to define home or building, equipped with special system that does some intelligent actuations according to situation. Integration of the home systems allows them to communicate with one another through the home controller in pre-programmed scenarios or operating modes. For example, when a person approaches to the outside door, system recognizes the person's identity and decides whether open the door or not. This is one actuation example about smart houses. We call these kinds of systems as "Context Aware Systems" that are aware of where the person is and make decisions about what actuation should be done. All of these smart home systems are used to make easier of people's daily life, especially disabled people's.

1.3. Motivation and Aims

Disabled people are more likely to be exposed to daily life problems than other healthy people. While deaf people cannot hear the door bell, Alzheimer diseased people can forget the gas open in the kitchen. These are some encountered examples when they

are alone at home. With the help of technology, assistant projects can be developed to overcome their difficulties.

Smart homes can also be used to support disabled people, providing safe, secure and empowering environments. The system can allow the user to control many features or automate them. The environment can also be monitored by the smart home system to ensure safety and alert people when there is some dangerous situation.

This project aims to develop a smart home system for disabled people to make their life easier by using WSN. There are three actuations for three kinds of disability:

The first actuation is developed for disabled people who do not have arms or hands. Because of their disability, they cannot use the key to open and lock the door. Door control system is developed for these people in this project. The system recognizes the person who approaches to the door, then decides to open or not open the door according to identity of person.

The second actuation is for deaf people. When deaf people are at home, they are not aware of any sound such as doorbell and gas leaking warning alarm. This project enables to make aware of deaf person by vibrating the device that is carried by person when something happened to warn him or her.

The third and last actuation is for Alzheimer diseased people. The main problem for Alzheimer diseased people is that they forget what they are doing. For example, when they cook, they can forget the gas open and leave the kitchen. If the gas starts leaking, smart home system detects that then warn person with sound, warning message and vibration.

All communication work through the project is managed by WSN. Software and hardware design is explained step by step with relative figures. Consequently, we suggest a helper smart home system to help these kinds of disabled people in this project.

2. RELATED WORK

Research on smart homes began in the late 1980's with the intent on making homes more intelligent. By the mid 1990's the focus had turned to incorporating these innovations into the lives of the elderly and disabled people. In Canada the elderly population had been increasing faster relative to the younger population and still does so today. [3] As such, home automation is becoming a viable option for the elderly and disabled people and there has been a considerable amount of research devoted to this topic. In this project, the form of smart home focuses on making it possible for disabled people to remain their life at home, safe and comfortable.

The work by Hussain et. al [4] combined WSN and Radio Frequency Identification (RFID) technology for door control system. Their project deals with the Radio Signal Strength Indicator (RSSI) of WSNs. RSSI is a measurement of how strong a signal appears to the node that is receiving the signal. The RSSI can be affected by many factors that can cause it to change quickly. As shown in Figure 2.1, two nodes placed at the outside of door frame look at the sudden changes that occur in RSSI when somebody moves between two nodes. They also used RFID that is a technology used for identifying people who carry identification badges. This technology consists of reader which reads an approaching badge to identify the person who is carrying the badge.

The problem in their project is that WSN nodes always make radio transmission in a very short period of time. A sensor expends maximum energy in radio communication both for transmission and reception. Thus, it causes to consume the battery of node shortly because of their limited source of power.

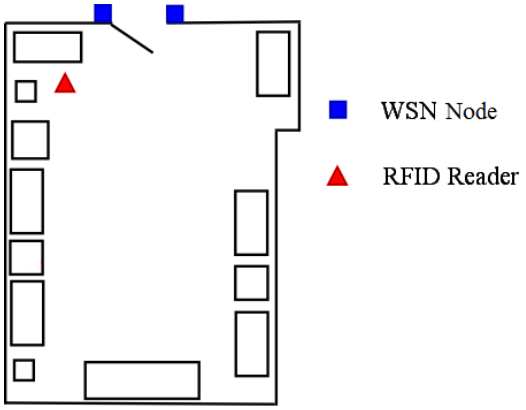

Figure 2.1 The environment of Hussain's et. al project

In our project, we achieved to notice person who approaches to door and identify his or her identity by using only WSN. Instead of making radio transmission to measure RSSI value always, Passive Infrared Sensors (PIR Sensors) are used to detect movement. Thus, usage of radio transmission is reduced dramatically and it makes battery life longer. The comparisons of current consumptions between radio chip and PIR sensor is shown in Table 2.1 and 2.2.

Radio Power Level	**Current Consumption On Stand By (µA)**	**Current Consumption During Radio Transmission (mA)**
Max (Level 31)	365	17.4
Min (Level 1)	365	7.2

Table 2.1 Current consumption of radio chip

Current Consumption On Stand By (µA)	**Current Consumption During Motion Detection (µA)**
52	136

Table 2.2 Current consumption of PIR sensor

WSN radio chip has programmable radio power. Thus, we used WSN nodes as the same functionality with RFID badges by reducing the transmission power of radio signal programmatically to minimum in execution time. It provides us to reduce the distance of radio transmission. It will be described in the Implementation part clearly.

3. OVERALL DESIGN

3.1. Hardware Design

In this engineering project, Tmote Sky sensor nodes [5] with tinyOS operating system are used to implement and test software. Tmote Sky has a radio chip called Chipcon CC2420, [6] in order to send and receive messages using radio frequency. This radio chip supports communication with IEEE 802.15.4 ZigBee standard. With sensitivity exceeding the IEEE 802.15.4 specification and low power operation, the CC2420 provides reliable wireless communication.

Sensor nodes can be classified according to their functionalities and tasks like that: sink node, door control node, gas detector node and human node.

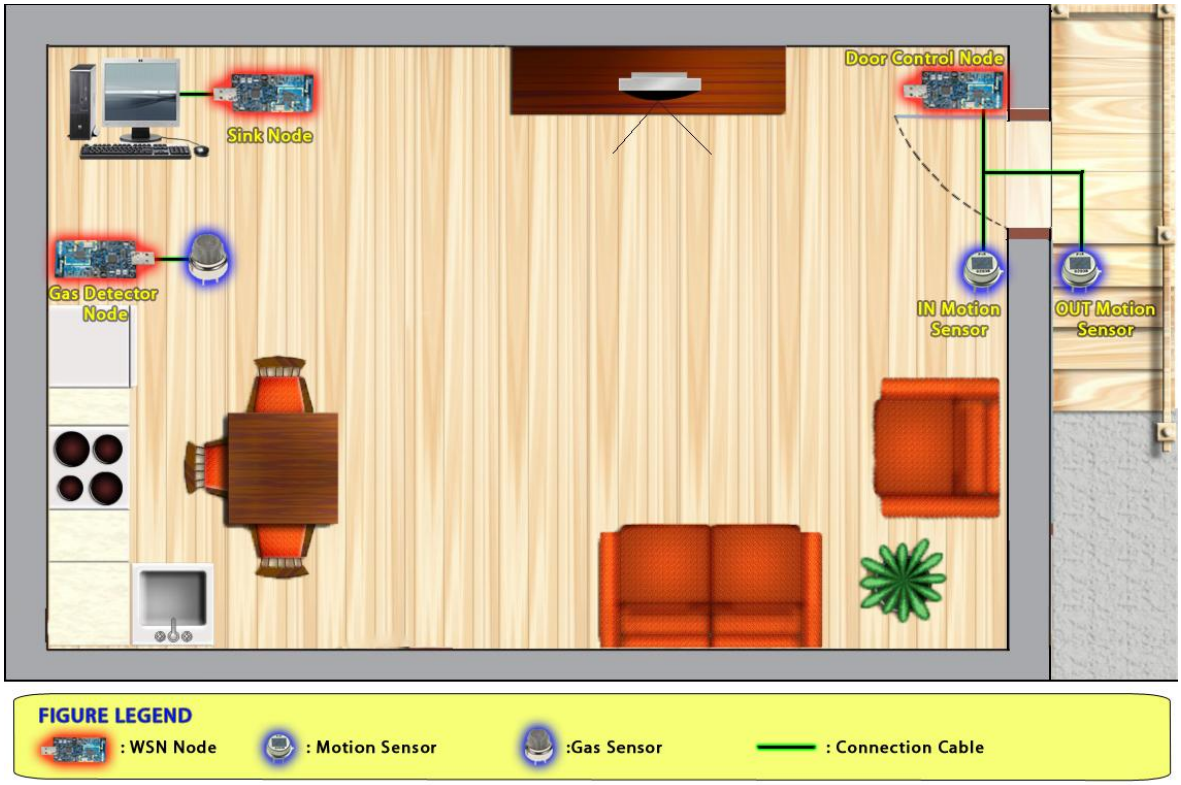

Figure 3.1 Example of home plan and situations of WSN Nodes

3.1.1. Sink Node

We can call this node as brain of the network. It is connected to server computer with USB port. While it is communicating with other nodes in the network, it is capable of communicating with the computer. It provides the data flow between computer and network. The data transmitted to computer with the help of sink node can be recorded to database or used to trigger another process.

3.1.2. Door Control Node

The task of door control node is to manage automatic door control system. It is a sense and actuator node. While this node is capable of detecting motion and doorbell button, it is also responsible for opening and locking the door. The hardware in Figure 3.2 is designed to demonstrate and simulate the automatic door control system.

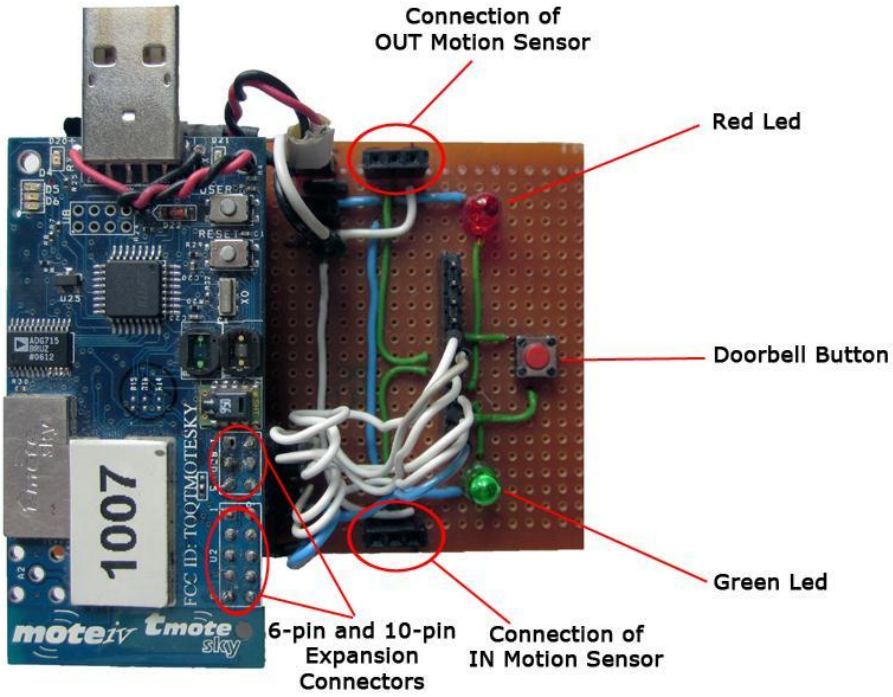

Figure 3.2 Door Control Node and its connections with other peripheral devices

Tmote Sky has two expansion connectors that are 10-pin and 6-pin. [5] Thanks to these connectors, any additional devices such as analog sensors, LCD displays and other digital peripherals can be controlled by Tmote Sky module. The output of the motion sensors and doorbell are connected to expansion slots of the door control node as input. The supplies of the red and green leds are connected to expansion slots of the door control node as output.

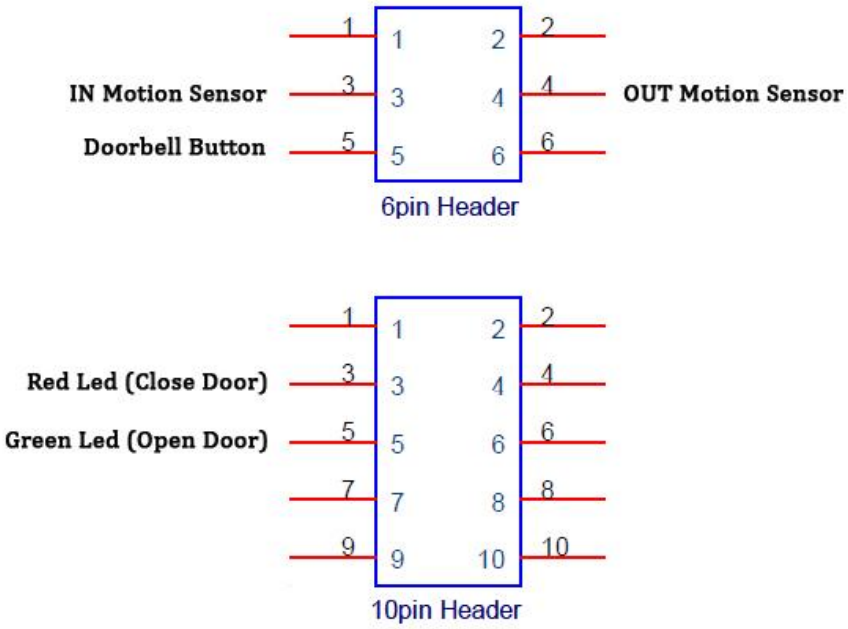

Figure 3.3 Expansion connectors of Door Control Node

Two Passive Infrared Sensors (PIR Sensors) are used to detect motion. These PIR sensors are connected to expansion connectors. They are placed at door frame. While one of them is responsible for detecting outdoor motions, the other one is detecting indoor motions. Thus, system understands if person is coming from outside or inside.

There is also a button connected to node. This button is a simulation of doorbell button. When somebody pushes this button, system actuates Scenario 2 that will be described at Section 3.3.

To simulate the locking and opening door actions, green and red leds are used. If the system opens the door, green led is lightened, otherwise red led is lightened. In the real

life, relay circuit will be used to open and lock the door. Relay is a small electronic device which drives (opens/closes) an electric switch that is capable of carrying much larger current amounts. Instead of lightening red or green led, system opens or closes the relay, and then relay derives the door lock.

3.1.3. Gas Detector Node

This node is responsible for detecting gas leaking. There is a peripheral gas detection circuit connected to node to detect gas leaking. When there is a gas leaking around the gas sensor, the output of the gas detection circuit is set to high logically and interrupts input of the node.

3.1.4. Human Node

This is the node that should be carried by human. It enables communication of other nodes with the human and detecting the identity of human. Every human node is programmed with different node id.

There is an extra peripheral device that is a small vibration motor connected to human node as shown in the Figure 3.4. It is controlled with the expansion connector of the node. It enables to warn human -especially deaf human- physically when there is something to warn.

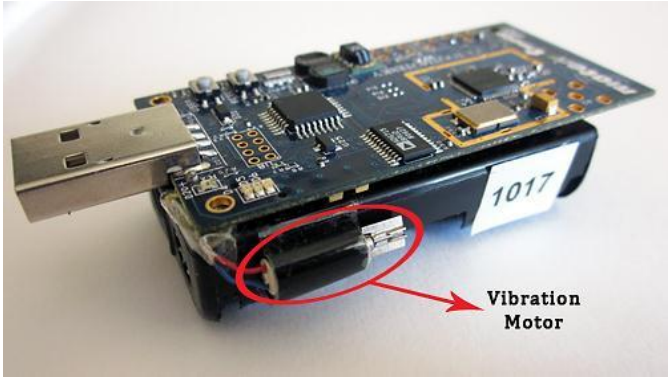

Figure 3.4 Human Node with vibration motor

3.1.5. PIR Sensors

Passive Infrared Sensors allow us to sense motion and detect a human has moved in the range of sensors. It is a pyro electric device that detects motion by measuring changes in the infrared levels emitted by surrounding objects. [7] They are small, inexpensive, low-power and easy to use.

The PIR sensor module is a prepared circuit that includes PIR sensor. It gives a simple on/off signal. When it detects a motion it gives logic high to its output pin.

Figure 3.5 PIR sensor itself

Figure 3.6 PIR sensor module

PIR sensor module has a 3-pin connection at the bottom as shown Figure 3.7. One pin is ground, another is output signal and the final one is power. Power is usually between 3.5 - 12 V DC input.

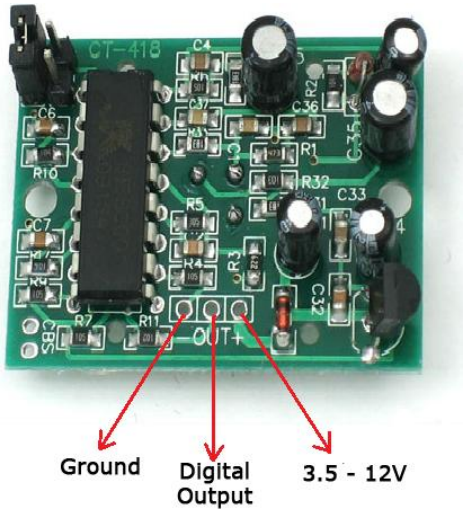

Figure 3.7 Other side of PIR sensor module and its connections

3.1.6. Gas Sensor

MQ-6 gas sensor in Figure 3.8 is used to detect the presence of a dangerous flammable gas leaking. It has high sensitivity to propane, butane and LPG, also response to natural gas. [8] It is has low cost and suitable for different application.

Figure 3.8 MQ-6 gas sensor itself

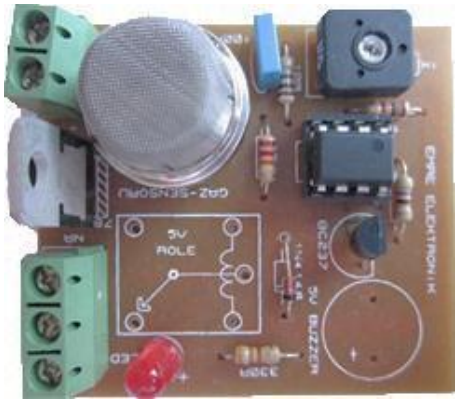

Figure 3.9 Gas detection circuit

Gas detection circuit in Figure 3.9 is prepared with MQ-6 gas sensor. It gives a simple on/off signal. When it detects a gas leaking it gives logic high to its output pin.

3.2. Scenario 1: Automatic Door Control System

The actor of this scenario is a disabled person who would lose his arms or would not use his hands because of old age. Because of his disability, he cannot use key to open and lock the door. When he comes home from outside, the door control system notices and recognizes him, and then opens the door automatically. When he enters into home, system locks the door again. The same scenario is also applicable for going out from home.

As shown in Figure 3.1, Door Control Node and two Motion Sensors connected to that node are placed at the door frame. One sensor is placed outside and other sensor is placed inside of home. Also, Sink Node is connected to computer and home automation program is running on computer. We assume the actor of this scenario is a member of this

house and his node's id is recorded in the database. The only need for him is to carry a pre-programmed WSN node.

In Figure 3.10 this scenario is summarized visually and the logic behind this system is described step by step.

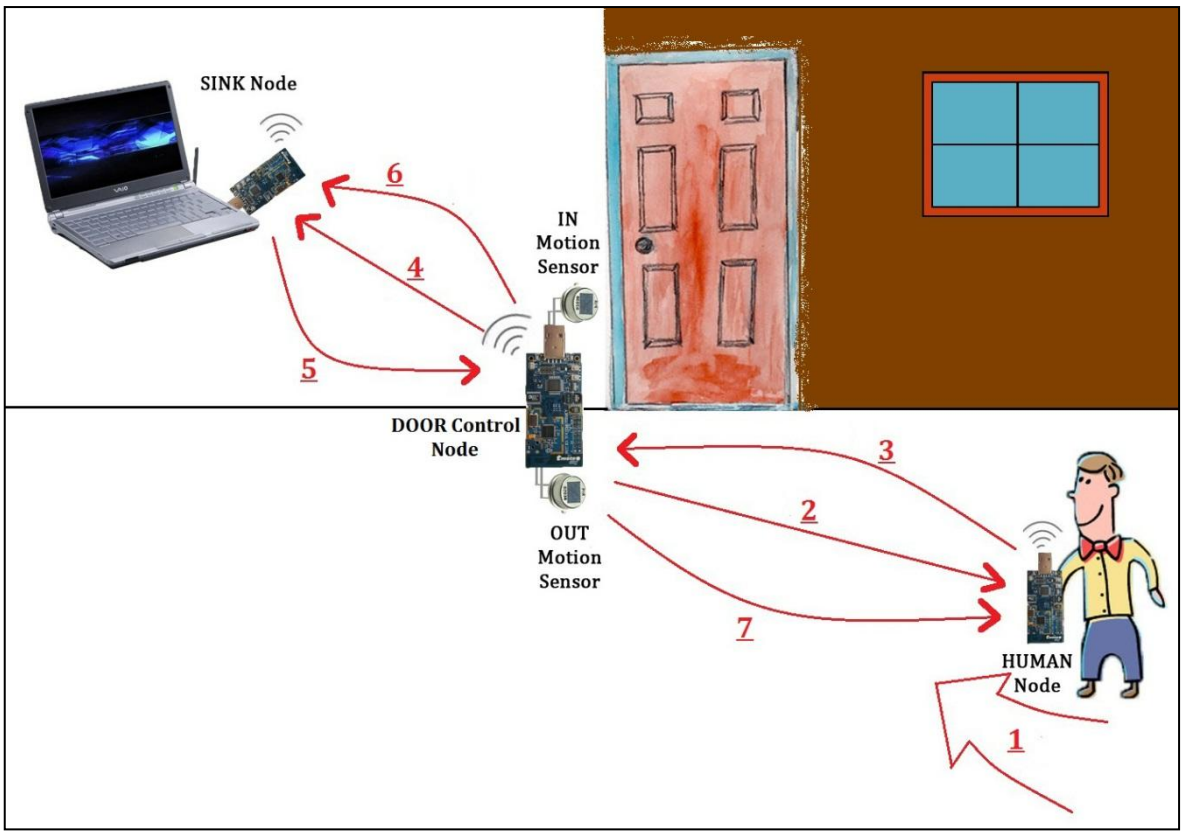

Figure 3.10 A figure of automatic door control system (Scenario 1)

Step 1: He is coming home from outside and approaching the door. When he is in the range of Out Motion Sensor, it detects the motion and interrupts Door Control Node. The meaning of this interrupt is that there is somebody outside of the door and wants to enter into home.

Step 2: When Door Control Node is interrupted by Out Motion Sensor, it broadcasts a radio message with minimum radio power. This message asks that question: "What is your id?".

Normally, every WSN node has an id and radio communication between two WSN nodes is achieved by sending message directly to other node's id. But broadcasting means that transmitting the message to all nodes over the area without knowing destination. The reason of broadcasting here is that Door Control Node does not know coming Human Node's id. It only knows that there is a motion at outside and somebody wants to enter into home.

The reason of broadcasting radio message with minimum radio power is to reduce radio distance. Because we do not want to transmit this message to other Human Nodes that are far away from door and not related with this scenario. With the help of this property, we provide transmitting broadcast to only related Human Node who wants to enter into home.

Step 3: Human Node receives "What is your id?" message from Door Control Node, then it sends back its id as an answer.

Step 4: Door Control Node receives the message that includes the coming human's id from Human Node. Then, it sends this id to Sink Node to learn if coming human is a member of this house or not. In other words, it wants to learn from Sink Node if it will open the door or not.

Step 5: When Sink Node receives the message from Door Control Node, it sends coming human's id to computer from serial port. Home automation program running on computer controls this id from database. If human is a member of this home and recorded in the database, Sink Node sends "Open Door" message to Door Control Node. Otherwise, it sends "Do Not Open Door" message.

If Door Control Node receives "Do Not Open Door" message, it does not open the door and the sixth and seventh steps do not occur.

If Door Control Node receives "Open Door" message, it opens the door and starts to wait 5 seconds for human to pass through the door. If nobody passes through door in 5 seconds, system locks door again. Sixth and seventh Steps also do not occur again.

Step 6: This step occurs if human enters into home after door is opened at Step 5. If In Motion Sensor detects a motion in 5 seconds, Door Control Node understands that human enters into home. After that, Door Control Node locks door and informs Sink Node about the action that human enters into home. Then, Sink Node informs computer about this action and home automation program logs this action to database.

Step 7: This step also occurs if human enters into home after door is opened at Step 5. In this step, Door Control Node informs Human Node about that he enters into home. Then, Human Node changes its state to "Inside" from "Outside".

The steps proceed in the same way when user wants to go out from home.

3.3. Scenario 2: Warning Deaf People With Vibration

This actuation aims to help deaf people. The problem for these people is that they are not aware of any sound in the environment such as doorbell. As mentioned in Section 3.1.4, a small vibration motor is connected to Human Node. The system enables to make aware of these people physically by driving vibration motor on Human Node when somebody pushes the doorbell button.

In Figure 3.11 this actuation is summarized visually and the logic behind this system is described step by step.

Step 1: There is someone at outside and pushes the doorbell button that is connected to Door Control Node. This action interrupts Door Control Node.

Step 2: Door Control Node broadcasts a message to other nodes. This message means that "There is someone at the door and doorbell is ringing!".

The message is received by Human Node and it starts vibration motor that is connected to node. The motor continues vibration during 5 seconds. Thus, deaf person is warned physically.

Also, the message is received by Sink Node. Then, an information message window pops up on computer screen that includes “There is somebody at door!” message as shown Figure 3.12. Also this action is recorded into database.

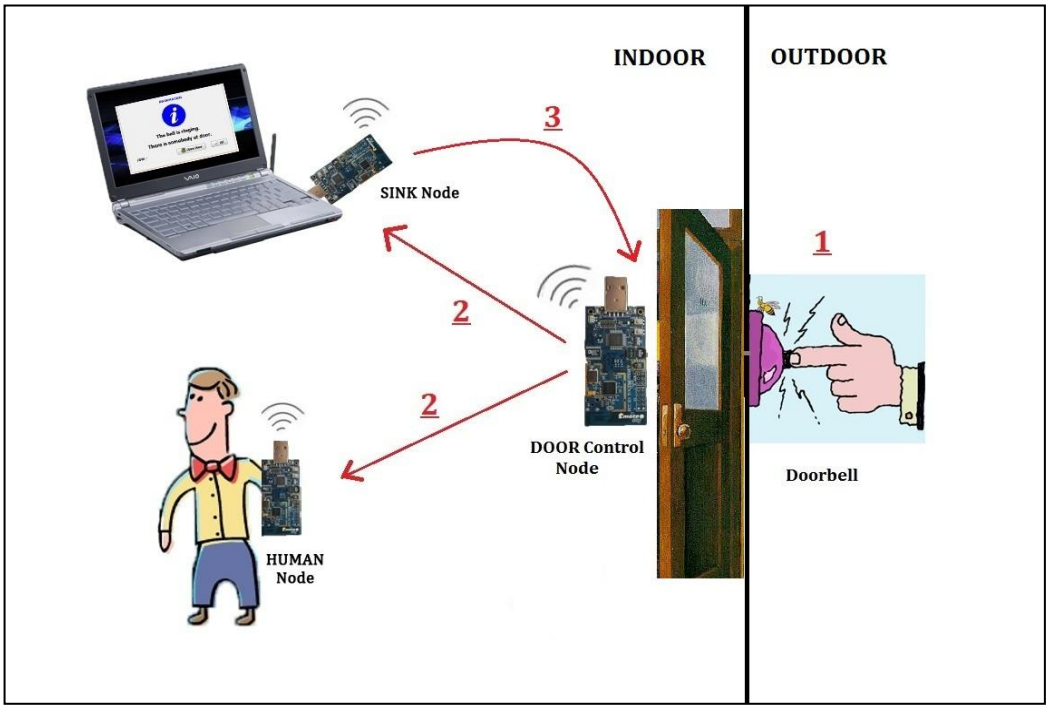

Figure 3.11 Warning Deaf Person with Vibration (Scenario 2)

Step 3: It is an optional step. It enables to open the door from computer screen by clicking a button. If the user click “OK” button on the information window, Step 3 does not occur. But if the user selects “Open Door” button, Sink Node sends a message to Door Control Node, and then it opens the door. After 5 seconds, it locks the door again.

Figure 3.12 Screenshot of information message window on computer

3.4. Scenario 3: Gas Detection For Alzheimer People

This scenario is prepared for Alzheimer diseased people. The problem for this people is that they forget what they are doing. Sometimes the forgotten event can be dangerous. For example, when they cook, they can forget the gas open and leave the kitchen. The system enables to warn this people when there is a gas leaking.

As mentioned in Section 3.1.3, Gas Detector Node is responsible for this actuation and a peripheral gas sensor circuit connected to it. If gas starts leaking, gas sensor circuit detects it and interrupts the node. Then, node broadcasts a warning message about gas leaking.

The message is received by Human Node and it starts to vibrate with vibration motor. The Sink Node also receives the warning message and a warning message window pops up on computer screen with alarm sound as shown in Figure 3.13. The warning notification is also recorded into database. Thus, Alzheimer person is warned with sound, warning message and vibration.

Figure 3.13 Screenshot of warning message window on computer

3.5. Graphical User Interface (GUI) Design

Graphical user interface (GUI) is a type of user interface item that allows people to interact with programs in more ways. A GUI offers graphical icons and visual indicators. The actions are usually performed through direct manipulation of the graphical elements. The GUI of our project is designed by Java programming language.

3.5.1. Main Menu

In our home automation program that is running on computer provides to manage all system and observe actuations done at home. It also enables to communicate with Sink Node and database.

Figure 3.14 Main menu of Home Automation Program

As shown in Figure 3.14, temperature, humidity and time is shown as real time applications in the main menu of program. Thanks to temperature and humidity sensors embedded in WSN Nodes, this information can be read and calculated. The calculation and calibration of temperature and humidity values that read from Sink Node will be described at Section 4 clearly.

There is also a home plan with the situations of WSN nodes. This picture changes visually when there is an actuation. For example, while someone is entering into home, this actuation is shown visually on home plan at same time as shown in Figure 3.15.

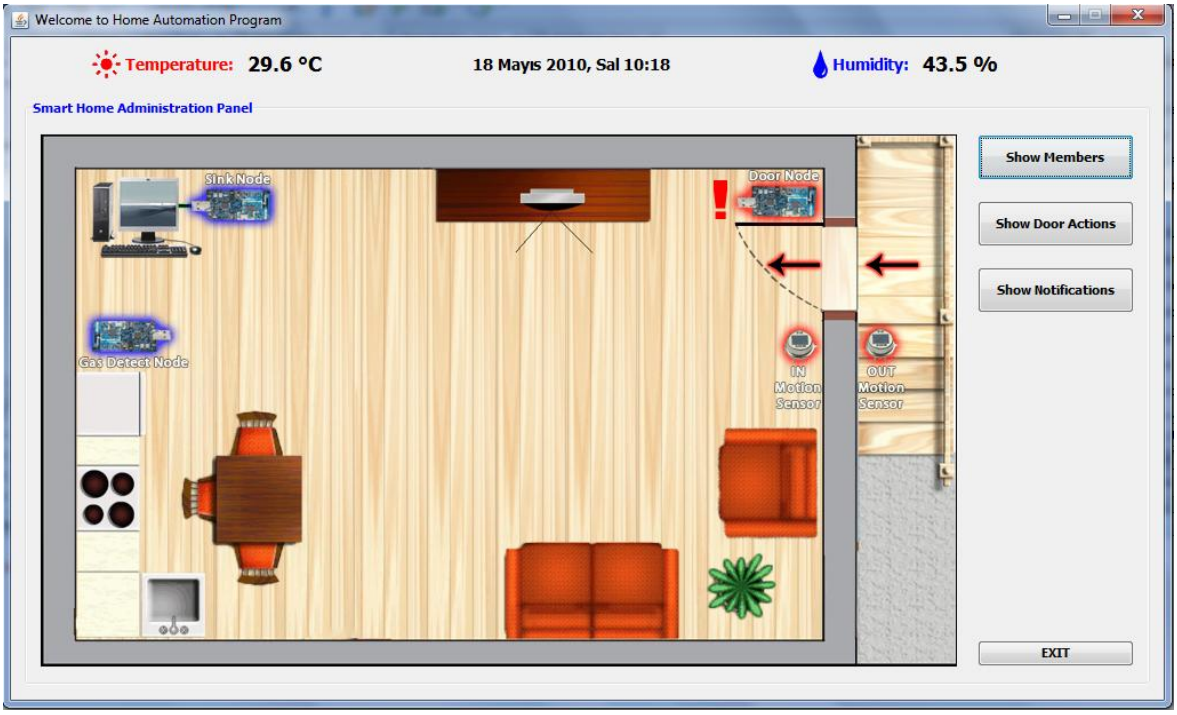

Figure 3.15 Changes at GUI while someone is entering home

3.5.2. Adding New Member

The people who live in smart home should record themselves into database. It means the ids of Human Nodes that are carried by house members should be recorded into database. If they do not record themselves, they cannot benefit from automatic door control system described at Scenario 1.

Actually, Human Nodes are pre-programmed WSN nodes and we assume that their ids are defined uniquely when they are manufactured. Thus, every Human Node has different id like uniqueness of traditional door keys.

To record Human Node into the database with GUI, user should press user button that is embedded in the node during 2 seconds. Then, Human Node sends a message to Sink Node and pop-up window appears on computer screen as shown in Figure 3.16.

Figure 3.16 Add New Member Window

After fill the first name and last name, user can add himself as a member of smart home. If user is added before, program does not allow adding himself again and warns user. The important thing is here that, ID textbox is not enabled to type and user cannot change the ID that is pre-defined in the Human Node uniquely.

3.5.3. Show Members Menu

Our program enables to see and edit members that are recorded before. User can remove member or change the information of members by using this menu. But it is restricted to change Node ID. Which members are at home and which members are outside can also be observed here.

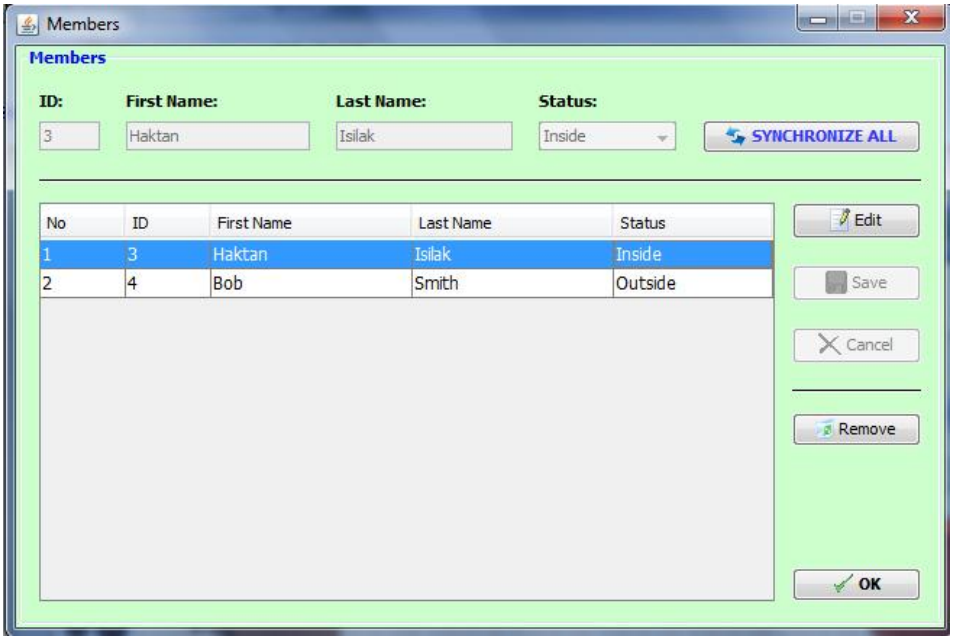

Figure 3.17 Show Members Menu

3.5.4. Show Door Actions Menu

This menu allows users to observe actions that are recorded by Door Control System. User can see coming and leaving times of the members.

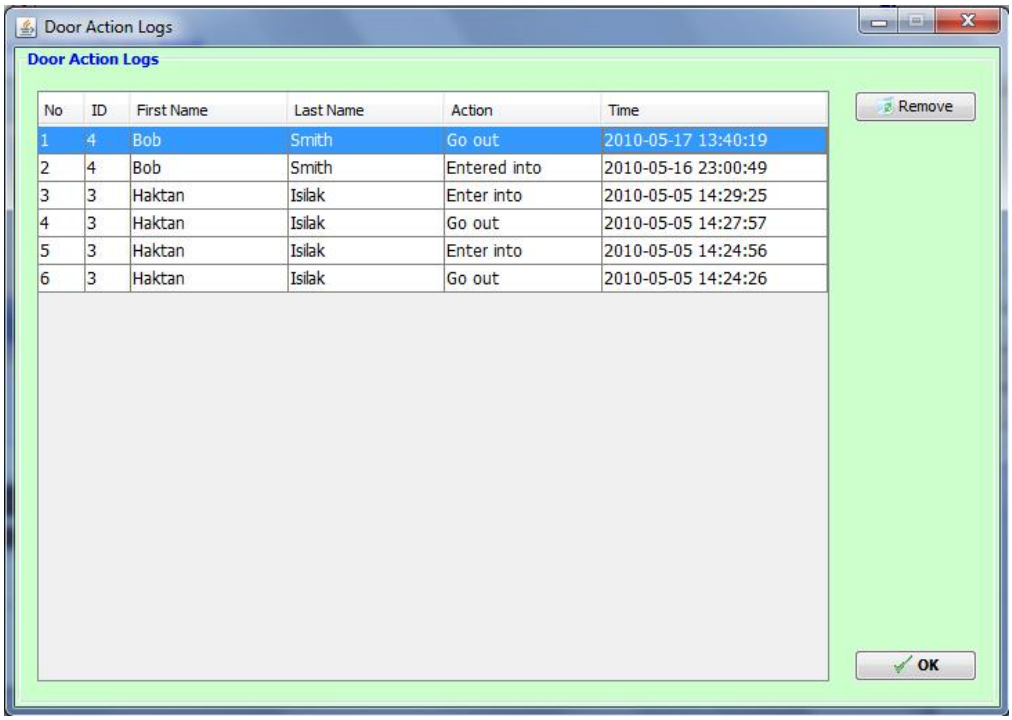

Figure 3.18 Show Door Actions Menu

3.5.5. Show Notifications Menu

This menu allows users to observe information and warning messages occurred before. When doorbell is ringing described in Scenario 2, this action is recorded as information message with time. When there is a gas leaking described in Scenario 3, this action is recorded as warning message.

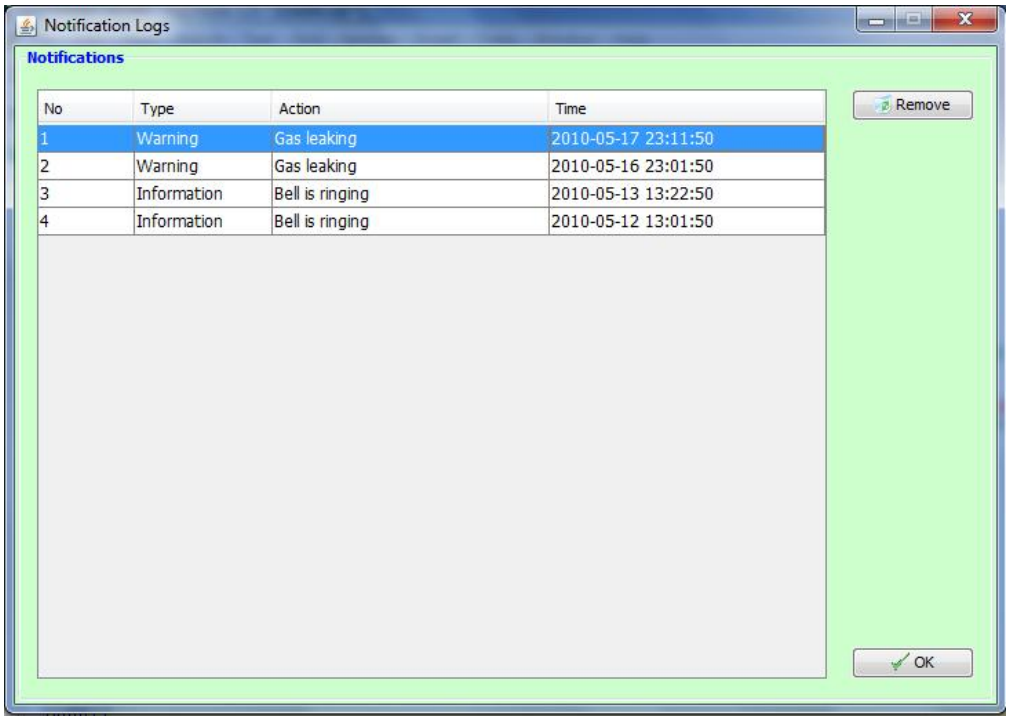

Figure 3.19 Show Notifications Menu

3.6. Database Design

Database normalization is known organizing data in a database. Eliminating the redundant data and making the database more flexible to new records are necessary methods in normalization techniques of databases.

In our project we did not deal with large number tables in database design, so we did not consider the normalization of our database necessary. In this subsection, we will briefly introduce and show the design schema of our database that resides in the server in Figure 3.20.

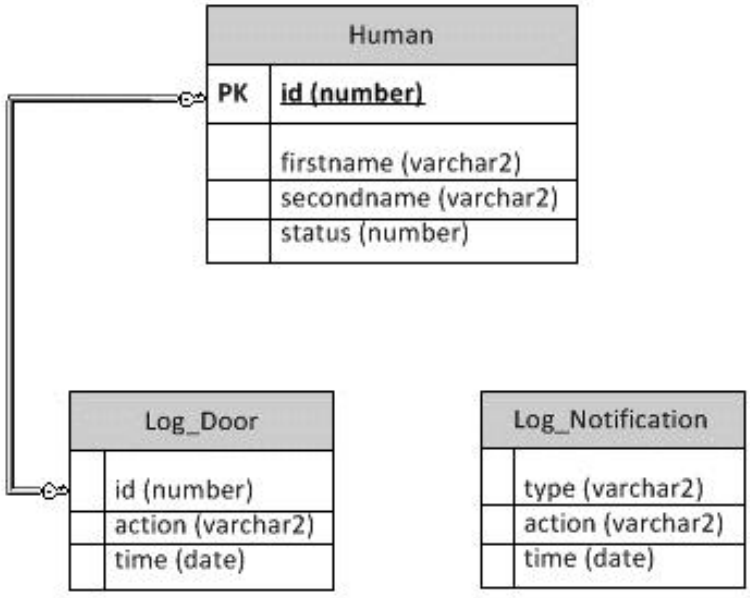

Figure 3.20 Database design and relationships between tables

Human table stores the members of smart home. When people add themselves as a new member, the information is recorded to this table. Id column at Human table is primary key, because each Human Node has different node id.

Log_Door table stores the actions that occur at Door Control System. When a member enters into or goes out home, member id and action is recorded to this table with time. The id column in this table is connected to id column at human table. Thus, there is a foreign key relationship between two tables.

Log_Notification table stores the information and warning notifications such as doorbell ringing and gas leaking. When one of them occurs, this information is recorded to this table with time.

3.7. State Diagrams

To describe the behavior of all WSN nodes in the system, simple diagrams are used to designate the interactions between devices and operations.

3.7.1. State Diagram Of Sink Node

Sink Node is connected to server computer and provides communication between computer and other nodes. Its state diagram is shown in Figure 3.21.

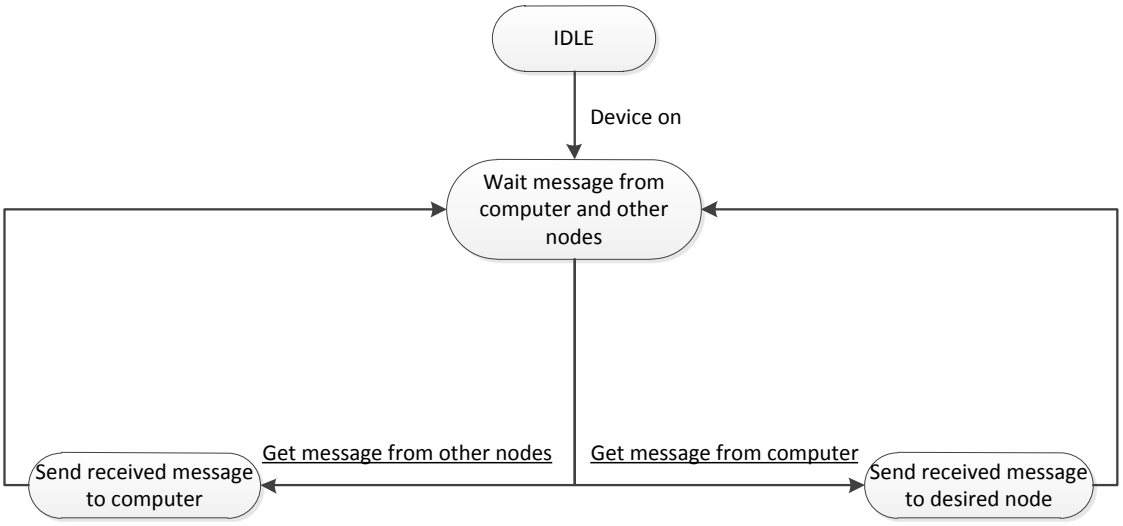

Figure 3.21 State Diagram of Sink Node

3.7.2. State Diagram Of Door Control Node

Door Control Node is responsible for automatic door control system and its state diagram is represented in Figure 3.22.

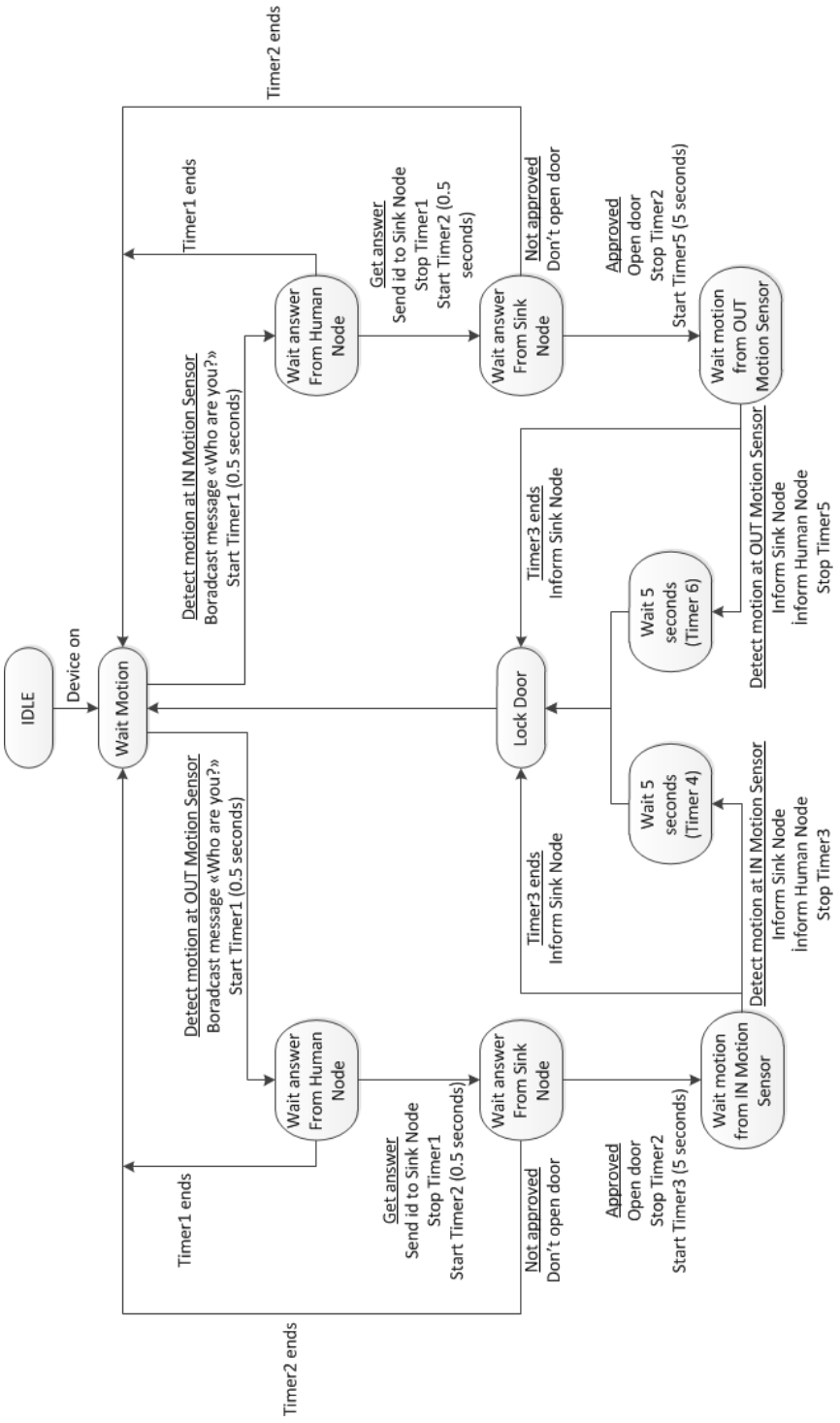

Figure 3.22 State Diagram of Door Control Node

3.7.3. State Diagram Of Gas Detector Node

This node is responsible for detecting gas leaking. Its state diagram is represented in Figure 3.23.

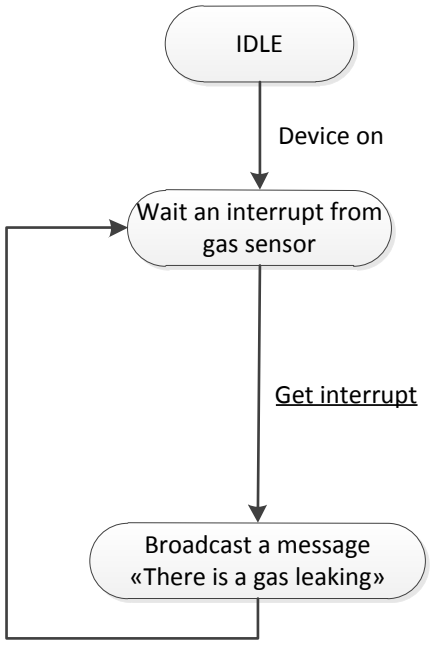

Figure 3.23 State Diagram of Gas Detector Node

3.7.4. State Diagram Of Human Node

Human Node is carried by disabled person to identify his identity and warn according to situation. The important thing here is that, Human Node's state changes according to position of it. If human enters into home, the state of Human Node changes to "IN State". If human goes out home, the state of Human Node changes to "OUT State". Its state diagram is represented in Figure 3.24.

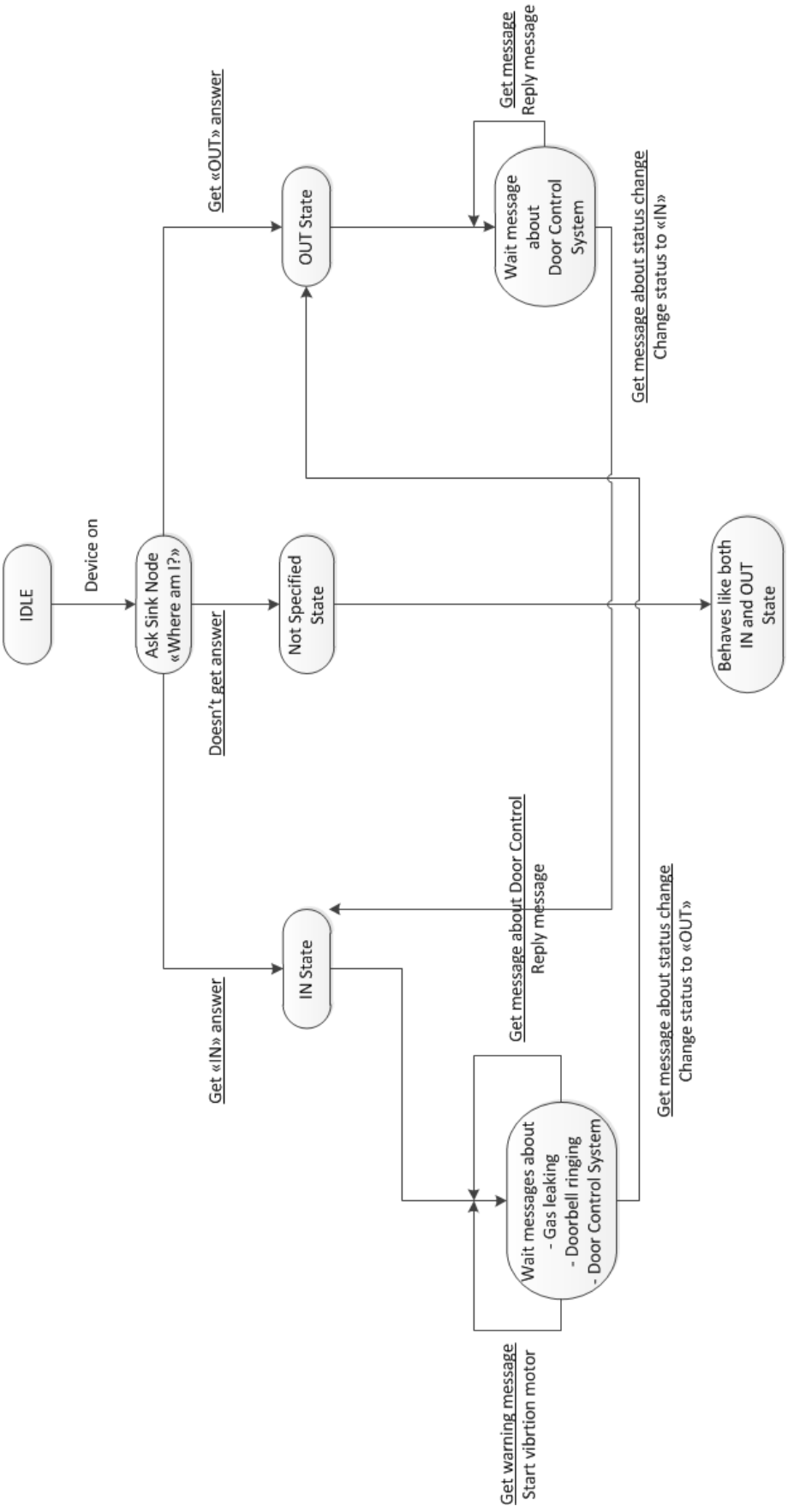

Figure 3.24 State Diagram of Human Node

4. IMPLEMENTATION

All of WSN nodes work with TinyOS that is an embedded operating system. TinyOS applications are written in nesC, a dialect of the C programming language optimized for the memory limitations of sensor networks.

Some components that are embedded on WSN nodes are shown in Figure 4.1. In the subparts of this section, implementation specifications of these components will be explained briefly.

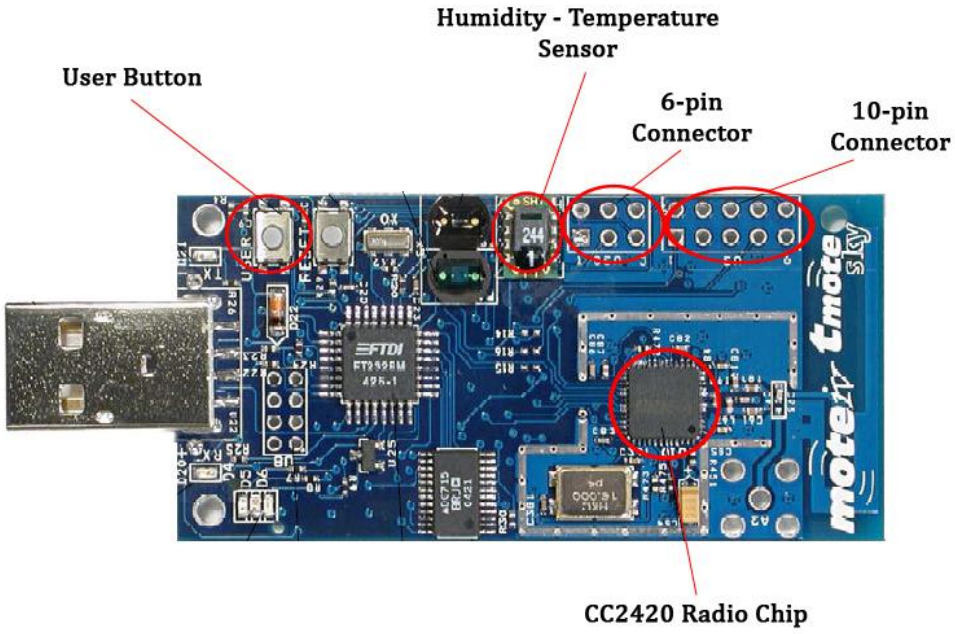

Figure 4.1 A WSN node with its components

4.1. Reducing Radio Power Of WSN Node At Execution Time

Wireless communication is provided with Chipcon CC2420 microchip that is embedded on WSN nodes. The CC2420 has programmable output power. Common CC2420 register values and their corresponding current consumption and output power are shown in Table 4.1. [5]

PA_LEVEL	Output Power (dbm)
31	0
27	-1
23	-3
19	-5
15	-7
11	-10
7	-15
3	-25

Table 4.1 Output power configuration for the CC2420

Changing radio power provides us to increase or decrease the transmission distance of radio message. Tmote Sky node is capable of setting radio power programmatically.

PA_LEVELs shown at Table 4.1 can be assigned as radio power in program. At PA_LEVEL 31, radio communication is done at maximum power. If there is no implementation written about radio power, default value 31 is assigned to WSN node.

Setting radio power can be done at compile time by adding code in Figure 4.1 to MakeFile. Makefile is a configuration file required for compilation and loading of written program to WSN node. It makes configurations of node which will be programmed.

```
CFLAGS += -DCC2420_DEF_RFPOWER=1
```

Figure 4.2 Code added to MakeFile to set radio power to level 1

But, we want to change radio power when actuation is being done. So, we need to change it in execution time. We achieved to set radio power to level 1 by writing some codes in Figure 4.3 and 4.4.

```
congifuration SampleApp {
}
implementation {
      components CC2420ActiveMessageC as CC;
      Sample.CC2420Packet -> CC;
}
```

Figure 4.3 Code written to Configuration file to set radio power

```
module Sample {
      uses interface CC2420Packet;
}
implementation {
      message_t packet;
      call CC2420Packet.setPower(&packet, 1);
}
```

Figure 4.4 Code written to Module file to set radio power

4.2. Calibrating and Reading Data From Temperature and Humidity Sensors

The WSN nodes are capable of sensing temperature and humidity by using sensors embedded on it. Codes are implemented to configuration and module files are described in Figure 4.5 and Fiure 4.6.

```
congifuration SampleApp {
}
implementation {
      components new SensirionSht11C() as SensorTempHum;
      Sample.ReadTemp -> SensorTempHum.Temperature;
      Sample.ReadHum -> SensorTempHum.Humidity;
}
```

Figure 4.5 Code written to Configuration file to sense temperature and humidity

```
module Sample {
      uses interface Read<uint16_t> as ReadTemp;
      uses interface Read<uint16_t> as ReadHum;
}
implementation {
      call ReadTemp.read();
      call ReadHum.read();
}
```

Figure 4.6 Code written to Module file to sense temperature and humidity

But, the data read from sensor should be calibrated to calculate real values of temperature and humidity. The equations described below shows how to convert values obtained from the sensors into International System Of Units. [9]

For Temperature, sensor returns a 14-bit value that can be converted to degrees Celsius:

(1) `temperature = -39.60 + 0.01*SOt` where SOt is the raw output of the sensor.

Humidity is a 12-bit value that is not temperature compensated.

`(2) humidity = -4 + 0.0405*SOrh + (-2.8 * 10^-6)*(SOrh^2)` where SOrh is the raw output of the relative humidity sensor

Using this calculation and the temperature measurement, you can correct the humidity measurement with temperature compensation:

`(3) humidity_true = (Tc - 25) * (0.01 + 0.00008*SOrh) + humidity`

where Tc is the temperature measured in degrees Celcius from Equation (1), SOrh is the raw output of the relative humidity sensor, and humidity is the uncompensated value calculated in Equation (2).

4.3. Programming User Button

There is a user button on WSN nodes to interact with user. It can be controlled programmatically when user presses and releases the button. Figure 4.7 and 4.8 shows the implementation of controlling user button in the program.

```
congifuration SampleApp {
}
implementation {
	components UserButtonC;
	Sample.Get -> UserButtonC;
	Sample.Notify -> UserButtonC;
}
```

Figure 4.7 Code written to Configuration file to use user button

```
#include <UserButton.h>
module Sample {
	uses interface Get<button_state_t>;
	uses interface Notify<button_state_t>;
}
implementation {
	event void Notify.notify(button_state_t val) {
		if (val == BUTTON_PRESSED) {
			// write what will be done when button pressed
		}
		else if (val == BUTTON_RELEASED) {
			// write what will be done when button released
		}
	}
}
```

Figure 4.8 Code written to Module file to use user button

4.4. Programming Expansion Connectors

WSN nodes have 6-pin and 10-pin expansion connectors to connect peripheral devices. These connectors can be used as both output and input. If you want to read data from a peripheral device, the pin connected to device should be implemented as input in the program. If you want to control a device such as opening and closing it, the pin connected to device should be implemented as output.

The functionalities of expansion connectors are shown in Figure 4.9. While 3rd, 5th, 7th and 10th pins of 10-pin expansion connector can be used as analog input and output, the 3rd and 4th pins of 6-pin expansion connector can be used as digital input and output.

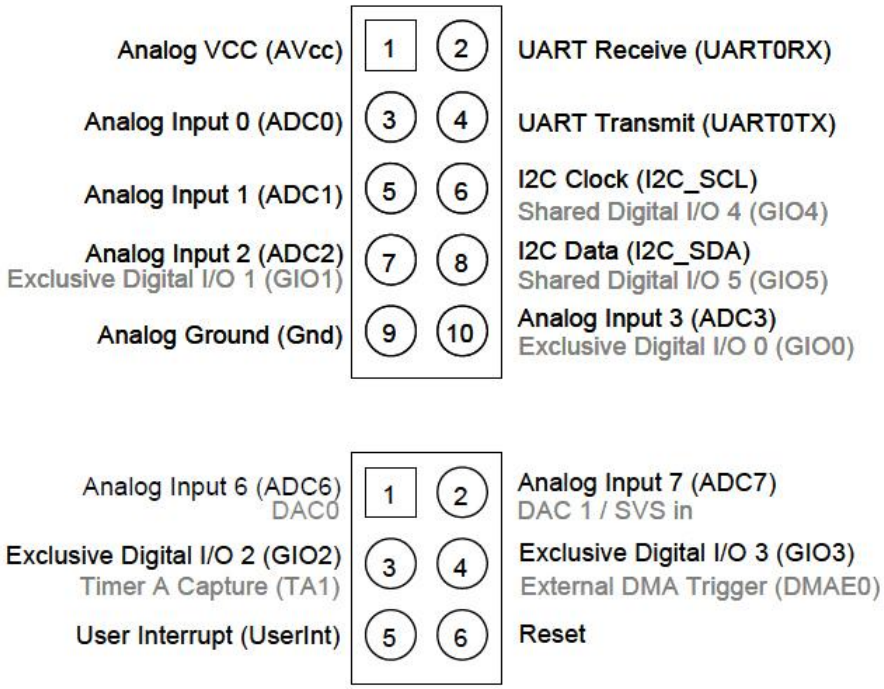

Figure 4.9 Functionalities of 10-pin and 6-pin expansion connectors

In the example implementation of the expansion connectors shown Figure 4.10 and 4.11, the 3rd pin of 6-pin expansion connector is used as input and the 5th pin of 10-pin expansion connector is used as output.

```
congifuration SampleApp {
}
implementation {
      components HplMsp430GeneralIOC as GIOC;
      components HplMsp430InterruptC as InterruptC;

      // 3rd pin of 6-pin expansion connector is used as input
      Sample.GIOIN -> GIOC.Port23;
      Sample.InterruptIN -> InterruptC.Port23;

      // 5th pin of 10-pin expansion connector is used as output
      Sample.GIOOUT -> GIOC.Port61;
}
```

Figure 4.10 Code written to Configuration file to use expansion connectors

```
module Sample {
      uses interface HplMsp430GeneralIO as GIOIN;
      uses interface HplMsp430Interrupt as InterruptIN;
      uses interface HplMsp430GeneralIO as GIOOUT;
}
implementation {
      command error_t Init.init() {
            call InterruptIN.clear();
            call InterruptIN.enable();
            call InterruptIN.edge(TRUE);
            call GIOIN.makeInput(); //make it input

            call GIOOUT.makeOutput(); //make it output
            call GIOOUT.set(); // make output pin logic high
            call GIOOUT.clr();// make output pin logic low
      }
      async event void InterruptIN.fired() {
            call InterruptIN.clear();
            /* write what will be done when input pin is interrupted /
            with logic high */
      }
}
```

Figure 4.11 Code written to Module file to use expansion connectors

5. TESTS AND RESULTS

5.1. Range Of Radio Distance

Table 5.1 shows the range of radio transmissions at different radio powers. Test is achieved by using Tmote Sky sensor nodes at outdoor.

PA_LEVEL	Transmission Distance (m)
31	182
27	180
23	170
19	155
15	96
11	72
7	35
3	13
1	1

Table 5.1 Range of outdoor radio transmissions at different radio powers

Thus, the WSN nodes become useful to communicate at different distance. In this project, we set PA_LEVEL to 1 at the first step of Scenario 1 and it enables us to use WSN nodes like RFID badges.

5.2. Range Of PIR Sensor

In this project, we used PIR sensors to detect the person who approaches to the door in Scenario 1. We placed PIR sensors at the door frame. One of them is placed outside of the door, other one is placed inside of the door. The aim of this test is to see detection range of PIR sensors.

Normally, if there is no obstacle in front of the sensors the tested range is as shown in Figure 5.1.

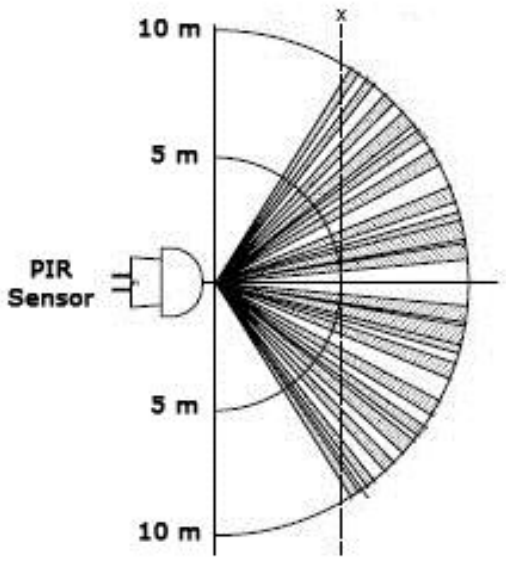

Figure 5.1 Range of PIR sensor if there is no obstacle

As shown in the Figure 5.1, the detection range of PIR sensor is approximately 10 meters to forward, 8 meters to left and right side of the sensor. However, in our project we need to reduce this range. Because we do not want to detect motion that occur too far from the door. To achieve this aim, we placed PIR sensor adjacent to the wall and we also covered front of the sensor eye with a small cap. Thus, we reduced to the range of sensor approximately 1 meter as shown in Figure 5.2.

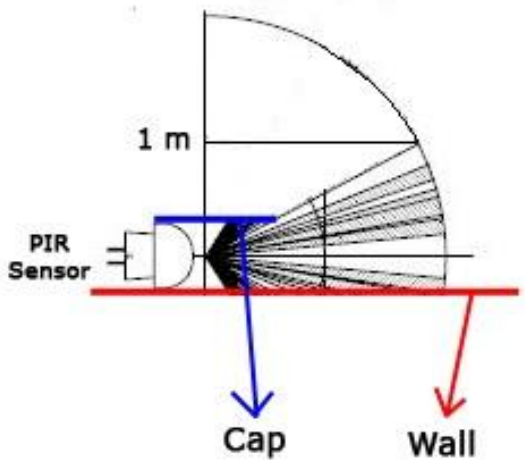

Figure 5.2 Range of PIR sensor is reduced with obstacles

5.3. Test Of Scenario 1

After designing and coding all WSN nodes, it is time to test our project in real environment. Thus, we designed an experimental test bad where the nodes are placed at suitable positions as shown in Figure 5.3.

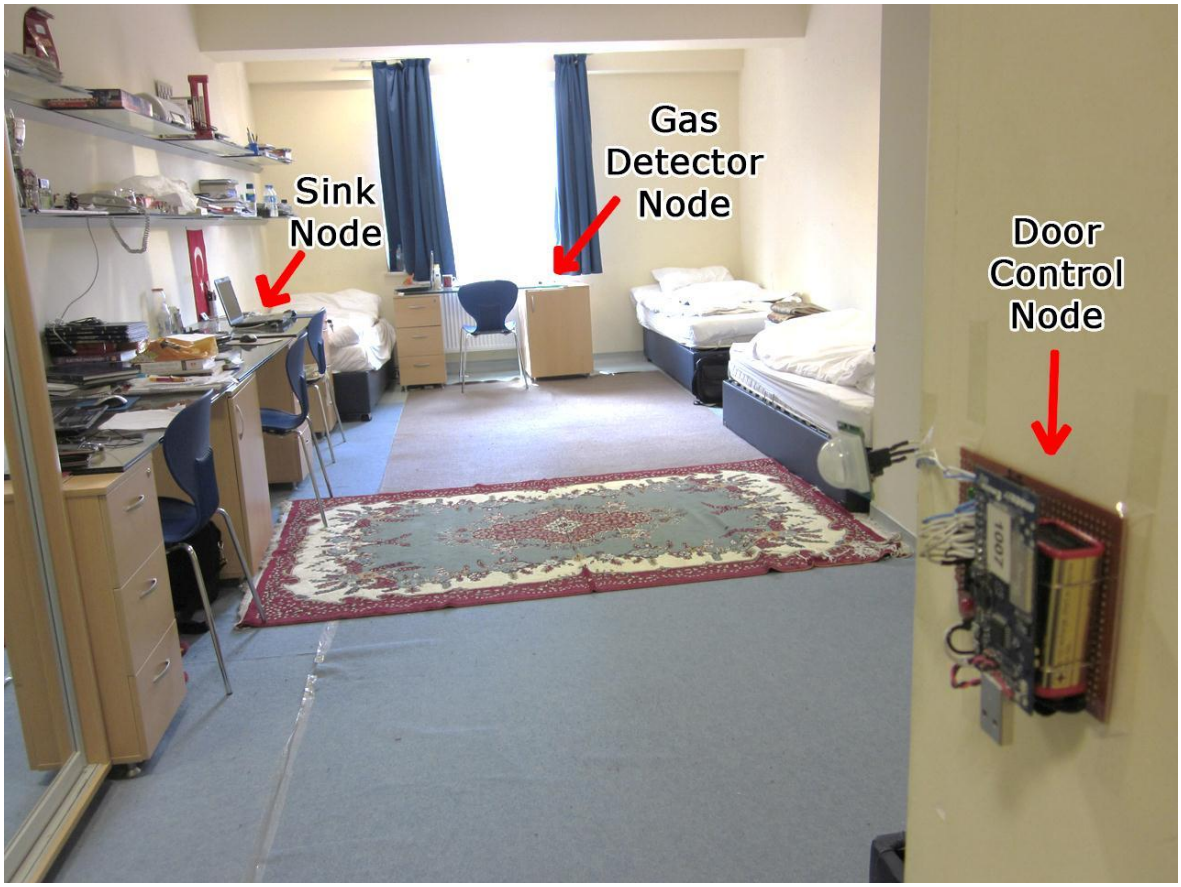

Figure 5.3 Experimental test bad

Firstly, we added user into the database as a member of house. When user pushes the user button of Human Node during 2 seconds, pop up window appeared on computer screen that includes the id of Human Node as shown in Figure 3.16. When we tried to add pre-added user, the program did not let to add this user again. We observed that it works successfully.

Then, we tried to go out from home. When we became closer to door, In Motion Sensor detected us and Door Control Node made a broadcast with low radio power that is

asking the question: “Who are you?”. Only Human Nodes that are at “Inside” state and close enough the door could answer this question. Human Nodes that are at “Outside” state could not answer this question.

Because of the low radio power communication at this step, sometimes Human Node cannot receive this message at the first time and there may be a packet loss. But, the packet loss is not important here because user is waiting near the door and PIR sensor detects the motion continuously. If there is a packet loss and Human Node cannot receive the message, PIR sensor detects a motion again and Door Control Node broadcasts same message again and again in every 500 msec.

In Figure 5.4, we tried to describe briefly the aim of reducing radio power. There were some people that are at “Inside” state and there was a person near the door who wants to go out from home. When the person approached the door at least 1 meter, only this person could receive the message that is broadcasted by Door Control Node. Other people inside the home did not hear that message and did not answer because of low radio power.

Figure 5.4 Aim of reducing radio power in Scenario 1

After Human Node answered the message back to Door Control Node, it sent the id of Human Node to Sink Node and started to wait a command to open or not open the door. If Door Control Node cannot receive the message from Sink Node in 500 msec, the system starts from the first step again and continue. But, in our tests we did not observe any packet loss at this step. Because we sent these messages at maximum radio power.

When Door Control Node received “Open Door” message from Sink Node, it opened the door for 5 seconds. When we did not walk through the door, Out Motion Sensor did not detect any motion and system understood that user did not go out and locked the door after 5 seconds. When we walked through the door, Out Motion Sensor detected a motion and understood that user went out and locked the door again.

When user went out, this action was sent to Sink Node to record into database and to Human Node to change its state from “Inside” to “Outside”. The same steps occur when user wanted to enter into home.

There is a different situation that should also be considered. What will the system do if more than one people want to enter into or go out home at same time? In this situation, system behaves like one person is waiting near the door. Door Control Node communicates only with one Human Node that answer the “Who are you?” message first. And only its state is changed. But after 5 minutes the action has been occurred, Sink Node starts to check the members who are recorded in the database by asking this question: “Can you hear me?”. Then the states of members who answer this question are changed into “Inside” state in both database and Human Nodes. Thus, system corrects itself automatically due to the possibility of errors.

5.4. Test Of Scenario 2

The aim of this scenario is to help deaf people by vibrating them physically when there is someone ringing the doorbell. When we pushed the doorbell button, all Human Nodes that are at “Inside“ state start to vibrate. Human Nodes that are at “Outside” state

and may be near the door from outside did not vibrate themselves. Because we only want to warn people who are at home.

Also, the information message window popped up at computer screen. When, user open the door by clicking the “open door” button, the door is opened and locked after 5 seconds again.

When we entered “Show Notifications Menu” in the program, we can see this information message with time when it is occurred.

5.5. Test Of Scenario 3

This scenario is developed for Alzheimer people. We aim to detect gas leaking near the oven in the kitchen. Because Alzheimer people can forget the gas open and it can cause dangerous accidents. We designed the system that includes Gas Detector Node and gas sensor hardware as shown in Figure 5.5.

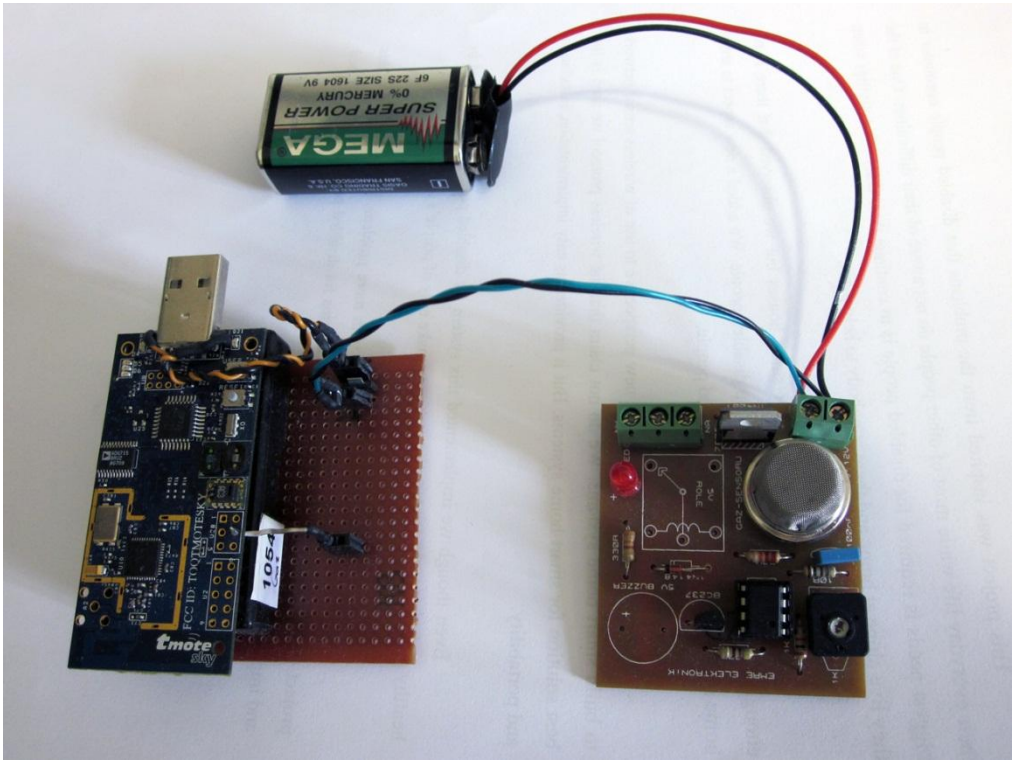

Figure 5.5 Gas Detector System

When we tested the sensitivity of gas sensor, we observed successful consequences. It detects the gas leaking very fast when gas reaches to surface of gas sensor.

After that, Gas Detector Node made a broadcast about gas leaking. Human Nodes that are at “Inside” state and Sink Node received this message. Human Nodes started to vibrate themselves and warning message windows popped up at computer.

When we entered “Show Notifications Menu” in the program, we can see this warning message with time when it is occurred.

5.6. Performance Analysis

Working scenarios were tried for many times. Figure 5.6 shows comparison of each scenario for their success in 20 trials execution.

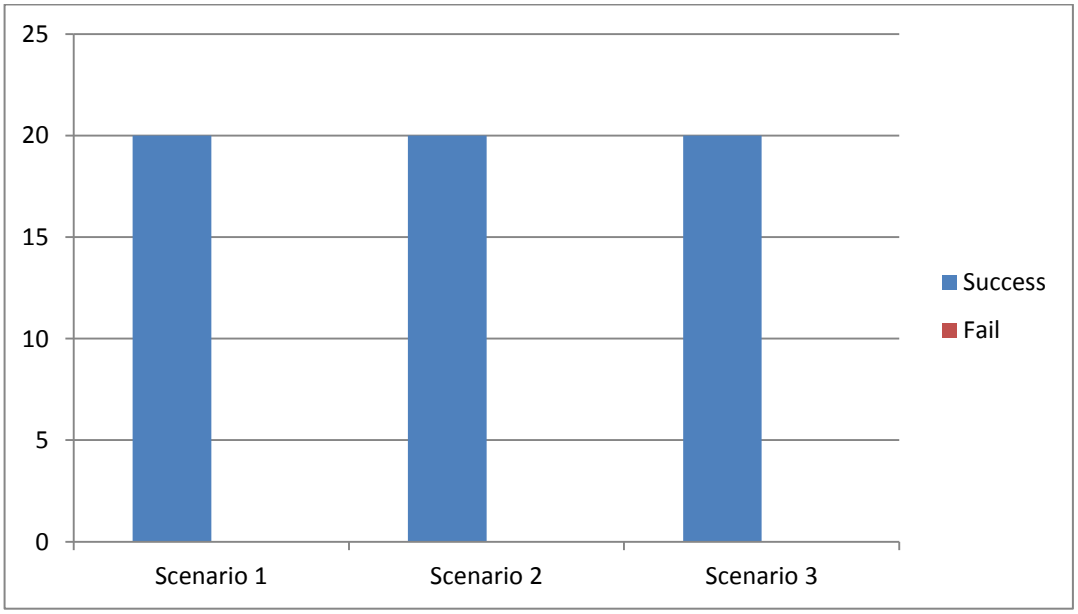

Figure 5.6 Comparison of each scenario for their success in 20 trials

5.7. Reliability Of The System

From the previous subjection with the test results we can trust the system. In our project we didn’t make further efforts to provide more reliability of the system. All wireless communications that are in this project, would give enough reliability for data transmissions.

6. CONCLUSION AND FUTURE WORK

This project was inspired from the problems that disabled people encounter in their everyday life while most of other people do not aware of their difficulties. One of the biggest needs required for disabled people is to continue their daily life activities when they are alone at home and there is nobody to help them.

There are many studies about smart houses but we observed that there is not enough smart home system aims to help disabled people. We added a new aspect to smart home systems by aiming to help disabled people.

In this project we suggested a new perspective to use of wireless sensor network to build smart home systems. We do not claim that the wireless protocol we used is the best solution for smart home systems. But it provides us easy implementation, installation and portability.

After designing and implementation works finished, whole system is tested and we obtained successful results.

Even though we implemented this system for disabled people, it can be used by healthy people. Because this system aims to make easy of people's daily life at home.

Actually disabled people encounter with more problems than mentioned in this project. For the future work, the actuation scenarios for disabled people can be increased and improved.

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