



SAVONIA

Home Automation

Smart home technology and template house design

Zeya Zheng

Bachelor's Thesis

Bachelor's degree (UAS)

| | | | |
|---|------------|------------------|----|
| Field of Study Technology, Communication and Transport | | | |
| Degree Programme Degree Programme in Industrial Management | | | |
| Author(s) Zheng Zeya | | | |
| Title of Thesis Home Automation | | | |
| Date | 01.06.2013 | Pages/Appendices | 49 |
| Supervisor(s) Harri Heikura | | | |
| Client Organisation/Partners | | | |
| <p>Abstract:</p> <p>In this thesis, home automation's general knowledge, technology information and each component will be introduced to the reader in the first half of the whole thesis. In the second half, thesis includes the Home Automation template design and market competitiveness analysis.</p> <p>The author assumes that the reader is going to spend lots of money to have a smart home. In this situation, the author introduces the home automation to the reader at each component. So the reader in this thesis actually is like a customer, the author in this thesis is like a salesman. Finally, the author will tell the reader which facility and equipment should be bought because of home automation project, and the entire home automation project's price will be clearly showed as well.</p> <p>This thesis helps a lot of people who are willing to decorate their home into a smart atmosphere. After reading this thesis, you will understand what is home automation, how many necessary components there are, how does this work, where to buy it and how much does it cost.</p> <p>The author totally believes that this thesis will be a useful guide for people who want to have their own home automation. It will also help spread the scientific and technological knowledge about home automation.</p> | | | |
| Keywords | | | |
| Home automation, Smart home, Digital Home, Smart living atmosphere, Smart device. | | | |

CONTENTS

| | | |
|-------|--|----|
| 1 | INTRODUCTION | 5 |
| 2 | BACKGROUND INFORMATION..... | 6 |
| 2.1 | Home automation history | 6 |
| 2.2 | Situation today | 7 |
| 2.3 | Future home | 9 |
| 2.4 | Entire elements of Home automation system | 12 |
| 2.5 | The main content in this thesis | 14 |
| 3 | THEORETICAL FRAMEWORK..... | 16 |
| 3.1 | Wireless control system..... | 16 |
| 3.1.1 | Introduction of ZigBee and IPv4 | 16 |
| 3.1.2 | Communication between Home Gateway and Appliances..... | 19 |
| 3.1.3 | Device protocol and programming | 21 |
| 3.1.4 | Energy management in wireless control | 22 |
| 3.1.5 | LONWROKS | 24 |
| 3.2 | Facilities and equipment in automatic home..... | 25 |
| 3.2.1 | Controller | 25 |
| 3.2.2 | Receiver | 26 |
| 3.2.3 | Terminal equipment | 27 |
| 4 | TEMPLATE HOUSE DESIGN..... | 28 |
| 4.1 | Heating, ventilation and air condoning (HVAC) | 28 |
| 4.2 | Lighting control system | 33 |
| 4.3 | Multi motion background mucic | 34 |
| 4.4 | Home theatre and entertainment room..... | 35 |
| 4.5 | Automatic shading | 36 |
| 4.6 | Safety, security and monitoring..... | 37 |
| 4.7 | Energy management..... | 38 |
| 4.8 | Arrangement of wire | 39 |
| 4.9 | An example of curtain installation | 40 |
| 5 | MAINTENANCE AND SERVICES | 28 |
| 5.1 | Standby unit | 42 |
| 5.2 | Maintenance book | 42 |
| 6 | EXPENSES AND MARKET COMPETITIVENESS | 43 |
| 6.1 | Total purchased cost of equipment..... | 43 |
| 6.2 | Budget of labour..... | 43 |

| | |
|---|----|
| 6.3 Market competitiveness analysis | 44 |
| 7 RESULT | 45 |
| 7.1 Benefits of the system | 45 |
| 7.2 Disadvantages | 45 |
| 8 CONCLUSION | 46 |
| REFERENCES..... | 47 |

1 INTRODUCTION

Home automation is similar to smart home, digital home, e-home and intelligent household. They both mean a high living condition with many smart devices.

It is the residential extension of building automation which is using automation technology, computer technology and telecommunication technology to give the user a developed living condition, entertainment and security. It helps people to reduce house working and household management by its automation and loop system. (Teenage, 2009)

In this thesis, the word *Home automation* is equal to *Smart home*. They both mean a technical high living condition with smart, intelligent and automatically interactive device and the central control system. When author use home automation, it tends to designer and builder, smart home tends to user and dweller.

The final targets of this thesis is to create an automatic home solution which is described in Chapter 4, 5 and 6. Those chapters will tell the reader that what kinds of appliances will be used for home automation, how widely they are used, which company produces them and where to purchase them. For freshman, this helps will know home automation better. For some specialized worker, this will give lots of useful information for their work and broaden their horizon.

To some extent, this thesis plays a more or less constructive role to world automation developing process. The reader will ultimately find that home automation is such interesting, useful, practical and near!

2 BACKGROUND INFORMATION

We will talk about home automation's history, situation today and future home in this chapter. The entire elements will be also showed on a list. Finally, the reader will be told which chapter is the core of this thesis. It will help the reader to have a purposeful reading.

2.1 Home automation history

Home automation technology and Smart home appeared very much in science fiction of the 1920s. But no one knows the exact date of the invention of home automation. Based on human's smart technology improving process, the home automation system does not come by immediate invention. It comes step by step with only insignificant improvement. The previous step is almost same with the next step. (Harper, 2003)

The first time people noticed the high technology in dwelling, they did some connection with home automation, it was 1960s. It was called "wired homes" at that time. It was built by some hobbyist. After that, the first official name of home automation appeared in 1984 by the American Association of House Builders. This development is the key to the modern smart homes. (Smith, 1988)

People at that time understood that a smart home is not owing to how well it is built, not how effectively it uses space, not due to how it is environmentally friendly. It is only because of how interactive technologies that it contains. Those are still useful rules for home automation technology today. (Smith, 1988)

In the 1960s, there were not so much interactive technologies. Even though Stanford University researched a lot of this kind of technology, they didn't become so successful. They concluded some principal reason for not succeeding is scientific research.

- a) Lacking of motivation to increase productivity in domestic work
- b) Less involvement of users of the technology in the design process
- c) The view held by product designers that domestic technology is unexciting
- d) A continued focus on stand-alone appliances in the design of new technology

(Harper, 2003.)

For marketing and technical purposes, those four factors mentioned above have become smart home industry's chance and challenge nowadays. In this thesis, smart home template design is also kept in author's mind.

2.2 Situation today

Nowadays home automation is a significant symbol of the human society civilization. The first automation facility which entered into people's home was the automatic washing machine, automation air-condition and so on. (Teenage, 2009)

When people think about home automation, most of them may imagine living in a smart home: One remote controller for every household appliance, cooking the rice automatically, starting air conditioner automatically, heating water for bath automatically and shading the window automatically when night coming. To some extent home automation equals to smart home. They both bring out smart living condition and make our life more convenient and fast. (Teenage, 2009)

Home automation satisfies the resident's needs and desires by adjustable light, temperature, ambient music, automatic shading, safety & security, even arrangement of wire. Home automation technologies are the latest fascination with housing mechanism. However, with the appearance of new electronic technologies and their combination with older, traditional building technologies, the smart home is at last becoming a reality. (Harper, 2003.)

The basic idea of home automation is to monitor a dwelling place by using sensors and control systems. Through adjustable various mechanisms, user can enjoy customized heat, ventilation, lighting, and other servers in living condition. The more closely adjust the entire living mechanical system and loop control system, the intelligent home can provide a safer, more comfortable, and more energy economical living condition. (Harper, 2003.)

For example, a home automation unit can notice that when the dweller is sleeping, the light is switched down or off, and the temperature control unit is switched down. According to the clock that dweller made, the home automation control unit can lift the curtain automatically and play morning music. It can also monitor the security

and fire alarm. In some countries, there are no district heating, home automation control unit can preheat water for bathing or washing. (Teenage, 2009)

Nowadays people are very familiar with Smart Phone, which gives user intelligent phone service. Smart home is similar like smart phone. It gives dweller smart living service. If you haven't experienced a smart home, you'll never know how amazing feeling dwelling ever could be. Even though you do not have this kind of experience, you do not need to be regretful. With pictures, this thesis will lead you to a smart home world.

The following picture, Figure 1, be said illustrates private smart home design and its location. However, it has to be said it's a very normal home automation. In some developed countries, people have this kind of level home automation, they even didn't notice about home automation. However, for people living in developing country's view point, wireless dimmer with Apple Company's air player is quite good home automation. (Ekon, 2013)



Figure 1. Normal private smart home design. (Ekon, 2013)

The following picture, Figure 2, illustrates the modern smart home in structural level. In this structure, PC and smart cell phone are internet remote controls. They go through the internet to dweller's intranet and the control device such as visitor panel, electric lock, security module, monitoring. In the home, dweller can use remote

controller or digital smart device like pad on the wall to control smart windows, electric curtain, lighting, air-condition, and background music. (Bechamp, 2013)

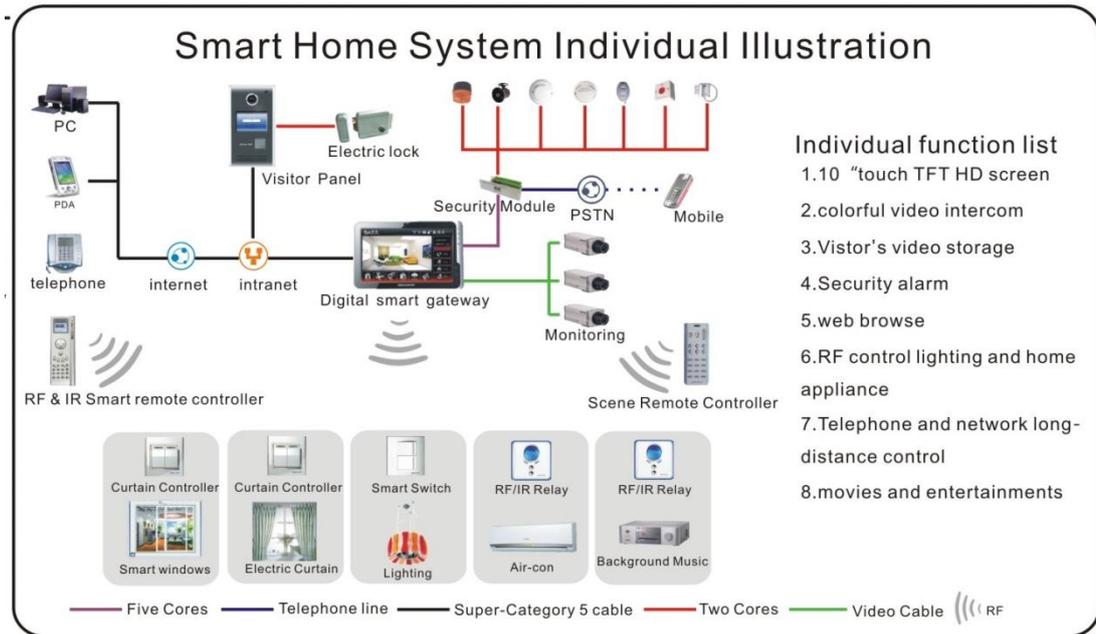


Figure 2. Smart home system individual illustration (Bechamp, 2013)

2.3 Future home

In the future, home automation will be as popular as mobile phone. Some specialist predict that to happen the 15 years. Every family will use smart home technology such as the central control system of household appliances, Wi-Fi controlled light and remote monitoring. Some optimistic expert even predict less than 15 years smart home will be as popular as smart phone. (Tencent, 2013)

There will be a system that can control all the household appliances. Now, Microsoft Company is testing a system that can control all the household appliances. The idea of this operating system is that dweller can control all the household appliances through by PC or smart phone. (Tencent, 2013)

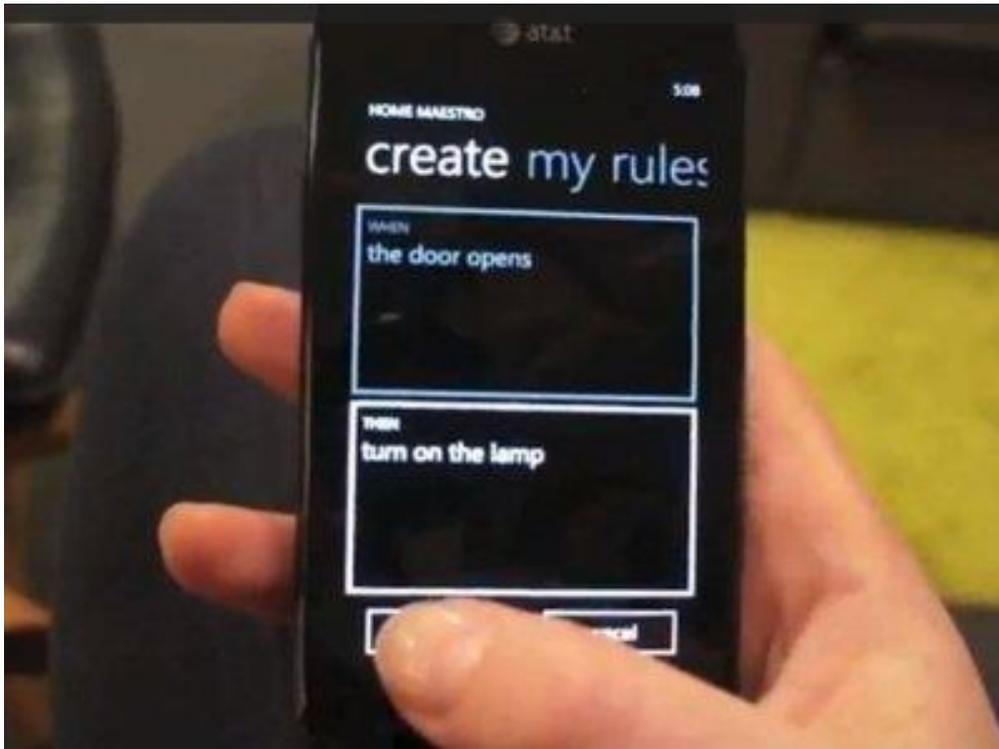


Figure 3. Central control system operated on the smart phone (Tencent, 2013)

Personal robot will become the modern family butler. Bossa Nova Robotics company has developed a smart robot named MObi. It almost can afford the work of a private secretary. It can use Skype by robot MObi, and clean the future home. This company wants to put this robot to the market at the end of 2013. The price is around 5000 dollars. (Wired, 2013)



Figure 4. MObi robot in the future home (Wired, 2013)

With the improvement of high technology of smart home, in the future, screen refrigerator will let you live more conveniently. Now, Samsung, LG Company and so on are going to develop screen refrigerator. In the previous Consumer Electronics Show (CES) Samsung Company demonstrated a smart screen refrigerator which uses android system. People can use this refrigerator to manage food, and buy food online. Depending on the food in the refrigerator, it can also provide a recipe for the user. (Tencent, 2013)



Figure 5. Smart shopping used in screen refrigerator (Tencent, 2013)

Touch screen will be everywhere. In the future, table cabinet, mirror, refrigerator, oven will also have a touch screen. They all will have a smart system, where people can download applications for their household appliances. (Tencent, 2013)



Figure 6. Touch screen will be everywhere. (Tencent, 2013)

2.4 Entire elements of Home automation system

Future is always full of surprises. However, we must face the reality. Home automation nowadays is not as cheap as every home we own. Some component like Wi-Fi dimmer is cheap, but some component like house central control system is expensive. The following picture is the host machine of the central control system. In the Chinese market, it costs around 5000 Euro. (Taobao, 2013)



Figure 7. Host machine of central control system (Taobao, 2013)

There is no doubt that the host machine of central control system is the most important element of Home Automation. After this, I will introduce other elements in the following list. Before you transform your house into home automation, you must take these things into consideration.

Cable and structured wiring products

- Connectors
- Router and modem
- Batteries
- Rack mount
- Structured panels
- Wire and cable management tools

Cameras and surveillance

- Cameras
- Surveillance screens
- Video monitoring kits
- Video recorders

Dimmers, lighting and appliance control

- Dimmers, wall switches, keypads and touchscreens
- Handheld and table top remotes
- Light bulbs, light fixtures
- Plug-in / screw-in modules or wire-in / outlet modules
- Technology bridges / converters

Door locks, access control and Security

- Door and gate access
- Garage door control
- Motorized gate & door control
- Vaults & mailboxes
- Intercoms
- Remote monitoring & control

Solar and energy management

- Automatic lighting
- Power monitoring and appliance efficiency
- Remote-control windows and coverings
- Solar panels
- Water and sprinkler management
- Heat pump

Speakers, a/v and home theatre

- Home theatre accessories
- Display screens or projector
- Speakers
- Volume controls and speaker switching
- Multi background music

Thermostats and HVAC controls

- Air filters
- Humidity sensing and control
- Temperature sensors and controllers
- Ventilation
- Weather stations and sensors

(Smart, 2013)

2.5 The main content in this thesis

In this thesis, the main content is technology information about ZigBee wireless transmission, heating system and ventilation.

ZigBee technology will be introduced in Chapter 3 verses 1, Wireless control system. All the information was researched by the knowledge related to the previous materials made by wireless professor hobbyist. In the end of this chapter, you can also find some comparison with Wi-Fi, Bluetooth, and ZigBee. LONWROKS will be also featured as a new communication technology. (Zou 2011)

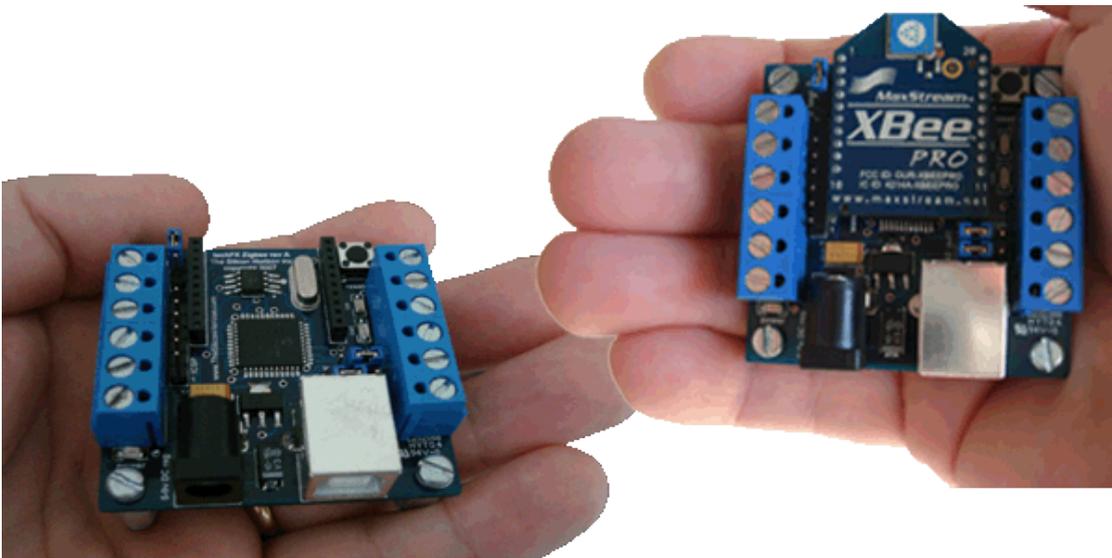


Figure 8. ZigBee, 802.15.4 wireless Networking Controller (Telecommunication, 2013)

Ventilation and heating system will be introduced in Chapter 4 verses Heating, Ventilation and Air Conditioning (HVAC). All the information was researched by the knowledge related to my previous course: Thermodynamics, Process Technology, Energy Technology, Manufacturing Automation and Environmental Technology. Some materials are found at some ventilation company's magazine and report. (Technology, 2013)

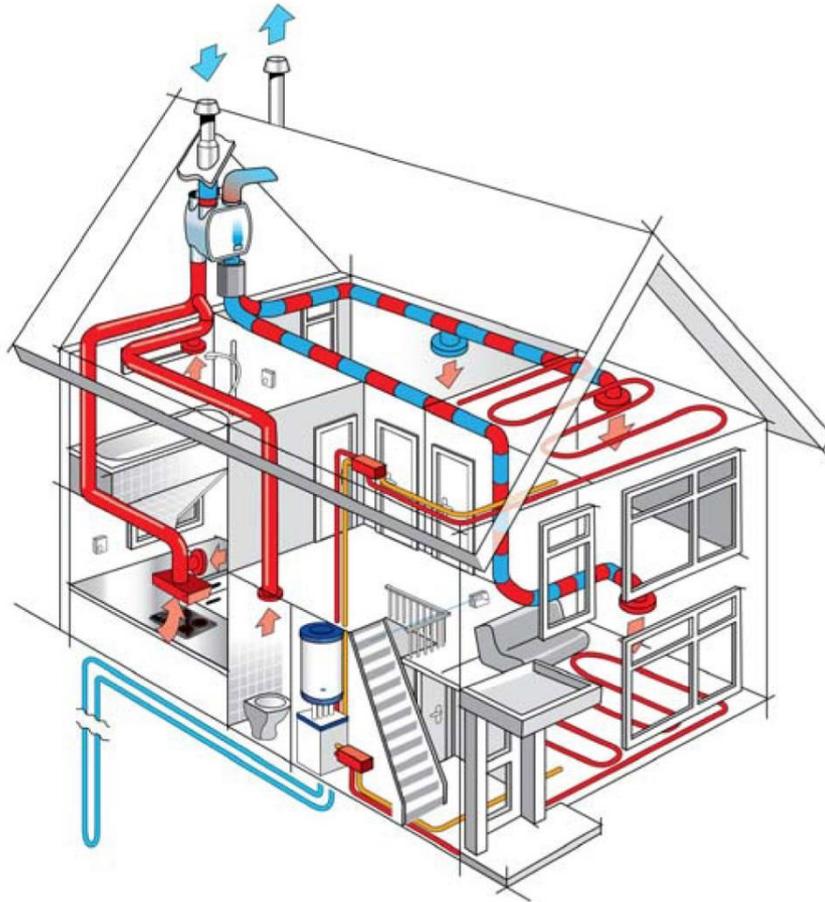


Figure 9. Heat recovery ventilation technology (Energy, 2013)

Next, you will find a technical world for home automation.

3 THEORETICAL FRAMEWORK

Home automation's main framework is wireless control and facilities. In this chapter, ZigBee technology will be clearly introduced to the reader. ZigBee is the most important content in this thesis.

3.1 Wireless control system

When we talk about wireless controller, majority of people may think about a TV remote control device and Wi-Fi. TV remote control device is the most basic remote, wireless controller prototype and Wi-Fi is an excellent invention they all bring such convenient life to human. But in home automation area there is a much more powerful wireless control method. It is ZigBee.

3.1.1 Introduction of ZigBee and IPv4

When different home automation devices are connected together, each needs own network address for this. IPv6 offers the new function such as the address that is extended from 32 bits to 128bits, auto-configuration and more powerful security. Therefore, it provides technological advantage over older IPv4 technology. Additionally, ZigBee is an emerging network technology as a wireless communication standard that has low cost, low power and wider coverage, since it is a good choice to provide the communication network between the devices. (Zou, 2011)

| Wireless Networking Technologies | | | | | | |
|----------------------------------|----------------------------|------------------------------|---------------------------------|---------------------------------------|--------------------------------------|----------------------------|
| | ZigBee | Bluetooth | UWB | Wi-Fi | LonWorks | Proprietary |
| Standard | IEEE 802.15.4 | IEEE 802.15.1 | IEEE 802.15.3a (to be ratified) | IEEE 802.11a, b, g (n to be ratified) | EIA 709.1, 2, 3 | Proprietary |
| Industry organizations | ZigBee Alliance | Bluetooth SIG | UWB Forum and WiMedia Alliance | Wi-Fi Alliance | LonMark Interoperability Association | N/A |
| Topology | Mesh, star, tree | Star | Star | Star | Medium-dependent | P2P, star, mesh |
| RF frequency | 868/915 MHz, 2.4 GHz | 2.4 GHz | 3.1 to 10.6 GHz (U.S.) | 2.4 GHz, 5.8 GHz | N/A (wired technology) | 433/868/900 MHz, 2/4 GHz |
| Data rate | 250 kbits/s | 723 kbits/s | 110 Mbits/s to 1.6 Gbits/s | 11 to 105 Mbits/s | 15 kbits/s to 10 Mbits/s | 10 to 250 kbits/s |
| Range | 10 to 300 m | 10 m | 4 to 20 m | 10 to 100 m | Medium-dependent | 10 to 70 m |
| Power | Very low | Low | Low | High | Wired | Very low to low |
| Battery operation (life) | Alkaline (months to years) | Rechargeable (days to weeks) | Rechargeable (hours to days) | Rechargeable (hours) | N/A | Alkaline (months to years) |
| Nodes | 65,000 | 8 | 128 | 32 | 32,000 | 100 to 1000 |

Figure 10. WPAN sensing and control solutions (Electronic, 2013.)

The principal architecture of the smart home network requires three types of devices: coordinator, router and end device. The next picture, Figure 11, illustrates this kind of architecture. This kind of intranet system can be implemented with ZigBee in low cost and good performance. The end devices will communicate with each other through coordinator who relays the data target terminals. Additionally, because all of the end devices have their own IPv6 addresses, they can be directly connected to the Internet. This allows remote control for appliances using computer which access the devices through the home gateway. This is important advantage that smart home can provide for today's busy and on the move homeowners that are not just limited controlling locally and centrally through the handy remote control device at their home. (Electronic, 2013.)

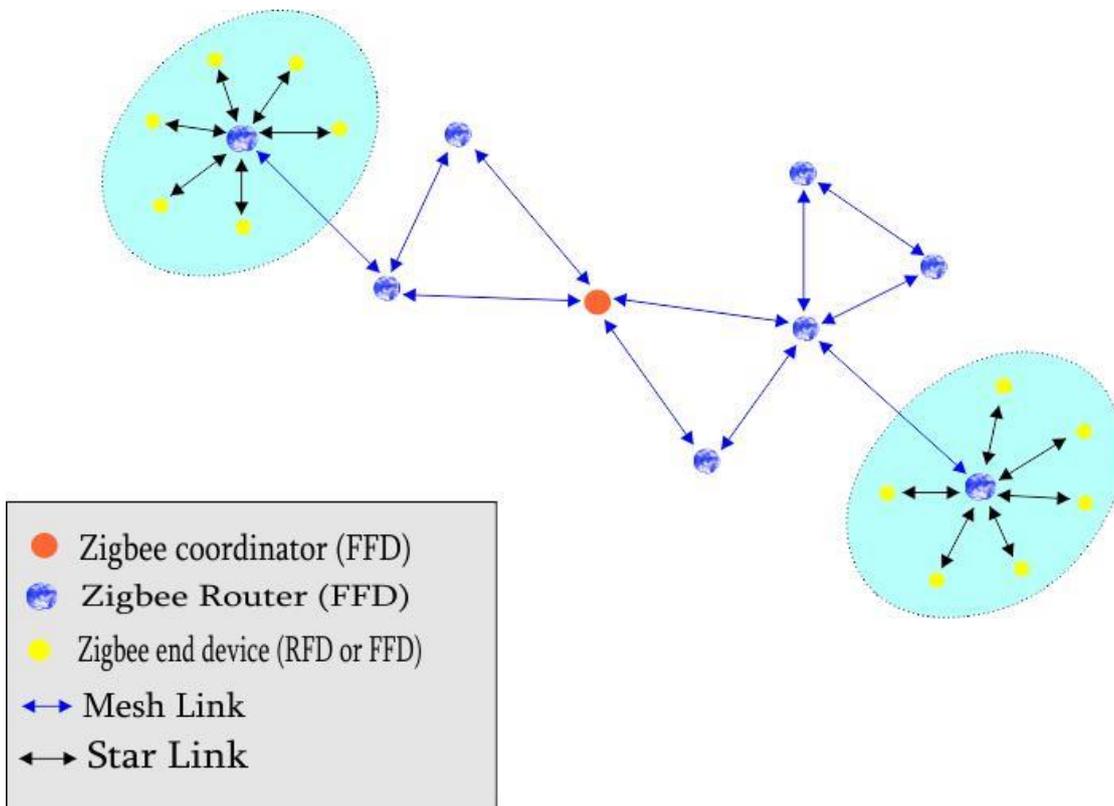


Figure 11. ZigBee connection structure (EngineersGarage, 2013)

Essential component in the smart home is the home gateway. It is a full-featured device, which acts as a network coordinator for a network establishment and normal operation. The wireless home network can be arranged in star topology consisting of home gateway and multitude of ZigBee sensors modules. Home gateway also plays an important role. User controls their intelligent home devices outside or in other places through mobile module embedded in the gateway for the remote user. Mobile terminals include tablets, remote controllers and mobile phones. Essential technology is for providing this the IPv6 mobility support. By this advantageous way users can complete the management of their home over the Internet to improve the system's flexibility and mobility. The following picture is home gateway technology components. (Zou, 2011)

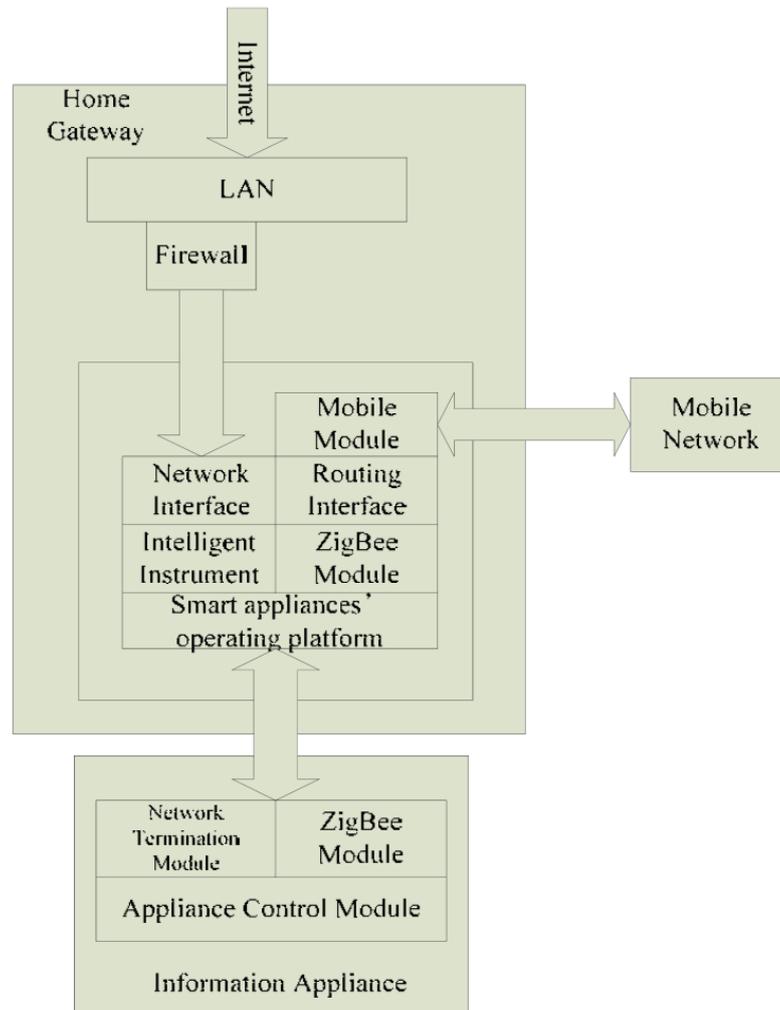


Figure 12. Home gateway technology components (Zou, 2011)

3.1.2 Communication between Home Gateway and Appliances

The home gateway is the control centre of the home network system. It coordinates all household appliances, monitor their work and their current status. It also acts as a bridge to outside, connects with the Internet, receive remote users' control and transfers applicable information to service providers e.g. electric provider. (Slash, 2013)

Internal communication in the ZigBee network is flexible because each node can communicate with each other, so wherever the users are in the house they can control the other room's appliances. Sequence is following: The appliance receives information from home gateway by ZigBee module and detects the household device status, and then matching status will be transmitted to the home gateway by ZigBee module. If all appliances are working as they should, home gateway stores

appliances' status. If not, home gateway reports an error message to the provider. (Slash, 2013)

External communication happened through the home gateway, which interconnects Internet and the home network. It can send devices with information in the home network to the portal server using IP level communication. And also it can control and monitor the devices data packet communication. It enables users to control and monitor their home networks through the Internet and even mobile phone since the portal server has the mobile interface. Sequence is the following: home gateway receives external IP packets, unpacking them revealing destination address. Next routing path is selected (destination device) and when data is transmitted, the end device (appliance node) then receives the data and checks for any errors. If the data are erroneous, the appliance returns an error message to the home gateway. If data is valid and correct, end device (appliance) implements given operation and returns the results to the home gateway. ((Zou, 2011)

Integral part of the smartness of the home network is the used communication protocol. For example, protocol enables each device to be aware of statuses of other device by polling or asking them the status constantly. To enable this, three types of packets are specified in protocol: request, response and event packet. These packets are identifiable with a special packet type field in the packet's header. In the header, there is also a name code that affects its appliances' label. Each appliance has to have a relevant name. These labels need to match with appliance words set in the system and they need to be unique. ((Zou, 2011)

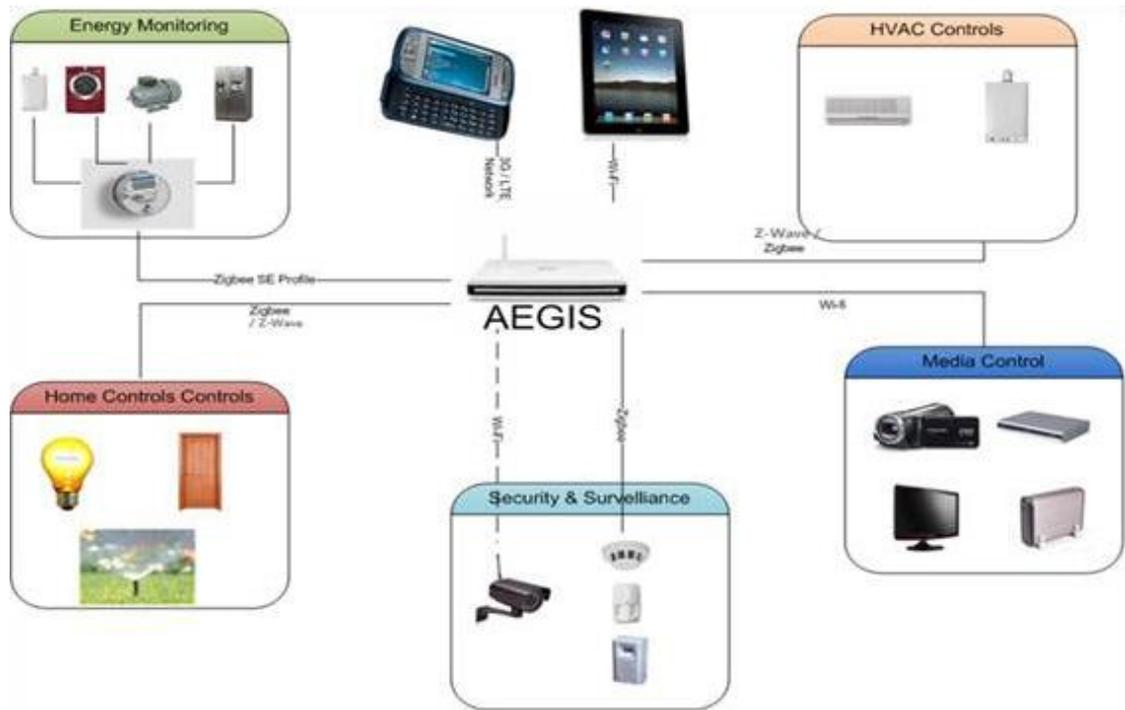


Figure 13. Communication between home gateway and appliances. (Slash, 2013)

3.1.3 Device protocol and programming

Important message in the system is the device's state code. It is returned from the device to tell the management module what status appliances are currently working. For example, “//Power on=on/Power off=off/Probe temperature=24/Turn up=off/Strong wind=on//”. Management module can then display device state codes directly to the user to show the state of a device. (Zou, 2011)

Another important message in the system is the command code. The protocol provides a packet structure that consists of one byte command code, input and return arguments. This structure length can vary. This kind of flexible structure allows easy integration of devices such as air conditioner etc. Of course, the device needs to decode the commands and gateway has to have support to control the devices thus it needs to know every kind of command message used by the end device. (Zou, 2011)

Special requirement set by the networking in the home is by home code. This definition in the protocol set's each home independent of the other homes. This is especially needed if the network physical network signal could be heard or is shared with other homes. It makes each home separately in the packet level of communication making all the communication privacy from neighbours. This home

code is generated into random 4 bytes values and it is used to prevent neighbour's data from coming over and interfering with one's own home's data. (Zou, 2011)

Internet and there used TCP/IP portal are the most widely used networking because of its reliability. One has to arrange communication between the popular ZigBee wireless network communication technology and the TCP/IP because the ZigBee itself is not compatible with the IP-based network. There is demand for interworking between ZigBee/802.15.4 and TCP/IP/802.3. The answer to this big challenge can be divided into three approaches (Zou, 2011)

The simplest approach is to make IPv6 to work over ZigBee by implementing IPv6 stack on the top of the ZigBee network layer. Then the entire ZigBee node would have an IPv6 address. (Zou, 2011)

Second approach is technology called IP-Net. It is a dual network stack approach. It has both the 6LoWPAN and ZigBee stack that are sharing the same 802.15.4 MAC address. (Zou, 2011)

Third approach is to have a gateway that allows both a 6LoWPAN and ZigBee devices to exist in the network. Preferably they would have an IPv6 address. Additionally, if we apply the IP-NET concept of a dual stack in one side of the gateway, fully interoperable gateway is achieved. (Zou, 2011)

3.1.4 Energy management in wireless control

In rising energy prices, the smart meters are important way to control and reduce power consumption. AMI Service includes installation of smart meters that allow remote reading of the electricity consumption, even connection and disconnection for the service and delivery of the electricity to homes. This kind of package integrates the makers of home appliance devices, home controls, and smart in-home displays. This kind of system keeps users informed whenever their energy related needs. (GIGAOM, 2013)



Figure 14. Smart meter. (GIGAOM, 2013)

The intelligent home energy management system relies on the power consumption history to control the use of electricity. It provides a group of functions that help remote monitoring, controlling, planning and repairing operations and provide necessary information on the status of installed devices in the network. The system also allows micro-generation which allows user to buyers or sellers of electricity at different times and with different price schemes. (GIGAOM, 2013)

Advanced systems also allow the direct interconnection between appliances. Typical example of this would be coordination between air conditioning and water heater. Both use lots of power. But if one input is the cold water released from the heating equipment into air conditioning device or the heat released from the refrigeration equipment to the heater, power will be saved by this kind of recycling use. (GIGAOM, 2013)

Core technologies on providing managed wireless home network are the IPv6 and ZigBee. They can be integrated into existing technologies. One important advantage of the smart home is the intelligent home energy management system that provides simple to use interface to save household's energy and comfortable living to smart home users. (GIGAOM, 2013)

3.1.5 LONWROKS

LONWROKS is also new networking platform which is a pervasive solution for today's advanced control-networking systems. This is the solution for an open, interoperable system which has been developed by the world biggest company's cooperation. The purpose of this networking system is to be simple, straight, and convenient.

The basic structure of this system is to use a common infrastructure. Briefly, each component is attached through one wire and can share common information. All the data and information can travel from one station to another station without any obstructions. It also promises the high-level security and allowing full component interoperability in a peer-to-peer fashion.



Figure 15. LONWROKS linx 100 (E-controls, 2013)

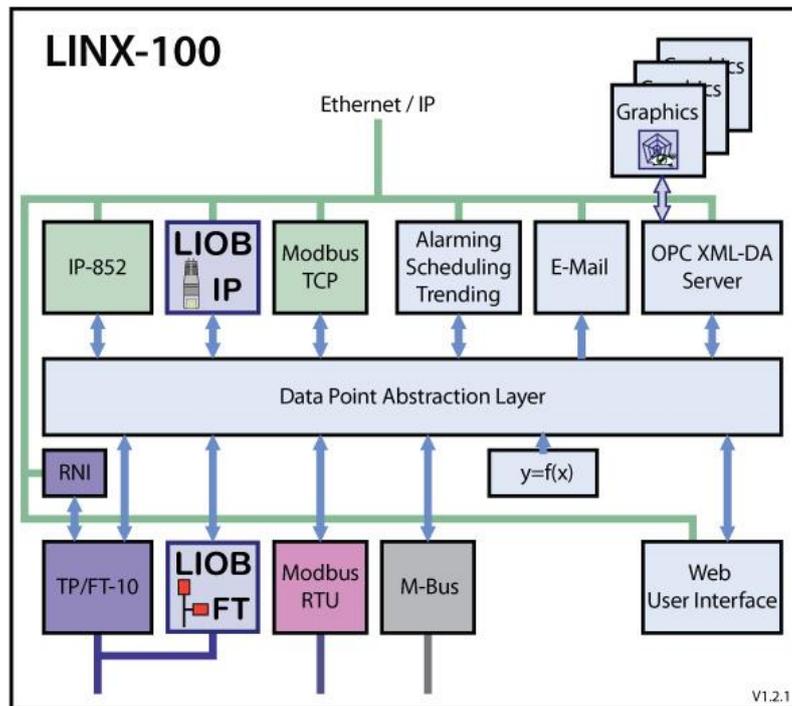


Figure 16. Internal construction blocked diagram of the LINX-100. (E-controls, 2013)

Because of the open and shared information system, LONWORKS has a very big market prospect. A good solution of signal patch removes all of the proprietary hooks. It gives the user wide variety of options.

3.2 Facilities and equipment in automatic home

There are many kinds of facilities and equipment in an automatic home, but they all belong to their group. There are only three groups of facilities; controller, receiver and terminal equipment.

3.2.1 Controller

In the home automation project, the controller has very wide variety options. The main four signal type controllers are analogue signal controller, GSM controller, intranet controller or internet controller and radio frequency controller.

Acoustic controlling, temperature controlling and light-dependent controlling belongs to analogue signal controller. For example, the switch of a lamp bulb in front of the door includes acoustic control unit and light control unit. When the host comes back home at night, the switch hears the sound of his car and turn on a light for him.

GSM Controller can be used for the long distance control. When you are travelling to another city and you are afraid of whether all of the electric appliances are switched off, you can send message to GSM controller, and then the GSM controller can send the instruction to the central mainframe to switch off all of the electricity. It can also switch off the controller itself, because of the controller uses battery. (Techwac, 2013)

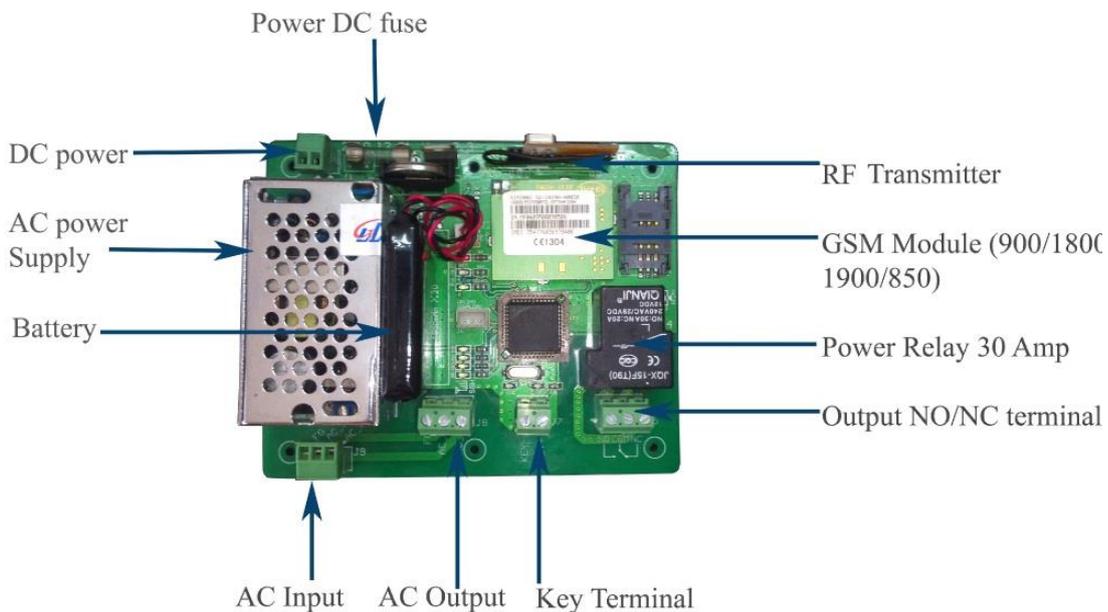


Figure 17. GSM Control all electronics applications. (Techwac, 2013)

Intranet and internet controllers are the most popular controller today. It called web control sometimes. If your smart device is connected to the intranet or wherever you are since you have the internet access, you can distance control your central mainframe and then control all of your home appliances.

Radio frequency controller is the most common controller. Ten years ago it appeared almost everywhere: in your TV remote control device, electric fan remote control device, air conditioning remote control device, car remote key and so on. In home automation project, RF also accessed between the dimmer and switch.

3.2.2 Receiver

Receiver in home automation project is always combined with controller or terminal equipment. Sometimes it works independently but most of the receiver are the main host computer. This host computer is very expensive. It receives controller's signal and transmits the signal to the terminal equipment at the same time.

3.2.3 Terminal equipment

Terminal equipment can be any kind of electronic product: main switch, lamp bulb, oven, refrigerator, rice cooker, coffee machine, washing machine, air condition, heater, computer, speaker, radio, electronic gate, car heater, print machine, monitor, ventilation equipment, humidity equipment, electronic curtain and so on.

If this electronic product is installed with a smart programme which has the same compatibility, it is possible to control its performance by the host computer. Otherwise, the host computer can control it to switch on and switch off at least.

4 TEMPLATE HOUSE DESIGN

This chapter will describe the basic module of home automation project. The technology is contributed from ZigBee and American X10 compatible.

4.1 Heating, ventilation and air conditioning (HVAC)

In a certain condition, temperature, humidity and quality of air in buildings can be controlled by the systems of heating, ventilation and air conditioning which are called HVAC. This system is working by transferring the heat and moisture into and out of the air. (Carbon, 2013)

The ventilation system takes the fresh air to the building and takes the polluted air away. The heat losses between the internal and external spaces can be compensated by the heating system. The temperature increases in many ways for example because of machines, people or the sun so that cooling is necessary. Heating, ventilation and air conditioning system is working differently in different functions. Some systems were being designed when the building was founded because they are too large. There are also systems that can let some buildings get the temperate through boilers and radiators, and also provide fresh air and cooling to some parts of building for example meeting rooms. Normally, it is not the original design that the individual comfort cooling units are included into a building to overcome a certain overheating problem. (Carbon, 2013)

Because of the interaction of the heating, ventilation and air conditioning with each other and the whole building, even they are separate we also should consider them holistically. If just regard HVAC system as the individual elements, not an interacting system, it will easily cause the energy waste problem. For instance, the heating equipment in a building try to increase the temperature, however the cooling system work in another way but tries to decrease the temperature. Each element of an HVAC system interacting well will save energy and money. (Carbon, 2013)

There are five significant factors which affect the energy use. The first factors are the design, layout and operation of construction structure. It acts how external environmental influence on internal temperatures and humidity. The second factors are requirement of indoor temperature and air quality. More extreme temperatures and purer air quality cost more energy. The third factors are generalized heat generation. It includes lighting, equipment and people. They all have an impact on

how warm your building is. The fourth factors are design and efficiency of the HVAC plant. A good design is that heat cooling and moisture control are exactly where they are needed in the building. The final factors are operating times of the HVAC equipment and ability of the controls. HVAC equipment can't work all the times. It should be limited to operate exactly when it is needed. (Carbon, 2013)

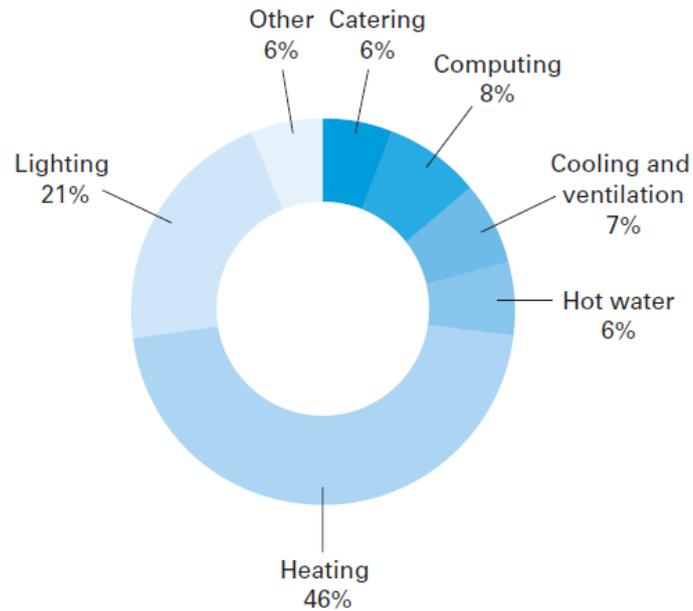


Figure 18. Total carbon emissions from energy use in public and commercial buildings 2008 (Carbon, 2013)

HVAC systems have many different components that make them up and how they are set up within a building. But they mostly contain some common basic components.

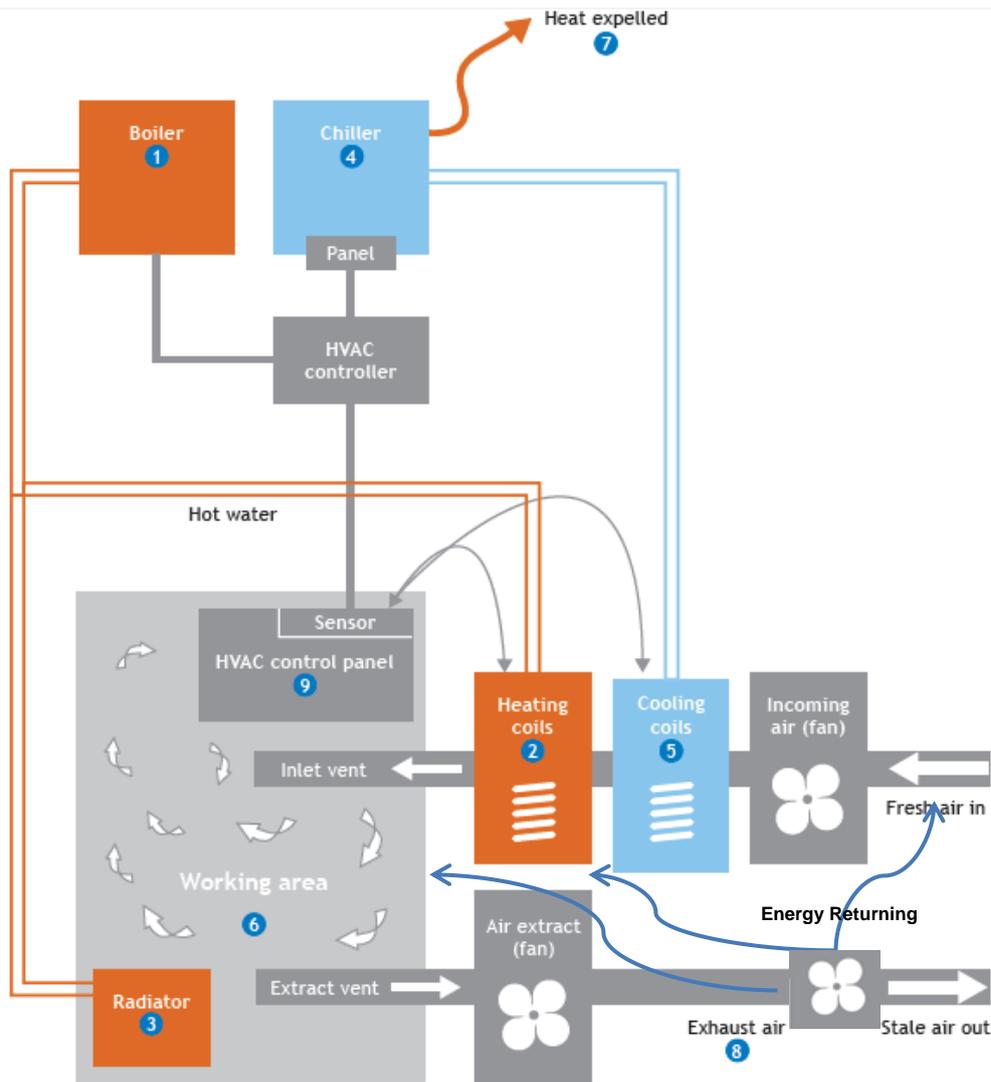


Figure 19. Whole HVAC system and its basic components (Carbon, 2013)

Boiler 1 is for producing hot water or water steam. It is distributed to the working space. This process is also done at the same time by Heating Coils 2 which get heat to the air which belongs to the ventilation system. Heat is provided through hot water pipes to the Radiators 3. Sometimes hot water and water steam are produced and delivered to building by district heating. (Carbon, 2013)

The equipment 4 is for cooling. It chills water and then pumps water to cooling coils. Then the treated air is blown over the chilled water coils into the space to be cooled in Working Area 6. As part of the refrigeration cycle in the chiller, heat must also be rejected from the system via a cooling tower or Condenser 7. (Carbon, 2013)

Pumps are used for circulating the required chilled and hot water based on the space and an exact temperature requirement. Stale and polluted air is usually exhausted by the fan through separate ducts and pipes outside which is number 8 in the previous picture. In the end of the exhaust air duct, there should be an energy saving returning

equipment like heat pump to return the heat back to the working area, heating coils, and ducts for incoming fresh air. (Carbon, 2013)

The central controls are needed to make all the components work together efficiently. They turn equipment on or off and adjust chillers and boilers, air and water flow rates, temperatures and pressures. A controller incorporating one or more Temperature Sensors 9 inside the workspace sends a signal to the heating or cooling coils to activate them. (Carbon, 2013)

If there is a demand for heating or cooling, then the controls may also send a signal to the chiller and boiler to operate as required. There are often other control panels on the chiller or boiler too, allowing users to have greater control. (Carbon, 2013)

In order to control the best temperature for people in this HVAC system, the central controller should be given the data about temperature requirement in a different room type. There is at least one temperature sensor in each room. Every sensor is marked with its location such as computer room, bedroom and living room. For the different room, the requirement of temperature is, of course, different. (Carbon, 2013)

Table 1. Temperature requirement in different room type (Carbon, 2013)

| Sector | Building/room type | Temperature (°C) |
|--------------------------------------|---|------------------|
| Offices/service companies | Computer rooms | 19-21 |
| | Banks, building societies, post offices | 19-21 |
| | Offices | 21-23 |
| Hospitality | Restaurants/dining rooms | 22-24 |
| | Bars | 20-22 |
| | Hotels | 19-21 |
| Schools/further and higher education | Educational buildings | 19-21 |
| Industrial/factories | Heavy work | 11-14 |
| | Light work | 16-19 |
| | Sedentary work | 19-21 |
| Hospitals and healthcare | Bedheads/wards | 22-24 |
| | Circulation spaces/wards | 19-24 |
| | Consulting/treatment rooms | 22-24 |
| | Nurses' stations | 19-22 |
| | Operating theatres | 17-19 |
| Public buildings | General building areas | 19-21 |
| | Law courts | 19-21 |
| | Libraries | 19-21 |
| | Exhibition halls | 19-21 |
| | Laundries | 16-19 |
| | Churches | 19-21 |
| | Museums and art galleries | 19-21 |
| | Prisons | 19-21 |
| | Retail | Retail buildings |
| Sports and leisure | Changing rooms | 20-25 |
| | Sports halls | 15 |
| | Pool halls | 28-30* |

The control method of the central controller can be very simple. If the sensor finds the current temperature to be lower than the marked temperature, then it sends a protocol to central controller for heating. Otherwise it sends fresh cooling air to this room. One economic principle is that not to do the cooling and heating at the same time. (Carbon, 2013)

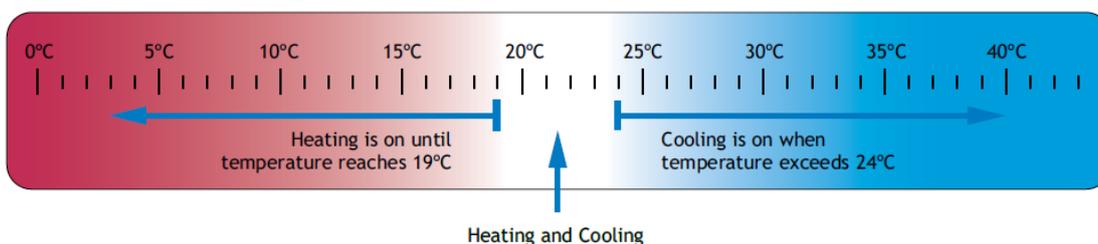


Figure 20. Heating and cooling method, heating or cooling (Carbon, 2013)

In the HVAC system of the home automation project, the Honeywell product. The assumption is that this automation project is for a 210 m² house. If there is not any other information mentioned about this home automation project, it all means this

project is based on a two floor house with 210 m² house areas, a 20 m² garage and a 40 m² garden. It has five bedrooms, two living rooms, two toilets with shower, one multimedia entertainment room, one spa room, one kitchen, one study, one store room.

According to its bidding price, 13.5 € per square meter, the total project price is around 2835 €. It includes the pipes arrangement, five thermometers and a user wall panel, and a heat exchanger. (Honeywell, 2013)



Figure 21. Sensor (115 €/pcs) and thermostat panel (130 €/pcs) of HVAC system (Product, 2013)

4.2 Lighting control system

The solution of intelligent lighting system is not only to save a lot of energy, but also to create a variety of wonderful atmospheres in the rooms. In the lighting control system of this home automation project, X10 compatible product is used in every rooms. This home automation project needs ten dimmers (53 €/pcs), three in-line modules (86 €/pcs), two open/close sensor (60 €/pcs), 1 motion sensor (86 €/pcs). Of course, a house needs lots of bulbs but the cost of bulbs is not included in the home automation project. After calculation, it costs 994 € totally. (Insteon, 2013)



Figure 22. Lighting control appliance (Insteon, 2013)

The central control computer and software are required components. They cost 3500 €. Central control computer is needed in every part of home automation beside this lighting part. (Smart, 2013)



Figure 23. Central control computer for every part of home automation (Smart, 2013)

This makes the home automation project costs $2835 \text{ €} + 994 \text{ €} + 4000 \text{ €} = 7829 \text{ €}$

4.3 Multi motion background music

Because of the control of the central computer, it is very easy to send different music to different rooms. Adults and children may have different music hobbies. When you are working you may also need music or 20 db noise to make your brain to concentrate on your work better. (Smart, 2013)

Nuvo 8 line amplifiers and eight sets of speakers are needed to purchase in this step. Nuvo 8 line amplifier is 1800 €, a set of speaker is 80 €. So the total price of this multi motion background music is 2440 € (Smart, 2013)



Figure 24. Amplifier and speaker (Smart, 2013)

This makes home automation cost 7329 €+ 2440 € =10269 €

4.4 Home theatre and entertainment room

Based on the multi background music system, multimedia entertainment room can be easily built up. It is actually a home theatre or game play room. The reason we have this room is for dweller relaxing. Nowadays more and more people are willing to watch movies or rent DVDs for watching at home. (Smart, 2013)

The system is illustrated in the following picture. For this, a powerful projector, a media converter and a blue DVD reader are needed. The lighting and temperature component was bought already in the previous step. (Smart, 2013)

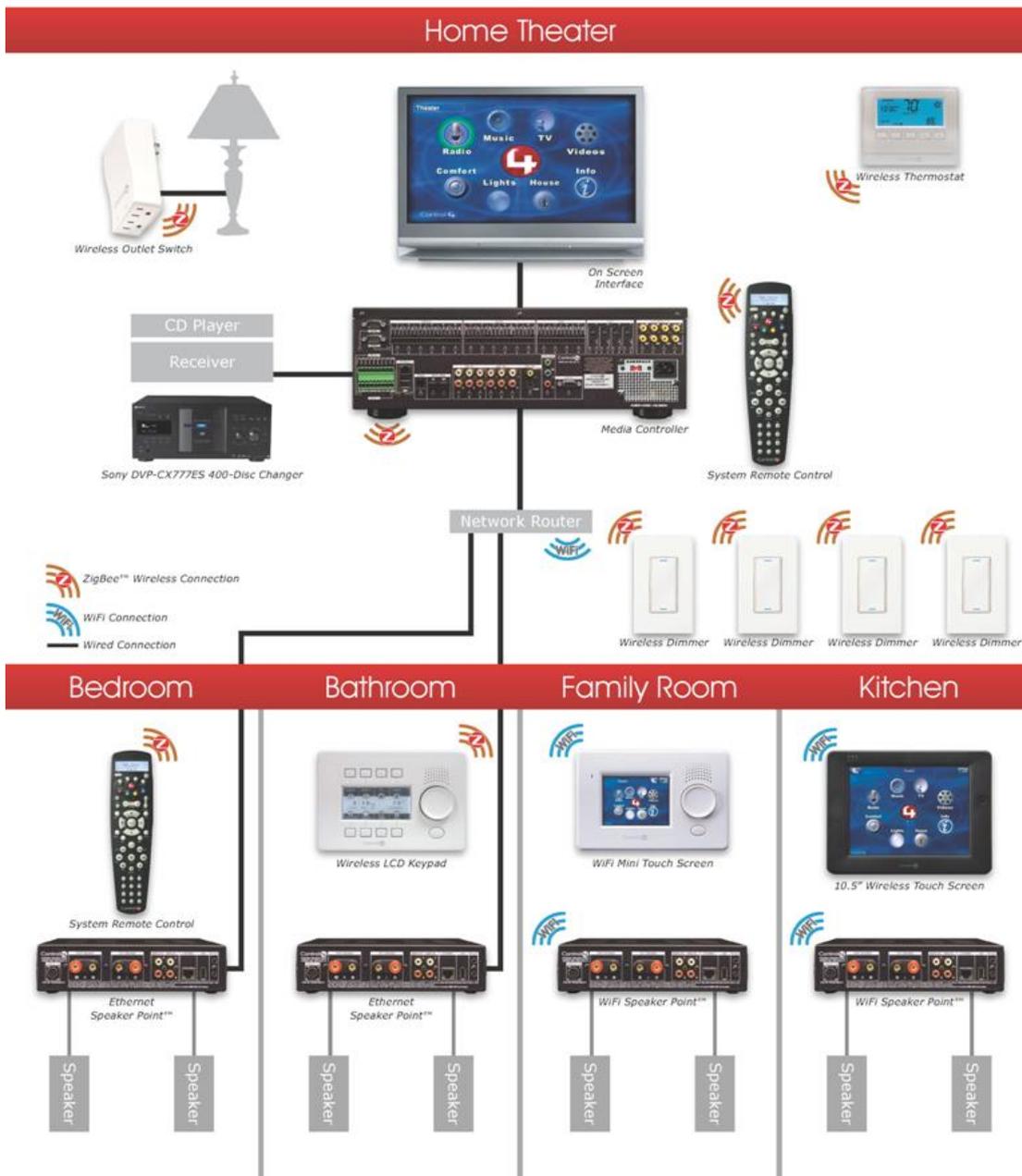


Figure 25. Home theater system. (Smart, 2013)

The projector costs 1300 €, the media converter costs 1500 €, DVD reader costs 1100 €. Home theatre part of home automation costs 3900 € totally. (Smart, 2013)

This makes the home automation cost 9769 € + 3900 € =14169 €

4.5 Automatic shading

Automatic shading gives a dweller better control of sunshine, intensity of illumination, temperature and motion feeling. The user can set the curtain to a customized mode.

It includes how long time the curtain opens after the sun rise up and when the curtain closes after the sunsets. Combined with multimotion background system the user can have a soft wake up with morning music and soft sunshine. The ZigBee controlled automatic curtain with one inside light sensor and one outside sensor cost 1300 €. For this house, we need two automatic curtains that cost 2600 €. (Smart, 2013)

This makes the automation project cost $13669 \text{ €} + 2600 \text{ €} = 16769 \text{ €}$

4.6 Safety, security and monitoring

Most of the dwellers of the smart home are rich people. Safety and security are very important for them. Smart safety and security are different from the transitional safety and security. A dweller can use iPhone or iPad to control whole security system in an easy way. This system has security alarm function. When a stranger crosses over your house yard, the laser beam enclosure will be blocked-up by him. Then the sensor will take photos of that area and give an instruction to host computer that some strangers or animals come into your yard by measurement of object size. After that the host computer will send an e-mail or message to the house owner. If there are really some thieves entering, he can call the police. Of course your iPhone or iPad can connect to the supervisor anytime anywhere.

There is not only a monitoring system that protects your security, but also entrance the guard system. A dweller can check easily anyone who knocks the door, and talks with them. Combining the door key and entrance code, the dweller can have double security. So if any home member loses the door key, they don't need to change the door lock immediately. The entrance password will protect them. Of course, owner has administrative authority to change the password, if he is worried about password is known by others.

With this system, the owner can live conveniently and safely at home. If his wife forgets the door key, she can call her husband to open the door by his iPhone with permissions.

In this step, the components are four pairs of laser enclosures 200 €, three view adjustable monitors 450 €, two password locks 600 €, one displacement sensor 40 €, one infrared sensor 60 €, and one security host central computer 800 €. They cost totally 2150 € (Smart, 2013)



Figure 26. Components of security system (Smart, 2013)

This makes the home automation project cost $16269 \text{ €} + 2150 \text{ €} = 18919 \text{ €}$.

4.7 Energy management

Home automation applies a light dimmer, a timer and a displacement sensor in order to reduce energy waste. For example, if the house has three bedrooms, when using the home automation equipment, it can release more than 550 kilograms carbon dioxides per year and it is almost equivalent to the energy used by one car.

In fact, lighting takes account for 20 % of the whole national electricity consumption. But, half of the consumption of lighting is being wasted in inefficient lighting or lighting for the empty rooms. In the lighting part, home automation is automated which means it will be turned on or off depending on the actual needs. Outdoor lighting can be controlled by the induction of moving objectives. It will turn on when there is the need, or the owner can set it to turn on when there is the sunset. Indoor lighting can detect the demand situation by the sensor and if there is nobody in the room it will be turned off.

Light dimmer is another good solution to save energy. By lowering the light level 25 % which cannot be recognised by the human eye, power consumption can be reduced by 20 % and the lamp life can be extended to four times longer. The surround light sensor can adjust the brightness of the light automatically in the

lighting regulator. This design satisfies the usage and energy-saving requirements for the customers.

By thermostat, home automation system can adjust the required temperature automatically by the motion sensors which can sense human activities. If people leave the room, it can reduce the cooling power and save energy.

It also can provide the convenient life for the customers. For instance, before the customer arrives home, the remote control device can control the heating or cooling by the air conditioner. Curtain automation can be customized according to the sunlight so that it can save more energy.



Figure 27. Energy consumption of lighting in America (Audio, 2013)

Energy management is implanted into programme of the central control computer. So this step doesn't increase expenses. The total cost is still 18419 €.

4.8 Arrangement of wire

In the beginning of the thesis, it was mentioned that smart home was called wired a house 30 years ago, because it really needs lots of wires. For preventing your house becoming extremely disordered by planning a mass of wires, many wire arrangement products are needed. In this home automation project, the house needs of wire arrangement product for about 600 €.



Figure 28. Wire arrangement product (Smart 2013)

In this wire arrangement step the purchase cost is 400 €. This makes the home automation project cost 18419 € + 600 € = 19519 € totally.

4.9 An example of curtain installation

The curtain installation will be an example of all home automation products. This chapter will help the reader to understand how home automation products be installed. It requires the installer to have a good handling ability. The chosen curtain is BTX Company's Tumo Solar System. It contains one drapery track, one 6-channel remote, one motor, one power supply and mounting brackets.



Figure 29. BTX Tumo Solar window automation (BTX, 2013)

Firstly, the wall is measured and then 10 holes are drilled. The screws are put in the hole with mounting brackets. Before the drapery track is put on the mounting bracket, one solar panel is installed on the surface of the window. This solar panel is the sensor of sunlight. Secondly, the drapery track is put on the mounting brackets. They connect each other by screws and bolts. There is a plug seat in the drapery track. It is for an indoor light sensor. The cooperation of solar panel and indoor light sensor can tell the system temperature and light difference between inside and outside. Of course, the solar panel and indoor light sensor are connected. One cable from indoor

sensor is plugged into the solar panel. After that a motor is connected with the drapery track. This motor uses power provided from a power supply. So the power supply should be fixed on the wall. Finally, the curtain is hung under the drapery track. When the installation is ready, the dweller can use the remote control to open or close the curtain. (Tumo, 2013.)

5 MAINTENANCE AND SERVICES

After the home automation product is installed, the products will begin their product life cycle. The most important thing to product's life cycle is maintenance and services.

5.1 Standby unit

When you evaluate a product, it is not only measured the using function now, but also the product life is concerned. Smart home is the same. Home automation cannot be about disposable products. It should have 20 years' service life at least. But some components for example, dimmers, liquid crystal display, projector and wall control panel can't work such a long time. So, for this home automation project we prepared the standby unit for changing the aged items. It doesn't matter if the changed part is from the different company. It only needs to be same compatibility. For video transmission, every product uses HDMI. For the wireless internet transmission, every product uses ZigBee. After many years, if some part doesn't work, user can easily replace it with the same compatibility product.

5.2 Maintenance book

The manuals of every product will be saved carefully. They will also be saved as digital data like PDF burned in a compact disc. All the installation software and programme will be also saved in this disc. So if there is some problem, the user can find the problem and figure out it easily with its prepared maintenance information. Of course, it is possible that it is still not enough for a normal user to maintain his home automation product by himself. Later he can call the maintenance aid to help. When we sell this home automation project, it includes visiting maintenance service once per year.

6 EXPENSES AND MARKET COMPETITIVENESS

Now the reader may have a misty image of expenses. This chapter will conclude all the expenses and discuss the market competitiveness.

6.1 Total cost of equipment purchased

The purchase fee of every component was showed in the previous chapter. Here is the table of detailed costs.

Table 2. The cost of each component and total

| Project name | Cost |
|---|-----------------|
| Central control machine | 4,000 € |
| Heating, ventilation and air condoning (HVAC) | 2,835 € |
| Lighting control system | 994 € |
| Multi motion background music | 2,440 € |
| Home theatre and entertainment room | 3,900 € |
| Automatic shading | 2,600 € |
| Safety, security and monitoring | 2,150 € |
| Arrangement of wire | 600 € |
| Total Equipment | 19,519 € |

6.2 Budget of labour

The budget of labour can be roughly counted by the working hours and wages. For example the light manual labour's wage is 40 €/h, and he works four hours every day in average. If he works one week for this home automation project, then the cost is $40 \text{ €/h} * 4 \text{ h} * 5 = 800 \text{ €}$.

Table 3. The budget cost of labour

| Labour properties | Wage/h | Time(h) | Cost |
|----------------------------|--------|---------|----------------|
| Light manual labour | 40 € | 28 | 1,120 € |
| Heavy manual labour | 60 € | 20 | 2,040 € |
| Purchase and delivery work | 50 € | 20 | 1,000 € |
| Installation and debugging | 60 € | 30 | 1,800 € |
| Space design | 80 € | 4 | 320 € |
| Total labour | - | - | 5,440 € |

6.3 Market competitiveness analysis

The total cost 24,959 € is not very expensive for home automation. The products chosen are in the industrial level, not customer level. It means a normal user or freshman in home automation can't install them well. Of course if we choose the customer level product the price will be higher than 24,959 €, but the appearance and controllability will be higher than those products. (Home, 2013)

Nowadays, there are many companies doing home automation business. In the USA, the top companies are Smarthome, Insteon, Leviton, Elk, X10 and so on.



Figure 30. Top home automation companies. (Home, 2013)

As we know, the home automation industry is an emerging industry, so there are too few compatibilities of each company's products, most of them cannot use with other company's products.

7 RESULT

In this result chapter, the reader will be told the benefits of the system and also the disadvantages.

7.1 Benefits of the system

Home automation can bring us a high level condition with decent servers with the smart devices. The more important thing is that the dweller will have a safer home. The security system will help dweller feel safer and more reassured. It can also help people to get away from heavy house work and increase the efficiency of working.

7.2 Disadvantages

Every coin has two sides. Home automation also has several disadvantages. Many people think it has a potential risk of electronic equipment radiation. We all know that high electronic equipment radiation can cause cancer and some other illnesses. Such appliance in the home will consume quite a lot of energy, even the stand-by energy consumption everyday is more than a normal countryside home energy use everyday. It's also disappointing that those products are luxurious, but their practical applicability is low.

8 CONCLUSION

Home automation is not a new industry anymore, but it is still an emerging industry in developing countries. The huge potential market leads many electronics corporation into home automation. Sony, Siemens and even Apple company are trying to share a market of home automation. But the home automation industry scale hasn't formed yet. The good and bad mixed products are together in the market. There are also no unified industry standards. It is the challenge of home automation.

When compared with smart phone's history, we can find that home automation has very big chance in the future. Even five years ago, there were not so many people who owned a smart phone. It didn't have unified industry standards also. But nowadays almost everyone has a smart phone or have used a smart phone, and Android system IOS system is becoming the standard.

If the price of home automation is decreased or the practical applicability increased, there will be more people willing to buy it. So it means the production ability and technology level should improve more and more. Then it will become as popular as smart phone in the future.

At last, I have to say home automation is like a rising sun. One day it will be like a burning sun bringing more decent, enjoyable and efficient life to people.

REFERENCES

Audio video invasion, 2013. *Custom home theatre systems New York*. [Read: 01.03.2013]. Available:

http://www.audiovideoinvasion.com/lighting_control.html

Bechamp smart home, 2013. *What we do*. [Read: 01.03.2013]. Available:

<http://www.18bc.com/en/production.asp>

BTX, 2013. Specialty Drapery Systems. [Read: 01.03.2013]. Available:

<http://www.btxinc.com/specialty-drapery-systems>

Carbon trust, 2013. *Heating, ventilation and air conditioning*. Company advertisement PDF.

E-controls, 2013. *The L-INX Automation Server LINX-100*. [Read: 01.03.2013]. Available:

<http://www.e-controls.es/overview-i/linX-100-LONWROKS/servidoresautomatizacion/157-7.html>

Ekon Smart Home design, 2013. *Product Details view*. [Read: 01.03.2013]. Available:

http://www.alibaba.com/productfree/107093675/Ekon_Smart_Home_phone/showimage.html

Electronic design, 2013. *Use ZigBee For Cost-Effective WPAN Sensing And Control Solutions*. [Read: 01.03.2013]. Available:

<http://electronicdesign.com/communications/use-ZigBee-cost-effective-wpan-sensing-and-control-solutions>

Energy Center, 2013. *Heat Recovery Ventilation*. [Read: 01.03.2013]. Available:

<http://www.glynns.ie/index.php?page=heat-recovery-ventilation>

EngineersGarage, 2013. *ZigBee Technology*. [Read: 01.03.2013]. Available:

<http://www.engineersgarage.com/articles/what-is-zigbee-technology?page=2>

GIGAOM, 2013. *Despite Hurdles, Smart Meters Still Ramping Up Fast*. . [Read: 01.03.2013]. Available:

<http://gigaom.com/2010/11/22/despite-hurdles-smart-meters-still-ramping-up-fast/>

Honeywell thermostats product, 2013. *Wi-Fi Programmable Thermostats*. [Read: 01.03.2013]. Available:

<http://wifithermostat.com/>

Harper R, 2003. *Inside the Smart Home*. Springer.

Home automation companies, *Global top home automation companies*. [Read: 01.03.2013]. Available:

<http://home-automation-systems-review.toptenreviews.com/>

Home automation info, 2013. *Top 50 home automation companies*. [Read: 01.03.2013]. Available:

http://www.homeautomationinfo.com/Drupal/HA_Company_Directory

Insteon, 2013. *Product document*. [Read: 01.03.2013]. Available:

<http://www.insteon.com/support.html>

Product show list, 2013. *Honeywell thermostats product*. [Read: 01.03.2013]. Available:

http://www.smarthome.com/_/Thermostats_HVAC_Controls/Honeywell/_/J/1yh/nav.a_spx

Slash gear, 2013. *HCL Aegis low-cost home automation gateway supports WiFi, ZigBee, DLNA, HomePlug & more*. [Read: 01.03.2013]. Available:

<http://www.slashgear.com/hcl-aegis-low-cost-home-automation-gateway-supports-wifi-ZigBee-dlna-homeplug-more-07124551/>

Smart home, 2013. *Smart lighting system*. [Read: 01.03.2013]. Available:

<http://www.smarting.cn/zh-cn/control4homeautomation/default.asp?pageID=33>

Smart home product, 2013. *Product list*. [Read: 01.03.2013]. Available:

http://www.smarthome.com/_/index.aspx

Smith, Ralph L, 1988. *Smart House: the Coming Revolution in Housing*. Columbia, MD: GP Publishing.

Techwac, 2013. *GSM Controller*. [Read: 01.03.2013]. Available:

<http://www.techwac.com/our-products/gsm-control>

Technology overview, 2013. *Heating and ventilation*. Carbon Trust: company magazine.

Telecommunication Networks, 2013. *ZigBee, Teknologi Wireless Masa Depan*. [Read: 01.03.2013]. Available:

<http://uniquelucky.wordpress.com/tag/wireless-personal-area-network-wpan/>

Taobao, 2013. *Product list*. [Read: 01.03.2013]. Available:

<http://item.taobao.com/item.htm?spm=a230r.1.14.52.VX1bp2&id=16410160403>

Tencent technology, 2013. *What is future smart home like?* [Read: 01.03.2013]. Available:

<http://tech.qq.com/a/20130428/000019.htm#p=5>

Teenage science education, 2009. *Home automation*. [Read: 01.03.2013]. Available:

http://www.cusdn.org.cn/news_detail.php?id=236838

Wired, 2013. *This Robot's Offspring Will Clean Your Future Home*. [Read: 01.03.2013]. Available:

<http://www.wired.com/gadgetlab/2012/10/mobi-ballbot-robot/>

Tumo Solar Installation, 2013. Tumo Solar Installation. [Read: 01.03.2013]. Available:

http://www.youtube.com/watch?feature=player_embedded&v=BXCg4XMWFeQ

Zou z, Lib K, Lia R and Wub S. 2011 *Smart Home System Based on IPV6 and ZIGBEE Technology*. Procedia Engineering: Elsevier Ltd