

Smart Home Implementation Based on Internet and WiFi Technology

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Abstract: Smart home has become more and more popular in recent years. It aims at helping people manage the home appliance freely and build an autonomous environment in home or work area. This paper introduces a wireless solution based on Internet protocol to manage the smart home units easily. Based on this approach, we design a smart home system with the implementation of related software and hardware. People can use smart phones or tablets to control or monitor the home appliances both locally and remotely. We come up with the concept of Smart Units and Home Proxy. Low cost WiFi module is used to build Smart Units. The combination of remote server and home proxy is a new scheme for remote control in which XMPP is used. The remote server can act as a service provider and provide service for different homes and offices.

Key Words: Smart Home, Home Automation, Remote Control, IOT, Internet, WiFi

1 Introduction

With the development of IOT (internet of things), the concept of smart device has become more and more popular. Devices are connected to the internet and stretch their reach. Mobile phone is not the only common smart device. Smart watch, smart rings, smart TV, smart air monitor, smart sensors, all kinds of traditional devices turn to smart and have the capability to access the internet. This contributes to the promotion of wireless home automation. Since home appliances can become smart, the home or the work area can be a smart area with easy automation control. Smart home system can connect the smart units together and provide a unified interface for users to interact with the home appliances.

[1] is a survey on WHANs (Wireless Home Automation Networks). It elaborates main current and emerging architectures and technologies tailored to or suitable for WHANs. A non-exhaustive list of examples is provided. Some main futures are listed such as light control, remote control, smart energy, remote care, security and safety. Different system may focus on different aspects. [2] is a review of Smart home which talks about the past, present, and future of smart home. It detailedly introduces the definition of smart home from relative literatures and also gives an elaboration of smart home futures and compares different approaches to the implementation. There are many researches on energy management and artificial intelligence in smart home system in recent years[3, 4], while we mainly focus on the architecture improvement in this study.

Remote control is a main future for smart home system or home automation system. Considerable efforts have been put into the development of remote control systems for home automation[5]. Earlier systems are mainly based on the use of telephone line[5]. [7, 8] introduce phone based controller of home and office automation. [9] comes up with a solution using a PC to control home appliances remotely through telephone lines. The above systems make use of the telephone as the remote control input device and have no any friendly user interface[5]. In[6] an assist-robot is used to act as a new interface in the smart home by following the person and recognizing the persons voice commands for taking notes,

reading notes and controlling smart home devices.

As with the development of the Internet, Internet based remote control solutions for home automation has been proposed. [10–12] introduce some architecture for internet based remote automation control. These Internet based approaches need a home server implemented on a personal computer running all the time. It is hard to supply a unified service for numerous home automation systems. The studies in [13–15] has some examples of web based automation. However, they are not too feasible to be implemented as a low cost solution[16]. [17] introduced a low cost secure web based, flexible, wireless solution where the home appliances of most types can be connected to a central node through a server. It also need a personal PC as web server in home and offer web service as the control interface.[19] developed a Java based home automation system. An embedded board physically connected all the home automation devices and, through integration with a personal computer (PC) based web server, provided remote access to the system. The use of Java technology, which incorporates built-in network security features, produces a secure solution. However, the system requires an intrusive and expensive wired installation and the use of a high end PC[20].

When it comes to the connectivity of different devices in home local network, technologies are used such as Zigbee, Bluetooth and WiFi. [18] describes a bluetooth based home automation system which contains a remote, mobile host controller and several client modules (home appliances). The client modules communicate with the host controller through Bluetooth devices. This approach is only for home local area without remote control access. [20] shows a ZigBee based smart home system where A ZigBee based home automation system and WiFi network are integrated through a common home gateway. In many literatures, the home gateway is a main component for remote access solution which provides network interoperability. The home gateway generally depends on a server installed on a personal pc or an embedded board with operating system. HTTP transportation or web interface serve the remote control ability. However, the details are not described and in many cases the independent IP address for the home gateway is an essential.

Remote control relies on the phone line or wireless methods such as GSM or Internet. Considering the development of the internet and its flexibility, internet based remote control approach will be a good choice. There are many approaches to establish the local network between devices or smart units. Physical wiring or partially hardwired solution is not easy to move or expand, which is more costly. In[21] wireless sensor networks (WSNs) and power line communications (PLCs) are used to implement a smart home control network. ZigBee, Bluetooth and Wi-Fi are commonly used to establish the local network. Under this condition, a home gateway is needed between the internet and WLAN. In most cases, the home gateway is more like a web server with a known IP in public internet, but this is not realistic for each home owning a server. It is in the stage of experiment but far from popularity and application.

In this paper, we present a low cost internet based wireless smart home system where home local network are established through WiFi technology. We will introduce the concept of Smart Home Proxy and Smart Units. We use smart home proxy to manage the smart units in home network and to communicate with the user control units. Home proxy can act as a proxy to connect to the central remote server, thus implementing the remote control access for the remote user where XMPP is used. Different smart units such as smart switch, smart light, smart appliances and smart sensors etc can cooperate with each other smartly. The central remote server can offer services for millions of homes or offices and provide a unified manage platform, so it is of much possibility to be popularized. Phones or tablets with the special application can interact with the system remotely or locally as control units.

The next section will briefly introduce the architecture of the proposed smart home system and basic system components will be described. Section 4 presents the implementation of the system, including the hardware and software design. Conclusions are drawn in section 4.

2 System Overview

This section elaborates the conceptual design of a flexible Smart Home infrastructure and system components are introduced detailedly.

2.1 System Architecture

Fig. 1 shows the main architecture of the proposed smart home system. The home local network is organized by the central router by which the WLAN can access the internet. Smart units (such as smart switch, smart light, smart sensors etc.) equipped with special Wi-Fi module can be configured to join the given home wireless network. Traditional home appliances are easy to be equipped with the Wi-Fi module which makes them having the wireless connection ability. There are no complex hardwired arrangements to build this system. The system supports to dynamically add or remove the smart units by user control platform. All the smart units are connected together in the home local network working cooperatively. A home proxy is used in the local wireless network to manage the connected smart units. The home proxy is an embedded control board with custom operating system. It can search the online smart units and communicate with them. The phones or tablets joining in the lo-

cal work can control the smart units and receive the feedback with the specific app. The communication protocol is designed and applied to this system. The other important function of the home proxy is that it can implement the remote communication with remote users outside the local network. Here remote server is configured and XMPP protocol is used for the remote communication. Home proxy can login into the server when home router has the internet access thus having the ability to push environment message or get remote control from remote users. Then remote user can use the phone or tablets with specific app to login into the server to send control message to the home proxy or get feedback from the home proxy. The remote server not only serves the communication between one remote user and one home proxy, it is multi-systems oriented. One user can register for different home proxy and a home proxy can be associated with multi-users which means that the server is a public service provider and can provide this kind of service for millions of homes and offices. The remote server need to supply a management for the enormous information for the users and a secure database management system is used.

2.2 System components

1) Home Router

Home router establishes the home wireless environment. Nowadays wireless routers are common devices for most families so this requirement for the system is easy to be satisfied. Standard home wireless network can be used to construct the smart home system which is free of establishing another specific wireless network. The smart home system can be regarded as an evaluation of our old WLAN. Common wireless routers provide alternative security mechanisms which are mature and reliable. On the other hand, home router is responsible for the internet access which can be implemented by different ways such as ADSL, VDSL.

2) Smart Units

Nowadays uart-wifi module has been widely used to help traditional industry adapted to IOT. It is a low cost module to make traditional appliances wireless enable. With the help of this kind of module we propose our smart units such as smart sensors, smart switch, smart IR(Infrared Radiation) learning module etc. Fig. 2 is an ordinary example of uart-wifi module.

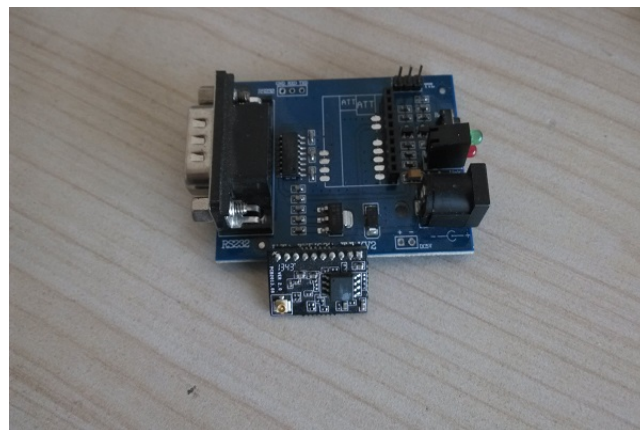


Fig. 2: Uart-WiFi Module Example

Fig. 3 shows the main structure of the smart units. We

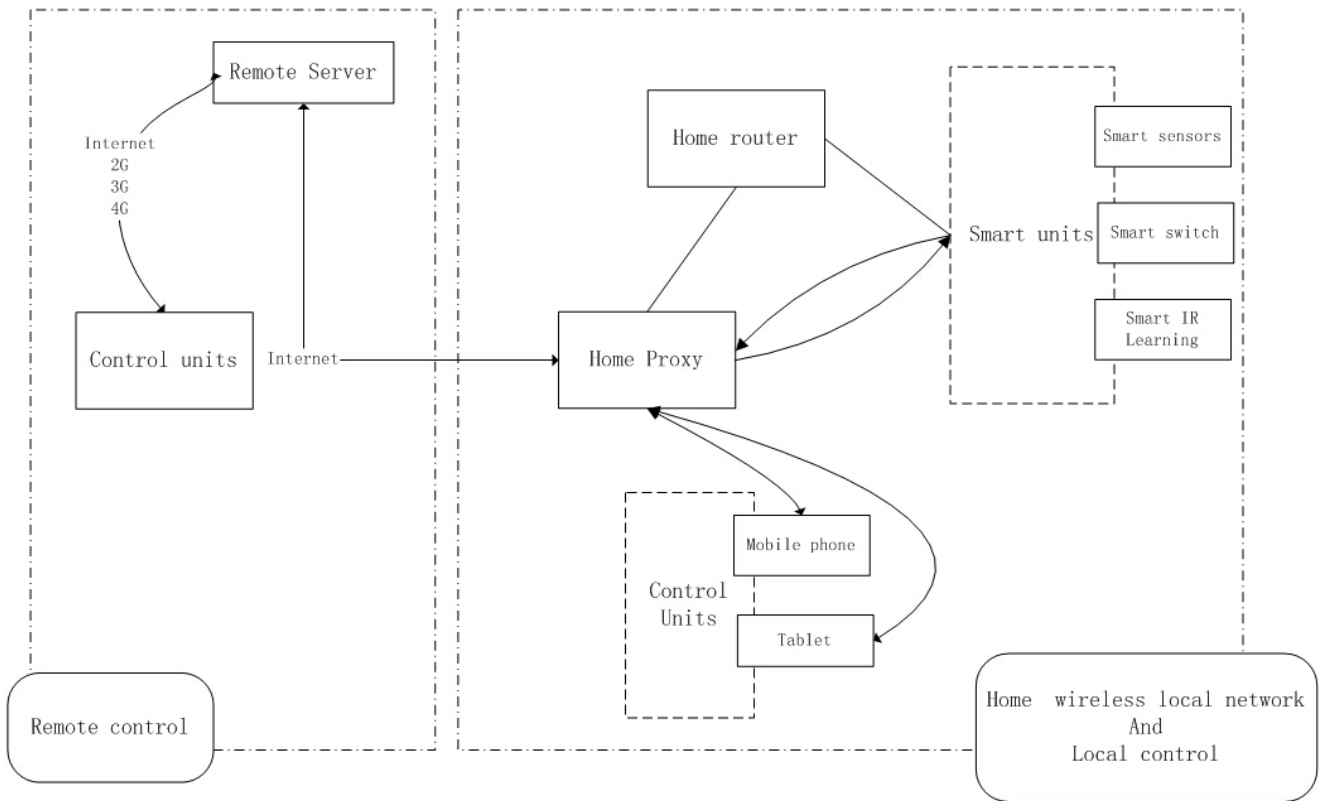


Fig. 1: System Architecture

use this module to make these units have the wireless function. Smart units can report their states and get commands wirelessly. To demonstrate the smart system, we take smart sensors, smart switch, smart IR learning module for example. The types of smart units are not limit to the examples.

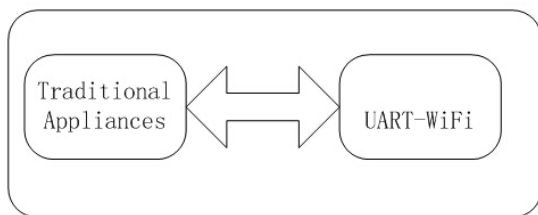


Fig. 3: Smart Units Structure

Smart sensors can sense the relative parameters such as temperature, humidity, light, noise, dust, air-quality etc. It is easy for the system to expand the types of the sensors. Smart sensors report the data to the Home Proxy and can act following the instructions from the Home Proxy. Smart switches can be controlled wirelessly by wireless commands. Home proxy or phones in the same home local network can easily control the switch(On/Off/timing). Smart IR learning module can be controlled wirelessly by wireless commands to store specific IR instructions and send specific IR instructions. This makes it possible that all the IR instructions for IR-controlled appliances can be integrated into one

module and users can just use their phone to control these appliances(such as TV, DVD, air conditioner etc.) by communicating with this module.

3)Home proxy

Home proxy is responsible for the management of the masses of Smart Units. It collects and stores the information including states and configurations. For the local network control, home proxy is a manager transmitting the message between user control ends and smart units. For the remote control, home proxy can connect to the remote server so that it can communicate with the remote control ends that can access the internet. In this situation it works just as a proxy in home getting and analyzing the message between home wireless network and the outside Internet. Home proxy will report the state of smart units to the remote server and the server will notify all the users who are bound with this home proxy. For remote control implementation, XMPP is used.

4)Remote server

The architecture of Remote server deployment is shown in Fig. 4. Remote server can be a windows server equipped with relative softwares. We use Openfire to support XMPP protocol and MySQL to supply DBMS. Remote server is a critical factor to implement remote control. The main functions of the remote server are as follows: Device registration, Remote Message Transmission, Data Management.

The control units (such as users phone, tablets) and home proxy should register on the server first before they can use the remote message transmission utility. After registration the control units can be bound with specified home proxies. Then home proxy can communicate remotely with bound phones or tablets. A phone can be bound with more than one

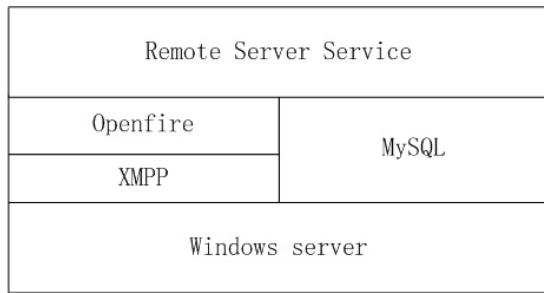


Fig. 4: Remote Server Architecture

home proxy which means that user use a phone to control multiple smart home systems is possible. The MAC address of the control unit is used for registering server. Reliable data management is supplied for registration info and smart home system info.

The remote server also can be deployed on clusters which supply more powerful service ability. Unlike the traditional experiment systems in which a home server is supplied to implement the remote access, our plan is more market oriented and is more feasible to be promoted.

5)Control units

Control units can be mobile phones or tablets. Based on the architecture and communication protocol we developed android software which makes user easy to control the system. This also can be implemented on other platforms. Mobile apps control for the system implements local control and remote control. The control flow will be presented in system implementation.

3 System Implementation

This section will introduce the implementation of the proposed system including hardware design for smart units, software design for home proxy and control units.

3.1 Hardware Design

As we have discussed in previous section, ordinary uart-wifi module is used to construct smart units. Fig. 5 is an integrated smart switch which is able to be controlled wirelessly. To combine uart-wifi module with IR learning module we can get smart IR learning units shown in Fig. 6. An example for smart sensor connection is shown in Fig. 7. The right of the figure is a dust sensor that can report the current dust density of the environment. The microcontroller is used to gather the value and AD converter can be used for some sensors which report analog values. Values of the sensors are collected by microcontroller and sent to uart-wifi module through rs232 interface. This can implement the wireless report.

Usually this kind of module has two different working mode : AP(Access Point) and STA(Station). Thus the smart units equipped with the module have these two kind of modes. In AP mode, the smart units establish a specific wireless network which enables other devices safely connect to it. The module server is established in specific local IP and port and the user can configure this module by communicating with this server using AT commands. By configuring the module to STA mode and setting the specific pa-



Fig. 5: Smart Switch



Fig. 6: Smart IR Learning Model

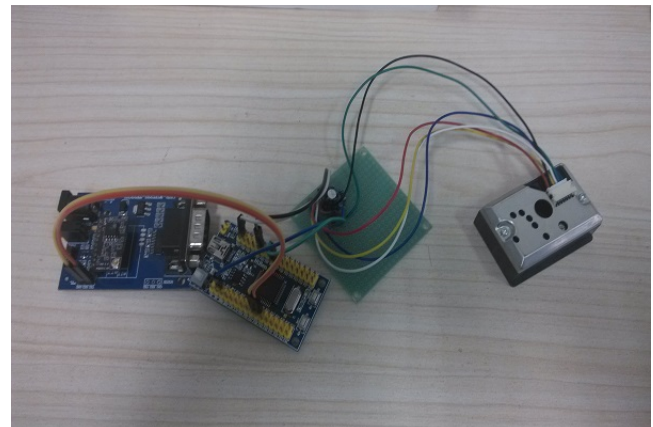


Fig. 7: Smart Sensor Connection

rameters(home wireless network's name, encryption method and password), the smart units restart to work in STA mode and connect the home wireless network. Then smart units can cooperate with each other and can communicate with the Home proxy or the mobile phone/tablets in the home wireless network. Home Proxy is an embedded board with android OS. Home Proxy software is installed and set to be run at boot time.

3.2 Software Design

This section will describe the design for the management software on the Home Proxy and the control software on mobile phones. The control software can be implemented on different platforms based on the design.

The workflow of the Home proxy software is shown in Fig. 8.

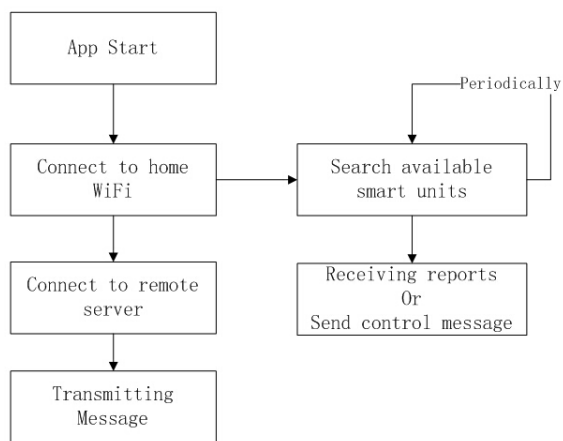


Fig. 8: Home Proxy Workflow

The operating system of the Home proxy embedded board is custom android OS. The program is running as a service of the operating system. Broadcast receiver is registered and once the system is started, the booting signal is captured and the home proxy service starts to run. At first, Home proxy will connect into the home wireless network. Then it will periodically search the available smart units in home wireless network. A dynamic smart units table will be maintained. Then the home proxy will establish connection with the available units, actively polling the states or receiving the state change or the alert report. The information of the smart units can be collected and pushed to the control units including control units in home wireless network and the outside remote users mobile phones. The remote push is implemented through the remote server using XMPP protocol. The local push is based on wireless broadcast. The home proxy will keep connected with the remote server so that it can get the latest message from the remote users thus implementing remote control.

The app workflow of the control units is shown in Fig. 9.

At the start time, the synchronization of configuration file will be processed. The configuration file describes the user customized information of the smart units and UI layouts. The software generates the UI based on the configuration file which is specific and unique in different smart home system. We use the latest modification time of the configuration file as the timestamp. By comparing this timestamp of the file in phone with that one in Home Proxy, we can get the newest one. Then the phone decides to upload the new one to the proxy or download the new one. Given that a second user is coming to a configured system, the app starts and synchronizes with the home proxy. Then it will download the configuration file in the proxy. So the second user is easy to get into the control stage. The app generates the UI and is ready for working. After configuration (which is used when new smart units are added) and synchronization, the app can get the states from the proxy and control the system through the proxy. Software implements Remote control and local control. The app will detect whether it is in home wireless network. For local control which means the phone is in home wireless network, it is easy to be done by the proxy transition. For remote control, if the phone has the access of the

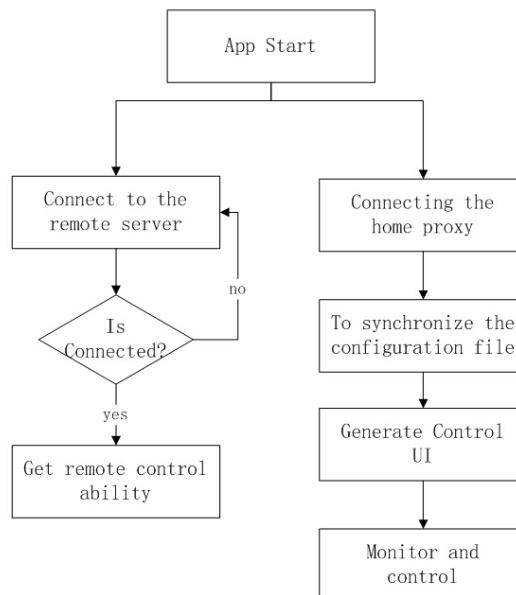


Fig. 9: Control Units Workflow

internet, it will login into the remote server and make remote XMPP connection with the Home proxy. The remote phone must be configured before in local environment which means the phone has registered for the proxy, otherwise the remote control is denied.

4 Conclusion

In this paper, we proposed a flexible, low cost smart home system based on Internet and WiFi. We come up with the concept of Smart Units and Home Proxy. The combination of remote server and home proxy is a new scheme for remote control in which XMPP is used. Low cost WiFi module is used to make smart units. Relative apps based on different platforms can be developed and android app is used to demonstrate the system. We use home proxy to solve the synchronization problem and the system supports multiuser. Also one phone can register different Home proxies, thus one phone can control more than one smart home system or smart office system. So the remote server can provide services for different homes and offices and the system is more likely to be promoted.

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