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Design and Realization of Smart Home Terminal Applications Based on IOT Technology

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Abstract

With the development of IoT technology, more and more smart household devices, such as sensors and smart mobile terminals, have appeared in our daily life. Users can remotely control almost all the devices in the smart home system and understand their information, thus effectively improving the user life quality. For background, this paper designs and develops two smart mobile terminal applications based on smart home technologies research: one is the smart remote control application based on infrared technology, which realizes remote controlling on infrared smart devices based on infrared transmission technology, Wi-Fi and Socket technology; the other is remote control and monitor application based on PhoneGap, which realizes remote controlling and monitoring on the devices directly connected to the gateway based on PhoneGap, HTTP request and HTML5 cache technology. Research on the mobile applications in the smart home system and their realization laid a solid foundation for the future research and function expansion of smart home and even smart city system.

Keywords: *Internet of Thing, smart home system, mobile application, smart devices*

1. Background of IoT Technology

IoT, which is short for "Internet of Things", constitutes an important part of the new generation information technology. It is generally considered to be first proposed by Pro. Ashton of MIT Auto-ID center in 1999 when researching RFID, Nowadays, IoT refers to a huge network formed by ubiquitous devices, such as radio frequency identification (RFID), infrared sensors, global positioning system (GPS) and laser scanner, with the prescribed protocols for smart identification, location, tracking, monitoring and management [1].

With the development of IoT technology, more and more smart household devices have appeared in our daily life to provide comfortable, safe and high-efficient living conditions for people [2]. With the strong advertisement power of big enterprises and media in recent years, vocabularies closely related with the smart home have been known to most family, such as smart home LAN, home gateway and smart devices. Design, development and realization of smart home has also become a research hotspot in IoT domain.

Smart devices, such as ubiquitous sensors and mobile terminals, are the most important part in smart home system. This paper designs and realizes the smart remote control and monitor applications based on these smart terminal devices. From the aspect of amenity, it realizes smart remote control of various devices, such as lamp, air conditioning and network TV, thus providing a comfortable living condition for people. From the aspect of convenience, it allows users access to the system data whenever and wherever possible, such as temperature, humidity, electricity and water consumption, to help people know more about their lives. From the aspect of security, the system serves to warn of danger with smoke sensor, temperature and humidity sensor, camera and other devices, thus minimizing the risk of burglary, fire and other dangers.

Specifically, this paper designs and develops two smart terminal applications:

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- One is for infrared controlling in family LAN of the infrared devices, such as TV, set-top box, air conditioning and infrared lamp. Wireless remote control can be realized by infrared instructions.
- The other is for remote controlling and monitoring of the devices directly connected to the gateway. Users can both control the devices by sending commands to the gateway, and monitor the devices by getting their information from the gateway.

2. Introduction of Smart Home Technology

Smart home is a kind of IoT systems, which constructs an effective management system of residential facilities and family agenda with integrated wiring technology, network communication technology, security technology, and automatic control technology, audio and video technology. It provides multiple functions, such as devices remote control, fire alarm, environment monitoring and programmable timing control, to improve the amenity, convenience, security, artistry and energy saving of living conditions.

2.1. Smart Mobile Terminal Operating Systems

Smart mobile terminal operating systems, such as mobile phone and Pad operating systems, have more powerful processing capability and functions compared with the traditional mobile terminal operating systems. Also, smart mobile terminals have powerful application scalability and friendly user interfaces, supporting users to install and remove applications freely. At present, iOS, Android and Windows Phone are three most popular operating systems on smart mobile terminals.

- iOS originally was called as iPhoneOS, and is for mobile devices of Apple company, such as iPhone and iPad. The system architecture of iPhoneOS can be divided into four layers: the Core OSlayer, the Core Servieslayer, the Media layer and theCocoa Touchlayer. iOS operating system takes about 1.1GB of storage space [3].
- Android is a kind of open source operating systems based on Linux system, and is mainly for mobile devices such as mobile phone and Pad. The system architecture of Android can also be divided into four layers: the Linux kernel layer, the system operating library layer, the application framework layer and the application layer. Android has features of openness, no boundaries among applications, easily embedded into network and parallel operations [4].
- Windows Phone, short for WP, is a kind of mobile terminal operating systems released by Microsoft Company. It is for mobile devices of Microsoft and Nokia, which integrates Xbox Live games, Xbox music and video into mobile terminals. WP allows advanced operating experiences such as a customized desktop, icons drag and sliding control [5].

2.2. Infrared Transmission Technology

Infrared transmission is to transmit data in infrared way, which can realize wireless connections in office and home conveniently and fast. This point-to-point transmission modes is suitable for two fixed devices, which is applied the most in infrared remote control systems. Infrared remote control technology is a kind of wireless and non-contact control technologies, with advantages of strong anti-interference ability, reliable information transmission, low cost and easy to be realized [6].

2.3. Phonegap Cross-Platform Technology

PhoneGap is a mobile terminal cross-platform applications development framework based on HTML, CSS and JavaScript technologies. It can be embedded into mobile devices to apply their core functions, such as geographic location, accelerator, contact, vibration and sound. It can not only complete almost all the functions of native App, but also has rich plug-in for

function extensions. Compared with other cross-platform architectures, PhoneGap has more powerful expansion packets, making it easy to access the local API and apply other mature JavaScript frameworks, such as JqueryMobile. Besides, PhoneGap is free, thus reducing the development cost.

In fact, PhoneGap is a collection of API (Application Programming Interface) of mobile devices, which can be accessed by JavaScript. As it can call the hardware and system resources, PhoneGap is very convenient for cross-platform applications development especially with UI frameworks of HTML5 and CSS3 technologies, such as jQuery Mobile and Sencha Touch.

However, the user experiences and interfaces of applications developed by PhoneGap are relatively poor, which response slowly in 3D games and requiring massive calculation. This is because that the running of PhoneGap applications are based on Webkit built in mobile devices, so it is influenced by the processing speed, hardware and software performances, resulting in it running slower than the natively developed applications. With the rapid development of HTML5 and hardware performances, we believe it will be solved soon [7].

2.4. Socket Technology

Socket is the cornerstone of communication, and is the basic operation unit of network communication supporting TCP/IP protocols [8]. It is an abstract representation in network communication process, including basic information in it: the protocols in connection, the local host IP, the protocol port in local process, the remote host IP and the protocol port in remote process. The connection of Socket includes the following three steps:

- Server listening: the server Socket is always in the state of waiting for connections. It listen the real-time network state and waits for the connection requests from the client at any time.
- Client Request: the client Socket firstly puts forward the connection request, which connects to the server Socket. The connection request specifies the address and port number of the server Socket.
- Connection Confirmation: when the server Socket listens or receives the connection request of client Socket, it immediately responds to the client request by establishing a new work thread and sending the receipt of server Socket to client. Once the client confirms this response, the Socket connection is formally established. Then the server Socket returns to server listening state, and continues to wait for connection requests from other clients.

2.5. HTML 5 Cache Technology

Flash abandons the support of mobile terminals, thus HTML5 has become the hot tool for Web applications. The traditional cache technologies only caches the site resources, and cannot cache the entrance HTML pages, so the Web applications cannot be accessed in the network outage.

HTML5 introduces the applications cache, namely that it can cache Web applications, which brings three advantages for Web applications [9]:

- Offline Access: users can access Web applications in the network outage.
- Fast Speed: the cached resources are loaded faster.
- Reduce Server Load: the browser only downloads the updated or changed resources from the server.

HTML5 provides two kinds of cache mechanisms: offline cache and local cache, which will be further presented in Section 4.

3. Smart Remote Control Application Based On Infrared Technology

3.1. System Architecture Design

Infrared devices in smart home include TV, set-top box, DVD player, air conditioning, capstone adjustable lamp, etc. This section designs and realizes the smart remote control application based on infrared technology. It is composed of three sub-systems: server platform, infrared adapter and remote control terminal, and Wi-Fi ensure all the devices in the same family LAN. The system architecture is shown in Figure 1 [10].

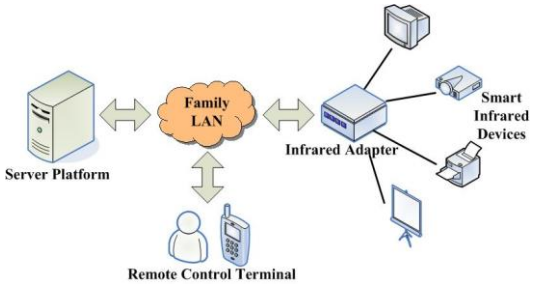

Figure 1. Smart Remote Control Application System Architecture

- Server Platform: it integrates and stores various information in the application and provides open API to facilitate developer's access to the data in fixed format including. The information includes: (1) program list and preview information of TV and other services; (2) smart device information, such as device type, location and sensor resources; (3) other data needed in infrared remote control application, such as user information, developer settings and infrared remote control instructions.
- Infrared Adapter: it connects the infrared devices to embed them into the smart home system. Infrared adapter is composed of learning infrared module, RM-04 serial port-to-Wi-Fi module and alloy shell. The infrared module connects to Wi-Fi module through TTL serial port, and power of Wi-Fi module is supplied by infrared module.
- Remote Control Terminal: on one hand, it accesses the server platform data through HTTP [11], and stores the parsed data in the local application; on the other hand, it sends the remote control instructions to the infrared adapter through Socket and Wi-Fi, and the instructions will be further sent to the corresponding devices after parsing by the infrared adapter.

Among these three sub-systems, smart remote control application is realized on the remote control terminal, and it is the key point of this section. The following will specifically introduce the device registration module of infrared devices on the infrared adapter, the communication module between remote control terminal and server platform, the communication module between remote control terminal and infrared adapter.

3.2. Device Registration Module

Device registration module connects the smart infrared devices with the infrared adapter, thus embed them into the smart home system. Through research and analysis, the infrared code file sizes of TV, set-top box, DVD player and air conditioning are 2570 bytes, 5654 bytes, 3598 bytes and 13364 bytes. Limited by the memory of infrared adapter, it can connect about 6 infrared devices. An infrared adapter cannot connect to too many devices, or it may lead dysfunction. Also, considering the infrared wave cannot pass through walls, each room should schedule the separate infrared adapter to connect the infrared devices in it.

Device registration can be achieved by the infrared adapter management interface, which provides device registration and device deletion functions. To finish device registration, device location, device type and device ID and other parameters must be provided.

3.3. Communication Module between Remote Control Terminal and Server Platform

Server platform provides most of the information of the remote control application. This section introduces the information communication between remote control terminal and server platform with TV program information download as an example.

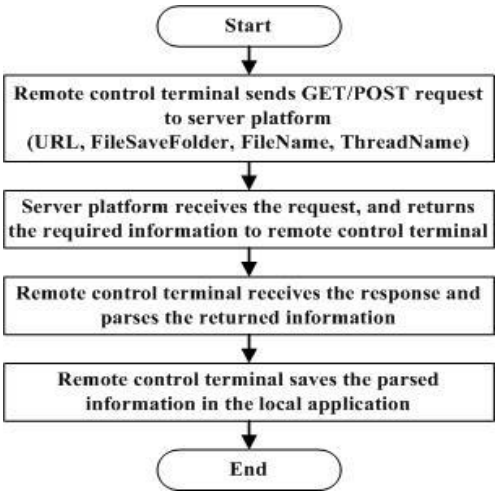

Figure 2. The Communication Process between Remote Control Terminal and Server Platform

The communication process is shown in Figure 2, the remote control terminal firstly sends GET/POST request to the server platform, which includes the required URL, FileSaveFolder, Folder Name and Thread Name. After server platform receiving the HTTP request, it returns response to the remote control terminal with required information. Then the remote control terminal parses the returned information, and saves them into the local application.

3.4. Communication Module between Remote Control Terminal and Infrared Adapter

Smart remote control terminal controls the infrared devices through communication with the infrared adapter. This section introduces the information communication between remote control terminal and infrared adapter with controlling TV as an example.

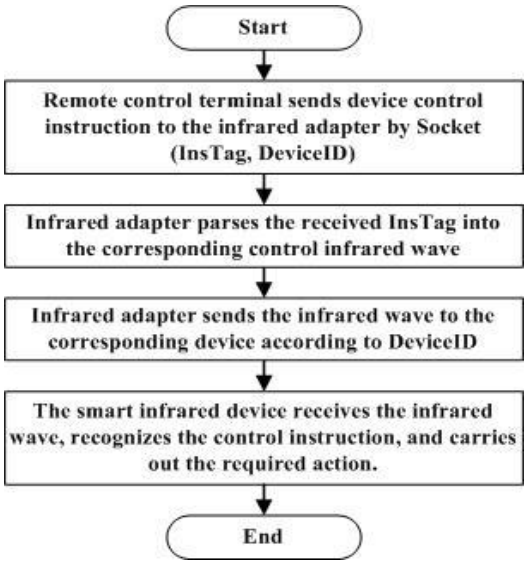

Figure 3. The Communication Process between Remote Control Terminal and Infrared Adapter

As shown in Figure 3, smart terminal application connects to the infrared adapter through Wi-Fi, and it sends device control instruction to the infrared adapter by Socket protocols. After receiving the control instruction, infrared module parses the Ins Tag and the Device ID, in which Ins Tag refers to the control command, such as changing channels, adjusting volume and muting, and Device ID refers to the device controlled. Then infrared adapter transfer Ins Tag into the corresponding infrared wave, and sends it to the right device, namely TV in this example. The smart infrared device recognizes the control instruction with the infrared wave and carries out the required action.

4. Remote Control and Monitor Application Based On Phone Gap

4.1. System Architecture Design

Smart home system monitors the temperature, humidity, real-time information of the devices to provide feasible, stable and prop gable services to users. The system architecture can be divided into sensing layer, gateway layer, platform layer and application layer, in which some devices in the sensing layer directly connect to the gateway, such as temperature and humidity sensors, light sensors, smoke sensor, curtains, smart socket and other devices. This section designs and realizes the remote control and monitor application for these devices based on Phone Gap, which has the following features [12]:

- Reliable and authoritative: it applies industrial sensors to provide precise, reliable and authoritative data measurement.
- Easy installation: it can be easily installed cross-platform with wireless transmission.
- Flexible structure and free information display: it is based on B/S system structure, so the application can be directly accessed without any So the application can be accessed without any software or plug-in. Devices information can be conveniently displayed in the mobile terminal application, such as temperature, humidity, light, device switch information and other historic information.
- Graph form display with powerful analysis functions: the real-time data, image resources and other device states can be displayed in the graph form, and it also provides powerful analysis functions, which it intuitive and thorough to the users.
- Remote video monitoring: the system installs remote network cameras, including ordinary cameras and night vision cameras, so all the information in the home can be observed by the surveillance video. Also, users can remotely control the sensors and devices with the network access and control access in the system, making users as if were at the scene.

PhoneGap is a cluster of mobile devices API, which can be accessed through JavaScript and call the hardware and system resources especially with UI frameworks of HTML5 and CSS3. PhoneGap can transplant a Web application program to both Android and iPhone smart terminal, which greatly saves the development cost, development cycle and improves the user experience consistency.

Remote control and monitor application based on Phone Gap can be divided into three modules: remote control module, remote monitor module and cache function module.

4.2. Remote Control Module

The function of remote control module is similar with the smart remote control application. Users remotely control the devices in the smart home system from the Web or mobile terminals, such as the device switch and the brightness control.

According to the API provided by the application, users sends POST request in fixed format [13], such as XML and JSON, which includes the DeviceID, InsTag and GatewayID. Then the application integrates this information into the device resource

URI, and access to the gateway interface defined by GatewayID to achieve the device remote control. URI integration in the application is realized as follows:

```
private static bool OpenSensor(string DeviceID, int i)
{
   string url = FunctionCollection.PreUrl();
   url = url + DeviceID + Ent.Ins + InsTag;
   PostHttpResponse(url, DeviceID, "open", "1" + i.ToString());
     const string RqContent = @"<?xml version = '1.0' encoding = 'UTF-8' standalone =
'yes'?>   <Device DeviceID = ""{0}"" version = ""1.0"";.
   <OP ID = ""{1}"">
   <parameters>
   <para name = ""channel"">{2}</para>
   </parameters>
   </OP>
   </Device>";
   StringBuilder statusBuilder = new StringBuilder();
   statusBuilder.AppendFormat (RqContent, DeviceID, Action);
   FunctionCollection.Post(url, statusBuilder.ToString());
}
```

4.3. Remote Monitor Module

Remote monitor module displays the smart home system information, including device information and all the data information collected by the sensors and other smart devices in the smart home system.

On the contrary with remote control module, users sends GET request to the gateway API to get the required information, and parses them into readable data. These data can be displayed to users in different forms, such as bar charts, pie charts, line charts and their combinations, thus users can clearly observe the required information and its trend. The temperature sensor requires and parsed data as follows:

```
S.ajax{{
type:”GET”,
url:”http://smarthome.openapi.cn/Sensor/”+GwNamearr[1] + ”/Tem/Value.xml”,
dataType:”xml”,
success:function(xml){
   unit.S(xml).find(“SensorValue”).attr(“Unit”);
   Tem_now = S(xml).find(“SensorValue”).text();
},
error:function(){
}
}}
```

Remote monitor module provides various or customized query services, such as query data in a certain day or a certain period time. For example, users can query the water consumption in the previous month, the visitor numbers in the current day at any time, effectively improving the user life quality.

4.4. Cache Function Module

In order to complete the cache functions of the application and make it can be accessed in the network outage; this paper applies the HTML5 cache mechanisms. It provides offline cache and local cache as follows [14]:

- Offline Cache: when accessing to the application HTML page at the first time, it sends request to get the manifest file and other caching resources, and saves them locally. The follow-up accesses to the application will read the HTML page and other resources from the local cache whether with the network or not.

- Local Cache: the local storage mechanism of HTML is divided from Web cache. It stores some customized information into the local hardware with SET/GET interfaces of the browser, such as user personalization and text data type [15]. This information can be accessed and displayed at any time.

The image cache in the remote control and monitor application applies HTML local cache method. The image resources are stored in the local storage, and they can be directly read and displayed with Data: image method in CSS3. This is a good method for Web cache; however, it can only store resources in 5M. Once beyond this range, the response will be very slow and even the resources cannot be cached. Therefore, this paper proposes a combination method of thread and cache, namely minimizing the download images before storing it to reduce the memory consumption.

As for the multimedia cache, the application stores the URL address with the HTML5 local cache mechanism. When user requires the multimedia resource, it will search the URL in the database, and download the resource from the server once searched successfully.

5. Application Testing and Deployment

Before application deployment, each module should execute strict functional and performance tests. Applications passed the testing can be deployed in the application [16]. Table 1 shows the functional testing and performance testing of remote sensor controlling and monitoring modules.

Table 1. Remote Sensor Controlling and Monitoring Modules Testing

	Remote Sensor Controlling	Remote Sensor Monitoring	Testing Result
Description	Test if the sensor can be remotely controlled within the required performances.	Test if the sensor can be remotely monitored within the required performance.	
Functional Testing	Send “turn on” instruction to the sensor, and observe the sensor turns on or not.	Require the current data from the sensor, and observe if the application displays it.	Yes
	Send “turn off” instruction to the sensor, and observe the sensor turns off or not.	Require data in the previous day from the sensor, and observe if the application displays it.	Yes
Performance Testing	Send “turn on” instruction to the sensor, and observe if the sensor responses within required time.	Require the current data from the sensor, and observe if the application responses within required time.	Yes
	Send “turn off” instruction to the sensor, and observe if the sensor responses within required time.	Require data in the previous day from the sensor, and observe if the application responses within the required time.	Yes

6. Conclusions

In the background of IoT technology, this paper designs and develops two smart mobile terminal applications as follows:

- Smart remote control application based on infrared technology: it realizes remote controlling on infrared smart devices in the smart home system, such as TV, set-top box, DVD player, air conditioning, capstone adjustable lamp, etc. The application includes three sub-systems: server platform, which integrates and stores most information of the application; infrared adapter, which connects all the infrared devices into the smart home system; and remote control terminal, which accesses information from the server and sends control instructions to the infrared devices by infrared adapter. The technologies applied in this application are infrared transmission technology, Wi-Fi and Socket technology.
- Remote control and monitor application based on PhoneGap: it realizes remote controlling and monitoring on the devices directly connected to the gateway, such as temperature and humidity sensors, light sensors, smoke sensor, curtains, smart socket and other devices. The application includes three modules: remote control module, which remotely control the devices with POST request, remote monitor module, which remotely require the devices information with GET request, cache function module, which allows application accessing in the network outage. The technologies applied in this application are PhoneGap, HTTP request and HTML5 cache technology.

Limited by the IoT technology and device performances, such as the disadvantages of infrared technology and PhoneGap, some problems still lie in the applications in this paper, for example, it responses slow with large data, and it displays different content with different browser kernel. However, with the development of hardware and software technologies in IoT, the smart devices are more and more intelligent, the above problems will be soon solved[17]. Almost all the devices in the smart home can be remotely controlled and monitored, which makes people's life more convenient and pleasant, and will further promote the development of smart city [18].

Acknowledgements

These should be brief and placed at the end of the text before the references.

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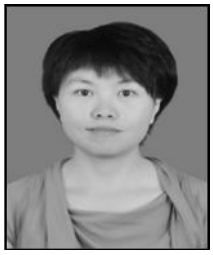

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