

Design and Realization of Internet of Things Based on Embedded System Used in Intelligent Campus

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Abstract

In order to satisfy the requirement of management in campus, an application platform of internet of things which used in intelligent campus is designed. The function of the system is achieved by embedded processor PXA270, ARM Linux operation system, new communication technology ZigBee and video monitor technology. The hardware and software designs of this system are illustrated in detail. By building embedded stream media server, the system completes video capture, compression, storage and transmission. The paper makes full analysis for the flow of programming. The experimental results show that the system can satisfy the requirement of management and has high quality video transmission.

Keywords: *Embedded Linux, B/S, ZigBee, TCP/IP, Video Monitor*

1. Introduction

Internet of Things is the network which connects the physical world integrated of network-aware technology of the sensor and the sensor network, transmission technology of communication networks and the Internet, intelligent computing and intelligent processing technology. In this network, information items are transmitted to each other without human intervention. Its essence is the using of automatic identification technology to achieve automatic identification of goods and to realize interconnection and sharing of information via computer and Internet. IoTs means that the objects information is collected by data collection equipments like RFID and sensor etc, and link with internet based on agreed communication protocols. That realized intelligent identification and management of objects information, which could be exchanged, inter-connected, and shared within all things. From the architecture, we can see that Internet of Things consists of three parts: perception layer, network layer, application layer. The bottom is the perception layer, formed by the sensors and sensor networks. The middle layer is the network layer, mainly by the mobile communication network and the Internet component; the top is the application layer, such as intelligent computing and intelligent processing [1].

Currently, the application of Internet of Things in the university campus is already universal. Internet of Things is the mutual integration production of the general-purpose computers and embedded systems development to advanced stage based on microprocessor [2]. The using of IoT is more extensive than other traditional networks, covered the fields of smart home, smart Healthcare, Smart city, Smart environmental protection, intelligent traffic, intelligent agriculture, smart transportation[3][4]. In this paper, ARM + Linux and zigbee and internet technology are used in parking management and classroom management in campus, preliminary attempt of the application of Internet of Things in campus is done.

2. System Design

The system consists of three parts, shown in Figure 1.

1) Terminal nodes: terminal nodes are data collection nodes with sensors, which collect and send parking data. Terminal nodes are organized as star network based on the ZigBee protocol.

2) Coordinator: network coordinator node is based on PXA270 processor [5] and the Linux operating system, which has conversion capabilities of Internet protocol and ZigBee protocol. It can receive all data transmitted from terminal nodes by wireless, process and send to the server through the Internet. Parking management data transmit by TCP protocol. The image data of classroom management are transmitted with UDP protocol.

3) Server: Server communicates with the coordinator by TCP/IP protocol or UDP protocol. When you enter the address of the server in the client's browse web, you can inquiry information of parking spaces and classrooms.

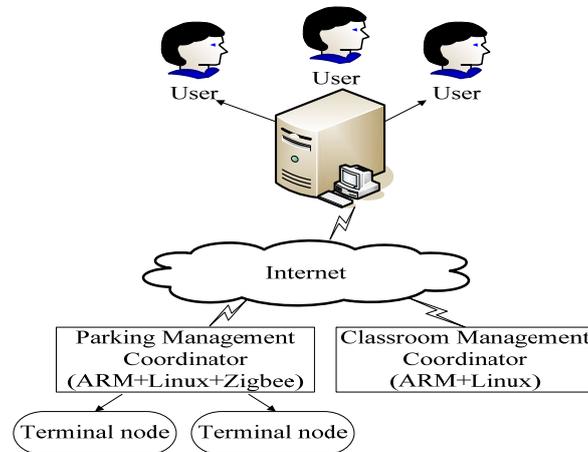


Figure 1.System Design

The work principle of the proposed system is shown as the following:

1) Parking Management: Real-time data of parking spaces is obtained by the sensors of ZigBee-based wireless network and then sent to the appropriate parking management gateway. Management Gateway integrates with the data to get information of parking spaces. On the one hand it transfers data to the server through the internet; on the other hand it transfers data to the display showing the current use of parking spaces.

2) Classroom management: The situation and environment of classroom acquired by sensors is transferred to the appropriate classroom management gateway, with all data integrated and processed by the gateway, and then it is transmitted to the server via the Internet.

Then the using of school's parking spaces and classroom can be accessed through the web browser real-timely.

3. System hardware design

System hardware consists of three parts: the terminal nodes, the coordinator nodes and the server.

3.1. Parking management terminal node

Parking terminal management node circuit mainly consists of the CC2430 [3] and sensors, and the structure diagram shown in Figure 2. Such nodes which are at state of sleep normally to conserve energy are widely distributed in the parking space and waken up by the co-ordination nodes periodically.

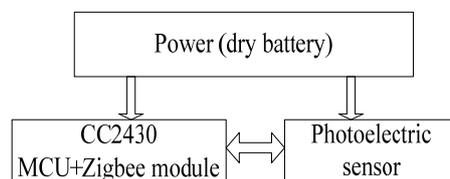


Figure 2. Parking Management Terminal Node

3.2. Coordination node

Coordination node consist of two type nodes: parking management coordinator and classroom management coordinator. Parking management coordination node consists of Intel's Xscale PXA270 [5] and external expansion circuit. The external expansion consists of several parts:

- 1) Memory modules: Nand Flash memory and SDRAM memory;
- 2) External communications interface module: network interface, serial interface, ZigBee wireless communication module;
- 3) LED display: LED display shows the use of parking spaces and guides the driver to stop the vehicle;
- 4) Power management. Power supply circuit for the processor chip used SPX1117 series chip to provide 3.3V and 1.8V voltage.

The architecture of Parking Management Coordinator is shown in Figure 3.

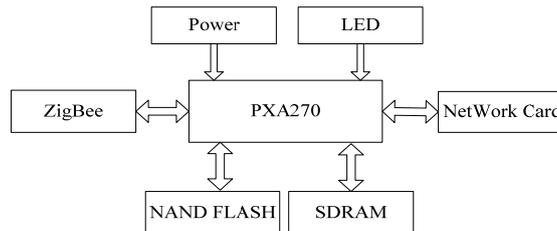


Figure 3. Parking Management Coordinator

Classroom management coordinator is shown in Figure 4:

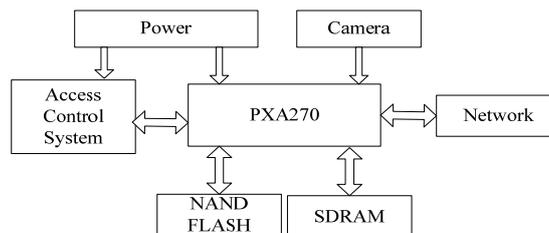


Figure 4. Classroom management coordinator

USB camera of the system use OV511 [6] as CMOS sensor chip, which is a high performance camera to USB interface controller chip. USB camera provide digital image signal to the acquisition system directly.

3.3. Server

Server is responsible for the coordination and management of the entire system, management software running on the server. It communicates with the parking management and coordinator through the TCP/IP protocol, and communicates with classroom management and coordinator by the TCP and UDP protocols. It also has function of video server and WEB server.

4. Software Design

System software design is divided into three parts: terminal node software program, coordinator node software program and server management software program.

4.1. Parking spaces terminal management node and coordinator node

Flow chart of parking management terminal node and coordinator node is shown in Figure 5:

Parking management terminal node sends signal to join the network after initialization successful. If joined the network successfully, the node collects parking information and sends to the coordinator

through Zigbee after treated by CC2430's processor. The coordinator node sends the data to the server after preliminary treatment.

Parking management terminal node is responsible for monitoring the status of parking spaces and sending ZigBee signal. Usually nodes are in a dormant state to conserve energy, only when state changed, then waken-up for data transmission.

Parking management coordinator is responsible for receiving sensor signals collected by all the parking terminal nodes, and the integrated information will be consolidated and sent to the server.

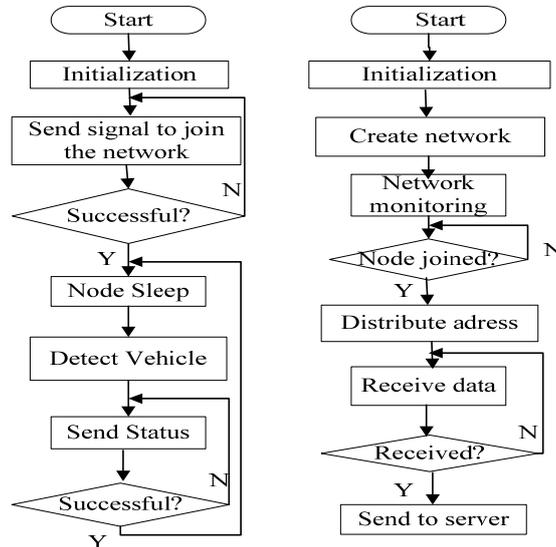


Figure 5. Flow chart of parking management terminal node

4.2. Classroom management coordinator

Classroom management function is used to monitor the using of the classroom real-timely. Access control system is used to control the door of the classroom and the camera is used to monitor the situation of classrooms.

Classroom management system is composed of three threads. One thread is sending the classroom access control system and environmental parameters to the server and accepting commands sent by the server; the others are image acquisition thread and image transmission thread. Circular buffer[7] is designed for coding thread and collection thread. When the using of classroom is inquired, the acquisition and transmission thread can be started. Otherwise they are all in a dormant state usually to save system resources.

Image acquisition function is by USB camera based on OV511. The OV511 chip is used in the camera. This chip is a high performance, image compression and. JPG data streams are output. This is a kind of static compression technology. Its characteristic is not considered in video stream at different frame between changes, only to separate frames to compress. The main function in image acquisition module is listed in Table1 [6].

Table 1. Main Function Representation

Function	Function representation
Init_video()	Initialize video equipment
Set_videoformat()	Setting video format and resolution
Grab_size()	Camera acquisition image size
Get_tjpg()	From drivers to grab image
Close_video()	Close video equipment

Because of the Linux operation system has OV511 driver, great convenience is brought for the development work. We can accomplish image capture function by loading necessary driver files and using V4L2 function interface.

In the arm-linux kernel directory execute the command: make menuconfig;

First, under the Device Drives → Multimedia devices → select (*) Video For Linux →, load video4Linux module for video capture device provides a programming interface;

Then, under the Device Drivers → USB support → select

<M> USB OV511 Camera support.

Compile the kernel to get ov511.ko, so we can load ov511.ko with insmod command.

Flow chart of image data acquisition [8][9] is shown in Figure 6

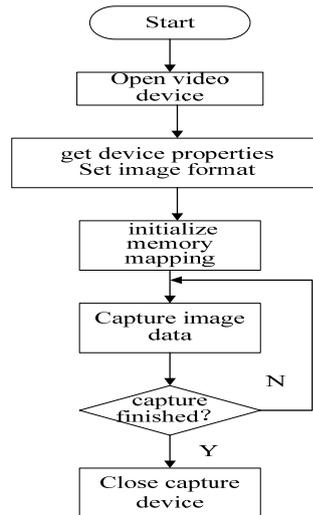


Figure 6. Flow chart of image data acquisition

1)Video Compression: In several open sources MPEG-4 encoding software, we select xvidcore as the core algorithm in the video compression module system. Xvidcore is an efficient and portable encoding software, library files generated by xvidcore cross compiled, provide a programming interface to the system's other modules. Encoded with Xvid is achieving through the using of library functions provided by xvidcore library, so you should transplant Xvidcore library to the embedded system development platform firstly. The latest version of Xvid is xvidcore1.2.2; you can download source code package xvidcore-1.2.2.tar.gz from <http://www.xvid.org/>.

Program design based on Xvid is divided into three parts: initialization, cycle encoding and ending. Accordingly there are three functions: enc_init (), enc_image (), enc_stop ().

XviD encoder initialization is accomplished by enc_init (). When the encoder parameter setting is finished, you can begin to create an instance of the encoder like the following function.

```
xerr=xvid_encore(NULL,XVID_ENC_CREATE,&xvid_enc_create,NULL);
```

When the instance of encoder is created successfully, the work of encoding is mainly accomplished by enc_image (). It asks xvid_encore() to encode and the encoded video data is copied to the transmit buffer to send. The main program loop achieves continuous video encoding.

When the end signal received, enc_stop () call xvid_encore (xvid_handle, XVID_ENC_DESTROY, NULL, NULL) to stop encoding work[10].

After capture module starts with video collection, we use getimage () function to get image buffer address and length circularly as input parameters of enc_image () function. Before an image encoded we should obtain the position of write pointer of the ring buffer, and it also should be transferred as an argument to the encode function. Encoding function read YUYV format raw frame data from frame buffer to encode and send the encoded data to the ring buffer directly.

2)Data transmission: Because of the small amount of data of classroom management, we use TCP protocol to transmit. UDP is non-connected and unreliable datagram transport protocol, but it provides an efficient connectionless service. UDP does not guarantee the reliability of data, so it has less

transmission delay. It is suitable for the occasion of high real-time applications and without requiring absolute reliability. Video image data has the characteristic of hard real-time and large amount, so the system uses this protocol to transfer data.

A sending thread is created on the node of coordinator of classroom, and is used to communication with server. Another thread is created to receive data which send from classroom coordinator node. All data is stored in the buffer space of each node.

4.3. Server system software design

Here we focus on how to view video images of classroom in browser. Because classroom coordinator node is embedded processing system, so its processing power and storage capacity is weak relatively. If the user accesses to the coordinator node directly without forwarding data through the server, the coordinator node will be crashed with the user increasing. The design of server allows users to increase without affecting the operation of the classroom coordinator, and solve the problem of storage.

Data received by the server is stored in the buffer space of each coordinator on the server. In order to solve the stream of receiving and forwarding problems, a multi-tasking video transmission technology based on circular buffer [11] are used. When a user requests to view the using of classroom through IE browser, the server sends video capture command to the coordinator node, video capture and transmission threads is waked up and accept real-time data to the buffer, then the server data transfer process starts.

Server-side requires three ports and four threads to meet the transport needs.

Port 1: listening port is used for monitoring the user's connection request.

Port 2: RTP packet port is used for the client to send RTP packets.

Port 3: RTCP packet sending and receiving port are used for sending and receiving RTCP packets.

The four threads are as follow:

Thread 1: listening thread is used to listen for user connection requests.

Thread 2: RTP packet sending thread is used to send RTP packet.

Thread 3: RTCP packet sending thread is used to send RTCP packet.

Thread 4: RTCP packet receiving thread is used to receive RTCP packet.

4.4. Client ActiveX plug-in design

Functions of video play controller include video stream receiving, image decoding and playback, as well as control begin and stop to play. Microsoft's DirectShow technology is used in decoding and display section, so Microsoft DirectX SDK and Microsoft DirectX runtime library program need to be installed for the development of computer programs.

Client is divided into three modules: data-receiving module, data-decoding module, video display modules, and each module implement a specific function.

(1) Data-receiving module: Receiving thread is responsible for receiving RTP packets from the specified port continuously and restored to one frame image, providing decoding thread to decode. Since an image is divided into multiple RTP packets for transmission, so the receiving thread must assemble contents of multiple data packets in the correct order to restore a frame of image.

Main realization process is as follows:

- 1) Initialization RTP session;
- 2) Set up receiving mode and receiving address list;
- 3) Receiving RTP packet;
- 4) Framing RTP packet.

(2) Data decompression module: Because RTP image frame is MPEG4 compression format, display the images Xvid decoder must be used. DivX decoder is used to decode data. DivX Decoder is stored in Directshow Filters directory usually and GUID is CLSID_LegacyAmFilterCategory. It includes an input Pin and an output Pin, MPEG-4 format data entered into input Pin, then through the output Pin passed to the next level Filter to display.

5. Experimental results

The system can manage the school parking spaces automatically, displaying state of spaces and indicating driver parking; also can query the usage and state of classroom real-timely. Figure 7 shows that the situation of classroom can be viewed through the web browser.



Figure 7. Situation of Classroom

6. Conclusion

This paper is an initial attempt of Internet of things based on embedded system in campus management. The system is base on ARM, Linux, Internet and ZigBee technology, combining efficient processing of ARM, low-cost and low power consumption advantages of ZigBee. And the system achieves parking management and real-time video monitoring of classrooms. Parking management terminal nodes, parking management and classroom management coordinator as well as server system is designed in this paper. A series of issues about parking management, classroom management and classroom control are solved. Tests results show that the design method is feasible, and provide a method of application of IOT in the campus. The benefits of the realized system are low power consumption, scalability and high real time. In the future we will combine with other campus management module to further expand the system capabilities.

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