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Design of Greenhouse Surveillance System Based on Embedded Web Server Technology

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Abstract

The embedded web technology is increasingly applied in precision agriculture. Based on ARM-Linux development environment, this paper constructs embedded web server and use it in acquisition and transmission of greenhouse information. The system could transmit the collected information effectively with benign stability and expansibility. Microprocessor S3C2440 based on ARM9 is used as the system processing unit, its rich resources can not only realize the system function, but also facilitate the system expansion in the future. Embedded web server Boa and embedded database management system (DBMS) SQLite are selected to construct the software system of web server. Common Gateway Interface (CGI) program is developed to implement dynamic web technology and the interaction with the users. Experiment results show that the working performance of the system is quite stable and can reach the design requirements in real-time data acquisition and remote control. Furthermore, the system has the characteristics of good expansibility, networking flexibility and low cost.

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Keywords: embedded web server; wireless sensor network; greenhouse monitoring

1. Introduction

In recent years, the modern large-scale greenhouse has been gradually built up in the precision agriculture zone. In greenhouse, soil temperature, moisture, conductivity and air temperature, moisture, illuminance, the concentration of carbon dioxide are the primary factors that affect the crops growth [1-3]. The most important thing for administrator is to master the greenhouse condition in time, and then take

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effective measures. The new tools applicable to precision agriculture are the advances in electronics and computers such as Wireless Sensor Network (WSN), INTERNET and GIS. These technologies cover the aspects including data collection, transfer and analysis or processing of information. Embedded technology is the basis of three technologies above mentioned [4-6]. It is expected that Internet applications based on the IP network can be used in embedded systems, and not only PC devices but various embedded devices can be connected to the Internet. Embedded web based environment condition monitoring system directly connects the devices and equipments to network as nodes. Using Browser/Server model, it provides the condition information by web page form for user browsing. The clients do not need special software and may monitor the current condition of devices and equipments through browsers [7, 8].

Integrating web and embedded technology, this paper proposes a design of monitor system for greenhouse based on embedded web server and wireless sensor network. A tiered architecture monitor system is discussed firstly, and then detailed design of the system is given including hardware and software of embedded web server and wireless sensor network. The embedding way of web server in the device enable the embedded devices to be connected to the Internet and also enable users to access, control and manage the embedded devices using a standard web browser over the Internet without restrict of time and space.

2 Structure design of the system

The architecture of the greenhouse environment monitoring system based on web server and wireless sensor networks consists of common sensor nodes, sink nodes, and communications system. A control center is not needed in this architecture compare with an traditional one. A large number of the sensors can be placed in the greenhouse and constructed a self-organized network to monitor the data change including temperature, humidity and gas concentration, etc. To perform a complete and accurate environment monitoring, it is significant to introduce image and video into sensor networks system in some applications [9]. Thus, image devices can be optionally equipped according to the need of application and the cost limitation. The common nodes will collect the data which transmitted to the sink node and stored in the embedded database on sink node. Users can send the control information to any node or read the data from any node in the network through Internet and sink node. That means sink nodes act as the media of the communication between common nodes and users, and it can not realized to directly send message between them. We used a CDMA modem to connect the wireless sensor network to the Internet, and then any authorized users can access the data through browser.

In order to connect the embedded devices to the Internet and enable users to monitor the embedded devices using a standard Web browser, the key technologies of embedded Internet are the embedded devices can provide the HTTP service and has the function of web server. The embedded web server provides the graphical web-based interfaces to users of the Internet/Intranet to carry out unified supervision and management of various devices linked to network. The special client management software is not needed.

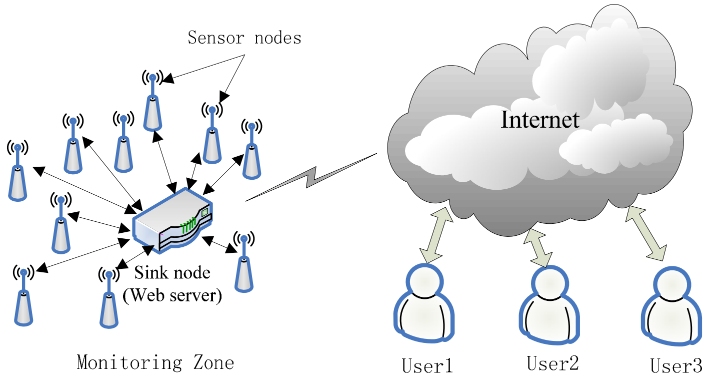

Fig. 1 The block of embedded web server

3 Hardware design of the system

As the most important part of a sensor node, processor and wireless chip exploits CC2430. The chip includes 2.4GHz RF transceiver and an industry-standard enhanced 8051 MCU, 32/64/128 KB flash memory, 8 KB RAM and many other powerful features. Thus it can content the need of high performance and low power in 2.4 GHz IEEE 802.15.4 band based ZigBee. The data integration and storage, positioning algorithm and other complex computation are completed by sink node, so a more advanced processor is needed. The design in this paper applies S3C2440 32-bit ARM microprocessor which takes ARM920T as its core. This microprocessor has rich resources, including Clock, USB, SDRAM, UART, Nand Flash, LCD, RS232 Interface, Ethernet Interface, JTAG, Power, etc. These modules can help achieve Internet services.

Sensor node is the basic platform of wireless sensor networks. The sensor node consists of five parts, sensor module, analog/digital (A/D) conversion module, processing module, wireless communication module and the power module. Sensor module is used to collect temperature, humidity, gas concentration and other parameters. Analog/digital conversion module can convert analog signal comes from sensor module to digital signal which can be recognized by processor unit. The processor module controls the operation of the sensor nodes, stores and processes the collected data, as well as complex computation and analysis. Wireless module communicates with sink nodes; exchanges control information; sends and receives data. In this paper, wireless communication module is based on ZigBee technology, which is the set of specs built around the IEEE 802.15.4 wireless protocol. ZigBee devices in a network can communicate at speeds of up to 250Kbps while physically separated by distances of up to hundreds of meters in typical circumstances and greater distances in an ideal environment. Based on ZigBee network communication technology and microprocessor technology, the system can deal with the various operating parameters of the remote transmission, real-time data collection and real-time monitoring. The power modular provides the energy to the sensor module, A/D conversion module, processing module and wireless communication module.

4 The design of embedded web server

4.1 The architecture of embedded web server

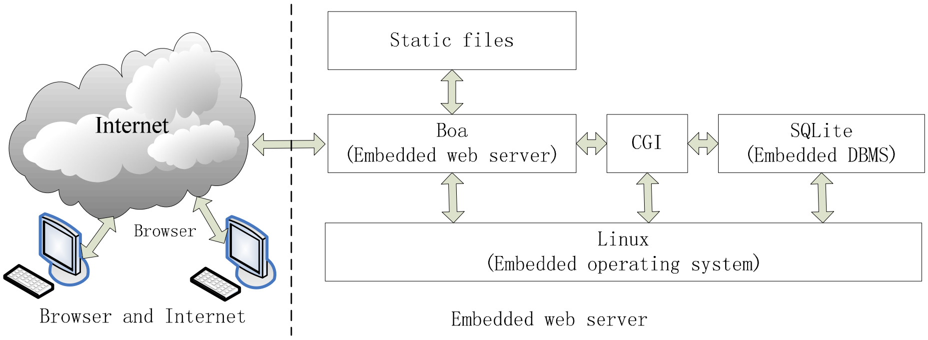

Fig. 2 The block of embedded web server

The architecture of embedded web server is shown in Fig. 2. The entire system uses B/S mode. The client is connected to the Internet through a browser and then gets access to the embedded web server. Through this way, remote login and operation are realized. Compared with the traditional C/S mode, this mode is simple to use, convenient to maintain, and easy to extend. The remote publishing of sensor data is achieved through the CGI technology. CGI is a standard interface for external applications to interact with a web server. We transplant embedded Linux system to S3C2440 processor and build Boa web server, which is responsible for listening to customer requests from the Internet as a running process in the background. When users send requests through browsers (for example, Internet explorer, Firefox, Chrome, etc.) to embedded web server to start the corresponding CGI program and accomplish the processing of parameters, the web server translates the request parameters into environment variables or standard input. CGI programs perform the corresponding query and update operations of SQLite database and the results are converted to the format which is recognized by web browsers. Then they are returned to the clients as HTTP response messages, thereby achieving the remote query of monitoring data collected by sensor networks.

4.2 The software choice of embedded web server

Considering the need of large dynamic data exchange during equipment monitoring, using Samsung's S3C2440 as the platform, the paper proposed a solution to implement embedded Web server in the embedded Linux operating system environment. The solution takes the general web design technique as foundation and combines embedded CGI (Common Gateway Interface), embedded database management system technology. It can well meet the application requirements in the greenhouse surveillance system. The remote monitoring client browser posts a HTTP request and then CGI programs operate SQLite database. The System software architecture is shown in Figure 2.

At present, there are three kinds of prevalent embedded web servers, i.e., httpd, Boa and thttpd. As the simplest web server, httpd has the weakest functions among them. It does not support authentication and CGI technology while Boa and thttpd support these functions. If some static web pages such as simple online help and system introduction are merely provided, a static server can be adopted. However, if an improvement of system security or interact with users are to be completed, such as real-time status query and devices controlling, then you have to use dynamic web technologies and Boa or thttpd are options. In our resolution, web server Boa is used. Compare with another web server thttpd, Boa is suitable for embedded system because the latter has less function and needs far more resources to run, while Boa is a single task web server. The difference between Boa and traditional web server is that Boa does not create a separate process for each connection when a connection request is accepted, nor handle multiple connections by copying itself. Instead, Boa handles multiple connections by establishing a list of HTTP requests, but it only forks new process for CGI program. In this way, the system resources are saved to the largest extent.

4.3 The mechanism of embedded web server

When http request URL is the external extended program, web server puts the client side input's form data in the environment variable. The results will be returned to the web server in HTML document form. This process exchanges data between web server and external extended program. According to CGI interface specification, the communication methods between application and web server have environment variables, command line, the standard input and output. The transmission has GET, POST and HEAD method. Different to standard CGI, the implementation of embedded CGI often aims at specific applications based upon the consideration of the characteristics of embedded systems. When the user setting equipment control parameters (such as data acquisition parameters) through the browser, the parameters can be analyzed from http message and handled correctly. Because of the function be greatly simplified, the solution of embedded CGI has the following characteristics: it does not involve complicated process in the embedded CGI program. It is called as a sub-function of the HTTP request handling process; after analyzed the form data from HTTP messages, the embedded CGI program create a dynamic memory area for writing form data, but not to use the environment variables. And then the dynamic memory address will be passed to CGI procedure as the called parameters; the results are directly passed to the client browser. This method increases the efficiency greatly.

The management and storage of acquired data by large mount of sensors is an essential problem, thus an effective database management is needed. The well-known open-source database SQLite is one of the most widely used embedded database, which abandons many complex features of traditional enterprise database and only implements the necessary functions in terms of a basic database.The system overhead is small and it has retrieval efficiency, supporting Atomic, Consistent, Isolated, and Durable (ACID) properties and SQL92 standard. Considering the features mentioned above, SQLite database is adopted in this scheme based on the embedded Linux operating system to manage data.

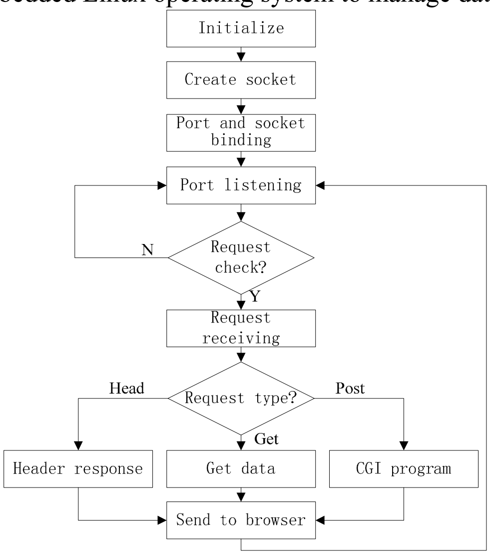

Fig. 3 The flowchart of embedded web server

6 Experiment results and conclusions

Through the main page of the embedded website, it can realize the remote access of sensor monitoring data and control the devices in the greenhouse, also it support the query of the historical records and download of the environmental monitoring data to the client according to requests. The remote video monitoring unit can implement both real-time image monitoring and the query of the photo image files automatically captured when the monitoring system in abnormal states.

It is significant that the latest tools of science and technologies are applied for precision agriculture. This paper described the design of a novel web-based monitoring system for agricultural environment. Compared with the traditional WSN method, the whole system has low-cost, good openness and portability, and is easy to maintain and upgrade. The results of long-term experiments confirm the good reliability and stability of the system. Further quantitive experiments and evaluation of the system are the topics of our future study.

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