Design and Implementation of Embedded Network Intelligent Control System Based on Big Data Era

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Abstract. Embedded systems transform the Internet to the Internet of Things, and promote cloud computing and large data service applications. Big data is the complete data group of human data and physical data in the Internet of Things. This paper presents an embedded network intelligent control system based on ARM & Linux. The system uses the embedded Boa server as the network server of the embedded network intelligent control system. Firstly, the architecture of embedded network intelligent control system based on web server is given. Secondly, the software system is described. Finally, the detailed modification process of Linux kernel for embedded network enabling control of terminal hardware is given. The embedded network intelligent control system architecture based on TCP/IP protocol stack can simplify the system architecture to a certain extent and has higher practicability. The experimental results show that the system works stably when the network communication speed is 1 Gb/s and the communication frequency is 80 Hz/s.

1. Introduction
After entering the Internet of Things era, embedded systems have entered the era of large-scale technology of intelligent services from the era of independent development. In the Internet of Things application, the embedded system undertakes the underlying physical information collection task. Traditional control systems often transmit sensor signals to the controller through point-to-point dedicated lines, and then control the actuators through point-to-point dedicated line control signals [1]. The embedded operating system is a versatile system software. It has the characteristics of real-time system commercial efficiency, strong hardware dependence, module loading and unloading, software can be solidified at any time, and application specificity. Through the connection of wireless communication sensor technology and Internet application platform, it is combined into a network system with intelligent identification and management functions [2]. Pushing the era of humanistic data in the Internet of Things to the era of big data including massive physical data. At present, the most popular technology in the field of control is fieldbus control technology. Fieldbus control technology is a computer control technology based on fieldbus, which is fully distributed, fully digital and fully open, and is suitable for industrial process control and other aspects [3]. The embedded network intelligent terminal control system studied in this paper organically combines the embedded operating system with the Internet network by directly connecting the microprocessor system with the Ethernet. Embedded control system is the product of the combination of information network and control network. It uses network technology and embedded technology to complete monitoring and control tasks, expanding the scope of monitoring to a larger space, and further promoting the development of control technology in the direction of networking, decentralization and openness.
2. Embedded System and Big Data

All data related to physical objects in big data are collected by various embedded system intelligent tools. Intelligent tools have the ability of real-time acquisition and real-time processing of physical data, thus ensuring the real-time nature of physical data in big data. The explosive growth of data information has prompted people to step into a fast-paced lifestyle, which makes it increasingly difficult for traditional products to meet users’ experiential needs [4]. Embedded system can convert analog data to digital data, so that this part of physical data can also enter the field of big data. The intelligence acquisition method of intelligent tools can expand the information content in data collection anytime and anywhere [5]. According to the relevant requirements, the required registers and their capacities have been set accordingly, so that these settings can be in a corresponding state with the smart terminal. Big data technology makes this brain have powerful self-perception, self-recognition, self-processing, self-decision ability, and the complex interactive working principle of intelligent products has become the focus of users. When a large amount of real analog quantity is not converted into a digital quantity, a large amount of information in the data is difficult to apply [6]. When converted into digital quantities, a large amount of information retained in the digital signal can be extracted through various signal processing means.

3. The Overall Scheme and Hardware Design of Embedded Network Intelligent Control System

3.1. Embedded network intelligent control system overall architecture

The embedded network intelligent control system ARM9 processor is the core, and the periphery of the chip expands the power supply, memory, network communication module, button module, display module and temperature measurement module. The embedded network intelligent terminal is directly connected to the Ethernet, and the data is transmitted to the Web server of the Internet wide area network. At this time, the host in the WAN can access the information in the web server at any time, and the purpose is to obtain the data generated by the embedded network intelligent terminal or to control the intelligent terminal. The scheduling server plays the role of load scheduling in the system, so as not to overload one of the Web servers [7]. The Web server group collects the data of the embedded network intelligent terminal system and answers the access of the WAN host. In practical applications, it can support a variety of CPU and hardware platforms, and can run without faults for many years. Now it has been widely used in data centers.

In this paper, Linux is used as the operating system platform for the network intelligent control system, which has strong network scalability and reliable device networking capability. Therefore, the system can realize remote user access, monitoring and control of the underlying sensor devices. The overall hardware design is shown in Figure 1.

![Figure 1. General architecture diagram of embedded network intelligent control system](image-url)
Because embedded equipment is a special computer system, it can adapt to the harsh environmental requirements of the control site by adopting a special hardware platform, while ordinary PCs may be disturbed due to power outage, electromagnetic interference, noise, etc. The DSP processor has strong control and signal processing capabilities, and can implement complex control algorithms [8]. The host in the WAN can randomly access the Web server to obtain the data of the embedded network intelligent terminal or control the embedded network intelligent terminal. The host with specific authority can directly access the embedded network intelligent terminal.

3.2. Chip selection
The development of microelectronics technology has made the embedded technology unprecedentedly developed. The performance of various embedded processors is continuously improved, the power consumption is continuously reduced, and the cost is becoming lower and lower. The current mainstream embedded processors are single-chip, DSP, ARM and other types. The embedded system is usually application-centric and based on the emblem processor. The software and hardware can be cut, and it is applied to the occasions where the reliability, cost, and power consumption are strict, and the object is specialized. Web servers are remotely managed, especially for devices that do not have a traditional user interface. Not only that, but the Web server can communicate with related remote devices and present relevant data. The single-chip microcomputer has the advantages of small size, low power consumption, low cost, etc., but the digital computing capability of the single-chip microcomputer is not strong enough [9]. At present, there is no transplanted protocol stack, so it is difficult to realize communication based on Ethernet. The internal register of AX88180 is configured by the network driver to realize the sending and receiving of Ethernet data, thus realizing the data communication between the system and the network. As the software and hardware of the embedded system can be cut out, some redundant functions in the system can be removed, and the possibility of the system being attacked can be reduced to a certain extent under the condition of connecting with the Internet; With the rapid development of computer network technology, Ethernet has been widely used in daily life and work. The application of embedded technology in network products has a broad development prospect. Analyzing the connection between embedded technology and Ethernet technology is bound to promote the development of remote control and management effect of embedded equipment.

3.3. ARM embedded microprocessor
Embedded microprocessor S3C2440 is based on ARM9TDMI core. The ARM9TDMI core provides a simple bus interface, allowing users to design their own Cache and storage system, which can be embedded into the target system as a separate core. The core platform is composed of ARM processor and Linux operating system. The hardware connects the Internet through DM9000 Ethernet network card. Embedded Linux operating system supports TCP/IP protocol stack, so the network data transmission between remote PC and gateway is based on socket. The controlled object software part deals with how the sensor collects the signals of the controlled object, how to drive the controlled object and peripherals, and how to transmit the signal to the embedded network intelligent control terminal [10]. When the microprocessor is running in user mode, some protected resources are not accessed. In addition to the user mode, the other six modes are called non-user mode or privileged mode. The five modes, except user mode and system mode, are also called exception modes, and are often used to handle interrupts and exceptions, as well as access to system resources that need to be protected. As shown in Table 1 below.

| Mode             | Schema description                          |
|------------------|---------------------------------------------|
| User             | Normal program execution state of ARM microprocessor |
| Quick interrupt  | For high-speed data transmission or channel processing |
| External interrupt | For general interrupt handling           |
| Management       | Operating system protection mode           |
| Data access aborted | Realize virtual storage and storage protection |
The AX88180 chip and 88E1111 chip are connected by Gigabit Ethernet Media Independent Interface (GRM II) mode to realize the function of network interface layer in TCP/IP protocol architecture and realize link layer protocol and physical layer protocol respectively. Because the ARM architecture uses multi-stage pipeline technology, for ARM instructions, the program counter PC always points to the address of the next two instructions of the current instruction, that is, the PC value is the current instruction address value plus 8 bytes. The chip module communication method is ZigBee wireless network technology, so the coordinator is connected to another ZigBee chip module through the ZigBee network, thereby controlling each function terminal module, and the gateway and the coordinator communicate through the serial port.

4. Porting and Driver Design of Embedded Operating System Linux

4.1. Embedded operating system

At the beginning of the development of embedded system, the development of embedded software was based on the direct programming of microprocessor without the support of operating system. At this time, the simple software is a single-cycle polling system (or even simpler), while the slightly more complicated is a front-end and back-end system with monitoring. The embedded operating system provides API for application programs upward and manages hardware devices downward through hardware drivers. The embedded operating system uses the embedded Linux operating system here. The embedded network intelligent terminal software part involves the modification of the kernel, the transplantation of the operating system, the file processing, the design of the graphical user interface, and the processing of tasks. Such as storage peripherals, network protocols, multitasking, multiprocessors, etc. At this time, it is very difficult to control the embedded system with only the loop, and a unified control system is urgently needed.

The cross development of embedded software can be divided into three stages: application software generation stage, application software debugging stage and application software curing operation stage. The steps of application generation are shown in Figure 2.
The control part of the embedded network intelligent control system is based on DSP. The DSP processor is connected with the FPGA. The connection signals include address bus, data bus, chip selection signal, bus holding signal, clock signal, preparation signal, interrupt signal, read signal and write signal. To a certain extent, the system has high reliability and ensures the continuous operation of the system. The reason for this is that the most important factor affecting the reliability of the system is the computer itself. There are various mechanical components in the host computer, which are most vulnerable to damage and make the operating system hang up. In order to realize the data storage function of the embedded network intelligent control system, it is also necessary to ensure the integrity of the data and ensure that the collected data will not be lost. After receiving the data sent by the equipment node, the data shall be stored in a timely manner, and relevant data acquisition information shall be recorded.

4.2. **Construction of embedded cross-compilation environment**

The general software development environment is the same as the running environment. Debugger and debuggee are two processes running on the same machine and the same operating system. Debugger processes control and access the debuggee through the call interface specially provided by the operating system. CSMA/CD working mechanism is used in Ethernet to enable stations to compete for channels in an orderly manner. ZigBee network uses a similar CSMA/CA. When a station sends information, it first monitors whether the idle time of the system channel is greater than the frame length, and if so, sends it. Otherwise, continue listening and do not send. It can allow modification of equipment parameters through the form of Common Gateway Interface (CGI), thus performing remote monitoring. Web servers have become the standard for remote management, especially those devices without traditional user interfaces. Therefore, it is necessary to adopt a mode called cross-development, that is, the development system is based on PC or workstation (commonly called host) with abundant hardware and software resources, and the editing, compiling and linking of embedded software are completed on the host. In the design, the uncertainties of time delay and the possibility of communication failure in TCP/IP network, especially in Internet network, are considered, which increases the reliability of GPRS
wireless MODEM. That is, real-time data acquisition of network nodes, remote control equipment nodes, Web browser user configuration and dynamic acquisition and display, and database storage. In order to realize the functions of each project, it is necessary to design modules, and use multi-threading technology to correspond to each functional module, accept and process various business.

4.3. Porting embedded Linux operating system
Porting is one of the most widely used concepts in embedded Linux software design. In a broad sense, migration includes software migration and hardware migration; in a narrow sense, migration refers to software migration, that is, software migration from one platform to another and work on different platforms. Cross-compilation refers to the generation of code on one host platform (such as PC) that can run on another platform (such as ARM). Different CPU have different instruction systems. Common PC's instruction set based on X86 is different from that based on ARM. In the application, according to the hardware, the Linux kernel source code and hardware closely related parts are modified accordingly. It is responsible for initializing hardware, booting the operating system kernel, and detecting various parameters for the use of the operating system kernel. Among them, the DSP software completes the conversion of communication protocol and carries out corresponding operations according to the communication protocol. FPGA software completes the conversion from network data to parallel bus data. When the embedded node detects that the network connection is abnormally closed or the connection is overtime, it dials the remote monitoring host through the wireless MODEM module to realize point-to-point communication of the wireless network and transmit important data information. In Linux, its kernel, file system and graphical user system (GUI window system) can be separated, and their development, migration, download and even operation can be separated. Because our commonly used PC has a powerful integrated development environment and debugging tools. However, embedded systems that only carry specific applications in the end generally have limited memory space and computing power.

5. System Testing
After the design of embedded network intelligent control system is completed, in order to ensure the reliability and security of the system, this chapter tests the performance of embedded network intelligent control system. The performance test of embedded network intelligent control system mainly includes the stability simulation test of network intelligent control part and the performance test of embedded Web server part. According to the structure of the system, the system needs to debug these modules: the communication between gateway and remote PC network, the serial communication between gateway and coordinator, the communication between ZigBee network nodes, and the realization of terminal function module. Finally, the operation of the system. The embedded network intelligent control system is tested by communication control software. The control software includes: Time code, working frequency, group IP address, port number, command code, number, command time, command parameters, etc. Embedded network intelligent control system realizes the integration of information network and control network, so the performance of embedded Web server plays a decisive role in the performance of the whole system. The performance of embedded Web server is tested by simultaneous access control of multiple PCs to embedded Web server. The experimental results show that the embedded network intelligent control system works stably and reliably with a communication speed of 1 Gb/s and a communication frequency of 80 Hz/s, and has no frame loss, frame string and data errors.

6. Summary
Intelligent products in big data environment are the product of the integration of high-tech, emerging technologies and various platforms. They have gradually moved towards people's daily life and changed people's thinking habits and usage habits. Universal network access of embedded systems transforms the Internet into the Internet of Things. At the same time, the massive human data in the Internet virtual world will be pushed into the era of big data where the real world and the virtual world blend with each other. This paper expounds the design method of embedded network interface control system from the
aspects of hardware circuit design and software implementation scheme, etc. The application of this technology has been successfully applied to a certain type of control system, which is separated from the control computer, solves the practical difficulties caused by the inability to use the computer, and completes the embedded system control work well. Embedded Linux operating system is used as the software platform, and embedded Boa server is used as the Web server of the system. In the design, the traditional PC is abandoned as the server hardware platform, so the system cost is greatly reduced. The working technical index meets the requirements of the system and is stable and reliable. The embedded network intelligent control technology has important practical significance for the design of embedded network intelligent control.

References
[1] Xi L, Shengfu Y, Xiaoting F. An Embedded Intelligent Measurement and Control System for Combustion Driven DF Lasers[J]. Chinese Journal of Lasers, 2017, 44(5):0501003.
[2] Javed A, Larijani H, Ahmadinia A, et al. Smart Random Neural Network Controller for HVAC Using Cloud Computing Technology[J]. IEEE Transactions on Industrial Informatics, 2016, 13(1):1-1.
[3] Geminiani A, Casellato C, Antonietti A, et al. A Multiple-Plasticity Spiking Neural Network Embedded in a Closed-Loop Control System to Model Cerebellar Pathologies[J]. International Journal of Neural Systems, 2017:1750017.
[4] Fadlullah Z, Tang F, Mao B, et al. State-of-the-Art Deep Learning: Evolving Machine Intelligence Toward Tomorrows Intelligent Network Traffic Control Systems[J]. IEEE Communications Surveys & Tutorials, 2017:1-1.
[5] Guan Z G, Miao Q H, Si W H, et al. Research on Highway Intelligent Monitoring and Warning System Based on Wireless Sensor Network[J]. Applied Mechanics and Materials, 2018, 876:173-176.
[6] Lv Y, Lin D. Design an intelligent real-time operation planning system in distributed manufacturing network[J]. Industrial Management & Data Systems, 2017, 117(4):IMDS-06-2016-0220.
[7] Faa-Jeng L, Su-Ying L, Jo-Yu C, et al. Intelligent PV Power Smoothing Control Using Probabilistic Fuzzy Neural Network with Asymmetric Membership Function[J]. International Journal of Photoenergy, 2017, 2017:1-15.
[8] Huang, Hsu-Chih. A Hybrid Metaheuristic Embedded System for Intelligent Vehicles Using Hypermutated Firefly Algorithm Optimized Radial Basis Function Neural Network[J]. IEEE Transactions on Industrial Informatics, 2018:1-1.
[9] Wu X, Huang Z, Peng X, et al. Building a Spatially-Embedded Network of Tourism Hotspots From Geotagged Social Media Data[J]. IEEE Access, 2018, 6:21945-21955.
[10] Design and Analysis of Multimodel-Based Anomaly Intrusion Detection Systems in Industrial Process Automation[J]. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2017, 45(10):1345-1360.