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Construction and Application of an Intelligent Monitoring Platform for Industrial Boilers

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Abstract. A self-developed embedded intelligent acquisition system and an Internet of Things (IoT) architecture system are integrated to build an intelligent monitoring platform for industrial boilers to address the difficulty in the intelligent monitoring of such boilers. This new platform can perform sample pretreatment, intelligent data acquisition, and remote network transmission. It utilizes cloud for intelligent management and data sharing. Its pilot application demonstrates that the platform can be applied to the intelligent collection and remote monitoring of all industrial boilers without relying on a boiler's original control system.

1. Introduction

The dynamic monitoring data of industrial boilers are difficult to obtain continuously due to the large quantity, scattered distribution, and difficult regulation of industrial boilers in China. This problem hinders the comprehensive safety supervision and energy consumption monitoring of industrial boilers. A remote monitoring system for boilers based on the Internet of Things (IoT) technology can provide a feasible solution and has been favored by many scholars [1–2]. Most existing studies [3–5] use programmable logic controller or integrated data acquisition module devices and commercial configuration software for data collection and communication. These technologies exhibit features, such as fast system integration and short development cycle, but have high production costs, poor scalability and difficulty in marketing. In [6–7], an intelligent terminal was constructed for the long-distance monitoring of industrial boilers using an embedded system and cloud computing technology, which demonstrate good compatibility and extensibility and strong field interaction. However, intelligence acquisition levels remain low, and numerous signals are collected. Overreliance on a boiler's original hardware control system is another problem [8].

In consideration of the aforementioned issues, an intelligent monitoring platform for industrial boilers based on embedded intelligent control and IoT technology is built in this work by integrating an embedded intelligent acquisition system and an IoT architecture system. The platform can achieve energy efficiency monitoring and early safety warning of industrial boilers. Information sample preprocessing, data intelligent acquisition, remote network transmission, intelligent cloud management, and data sharing applications are integrated into the platform to solve the problems of the intelligent monitoring of industrial boiler energy efficiency and excessive reliance on the original hardware system of boilers. The proposed platform provides remote intelligent monitoring of industrial boilers with certain technical support.

2. System architecture and principle

The intelligent monitoring platform for industrial boilers adopts the basic architecture of a self-developed embedded intelligent acquisition system and an IoT architecture system. The overall architecture is shown in Figure 1. The platform consists of a sensing, network, management, and application layers. The system starts with a unified bus. All the monitoring devices are mounted on an RS485 bus. The polling method is used for data communication. The self-developed embedded system is mainly equipped with a sensor layer bus module and a network layer GPRS module. These layers facilitate the exchange and transparent transmission of TCP and fieldbus signals and enable the connection between the sensing layer monitoring device and the management cloud server. The cloud server establishes multi-threaded data transceiver applications to implement one-to-many connection. Simultaneously, the database and web application are hosted on the cloud server. The data collected are analyzed and fitted to obtain information on boiler energy efficiency and early warning information. The historical records and the analysis results are displayed via the application layer terminal through web applications. The terminal is a self-developed app for building an intelligent monitoring platform. The embedded intelligent collection system in the platform can be independently expanded according to the monitoring object, and the management and application layers can realize one-to-many matching and sharing.

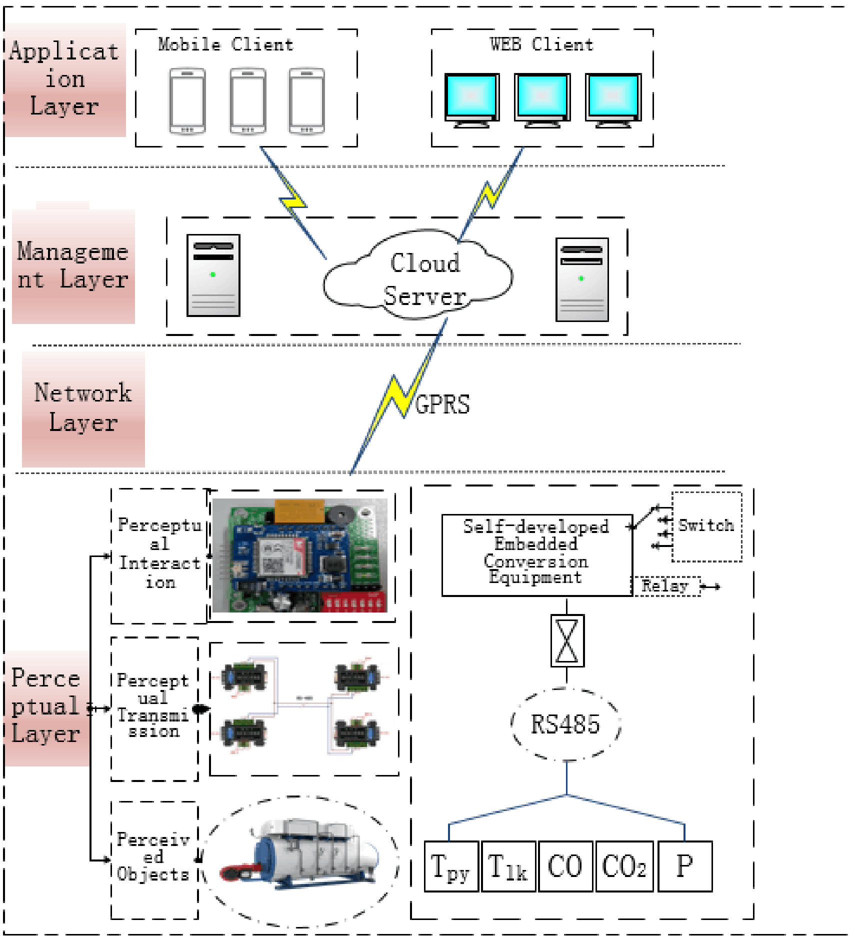

Figure 1. Schematic of the intelligent monitoring system for industrial boilers

3. Sample preparation system

The appropriate boiler exhaust temperature, cold air temperature, oxygen content, carbon monoxide content, working pressure, and other key indicators for monitoring are selected according to the industrial boiler efficiency test and evaluation rules (TSG G0003-2010) for industrial boiler operating conditions of thermal efficiency and simple test requirements. To ensure the accuracy of the test results and increase the lifetime of the acquisition system, a smoke gas dust filter and a flue gas semiconductor cooling device are installed in the data acquisition system. The device can cool the 300 °C flue gas to below 50 °C within a few seconds. The device can meet the requirements of various indicators for monitoring temperature.

4. Embedded intelligent acquisition system

To achieve intelligent collection, the best time for smoke collection is determined according to the pressure value from the cloud server. The embedded intelligent acquisition system is a remote monitoring device that connects sensors and cloud servers. Therefore, its security, reliability, and scalability are crucial. Its technical requirements are presented in Table 1.

Table 1. Technical Requirements for the Embedded Intelligent Acquisition System

No.	Functional requirements	Performance	Note
1	Serial communication	1-way RS485 serial communication channel with isolation and surge protection	For communication with sensors
2	Wireless communication	Integrated GPRS wireless communication module, high transmission stability	Establish a communication connection with the server
3	Switch signal acquisition	8-channel digital inputs, including 4 open-drain inputs and 4 pull-down inputs.	By accessing the relevant relays in the boiler control cabinet, signal signals, contactors, indicator lights and other switching signals
4	Switch output	1 AC220V relay output	Reserved for expansion
5	Equipment operation indicator	Can reflect the operation of the equipment, networking status	
6	storage	Save the last 1000 sensor return data	For remote server to extract information
7	Real Time Clock	Integrated real-time clock chip	

The embedded intelligent acquisition system consists of a hardware system and a microcontroller unit (MCU) software control system. The hardware design mainly includes the power module, RS485 module, GPRS communication module, switch signal acquisition module, and relay output. The structure of the embedded intelligent acquisition system and its physical map are shown in Figure 2.

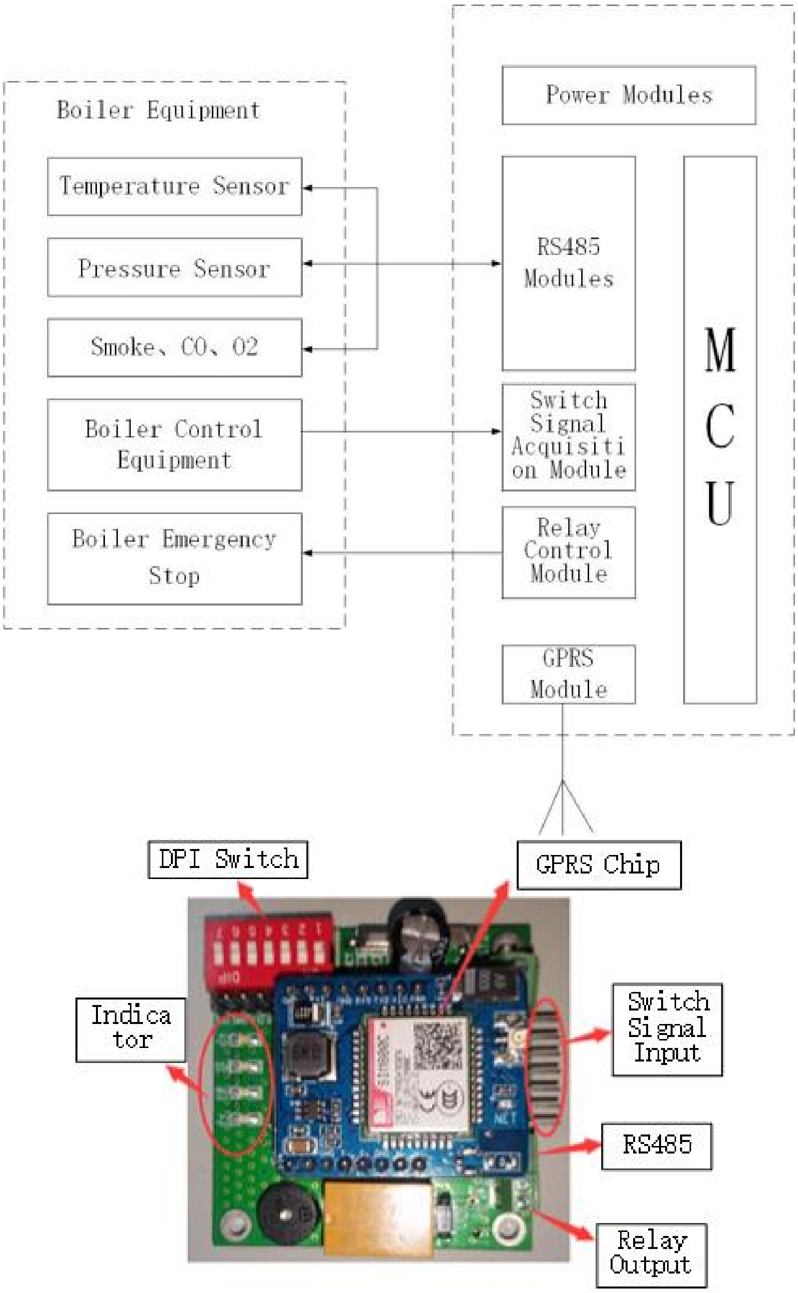

Figure 2. Structure and Physical Map of the Embedded Intelligent Acquisition System

External sensors include temperature, pressure, and smoke components, with an RS485 output interface. The MCU uses a Freescale MK22FN128VLH10 chip with a general purpose computing and information processing capabilities that can operate within the range of –40 °C to 105 °C and has built-in peripherals that satisfy the monitoring conditions of industrial boilers.

The switching signal acquisition module uses a TLP176GA optocoupler as the isolation device for signal acquisition. It mainly collects switching signals, such as alarm and boiler start–stop.

The RS485 module uses a MAX485 chip and is connected to the MCU to convert the serial TTL signal to a differential level signal. Simultaneously, a surge protection transient suppression circuit is installed at the output and used with a high-speed optocoupler 6N137 for isolation to ensure strong RS485 communication with anti-interference capability.

The GPRS module adopts the SIM800C of core news companies as the core chip of the wireless transceiver module. It can integrate the standard AT command and the serial port of the MCU for direct communication.

The power module uses a 7V-28V wide voltage input adapter. MP1584EN is used internally as the DC–DC BUCK converter chip, with a maximum output of 3A. Meanwhile, conversion from 5 V to 3.3 V is achieved through LM1117 to supply power to the MCU.

The dial switch facilitates communication between the devices and the server; that is, it allows the server to identify the device easily. Indicators can be used by field personnel to monitor their work and networking status.

5. Cloud server architecture and software design

The cloud server is mainly composed of a communication monitoring server, a web application server, and a database server. The schematic of the framework is shown in Figure 3.

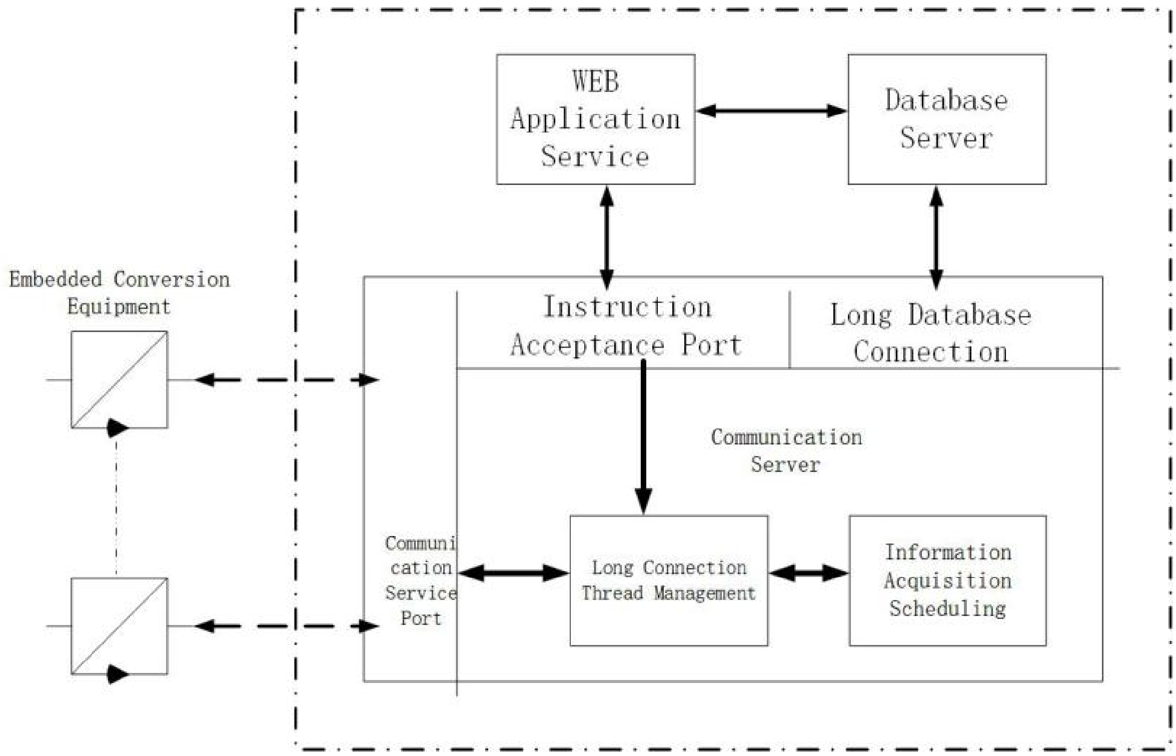

Figure 3. Cloud server framework

The communication monitoring server turns on the network port used for the communication server, and the built-in long connection management module on the watch server automatically monitors the communication service port data, opens the long connection thread, and collects and exchanges data information. Simultaneously, the online state of the connected device can be determined by sending a heartbeat packet.

The information acquisition and dispatching module can call the data information of the corresponding device from the database through an automatic cycle approach, send an instruction to collect sensor data from each long connection, and analyze the data returned to the communication service port. Energy efficiency and early warning information can be obtained as guide data through the calculation and evaluation models of TSG G0003-2010.

Meanwhile, the communication monitoring server has a built-in listening port for receiving control commands. Relays to the corresponding devices are controlled through the long connection management module. For example, the start and stop of the energy efficiency monitoring sensors can be controlled through the accepted pressure values. The flowchart of the communication attendance service is shown in Figure 4.

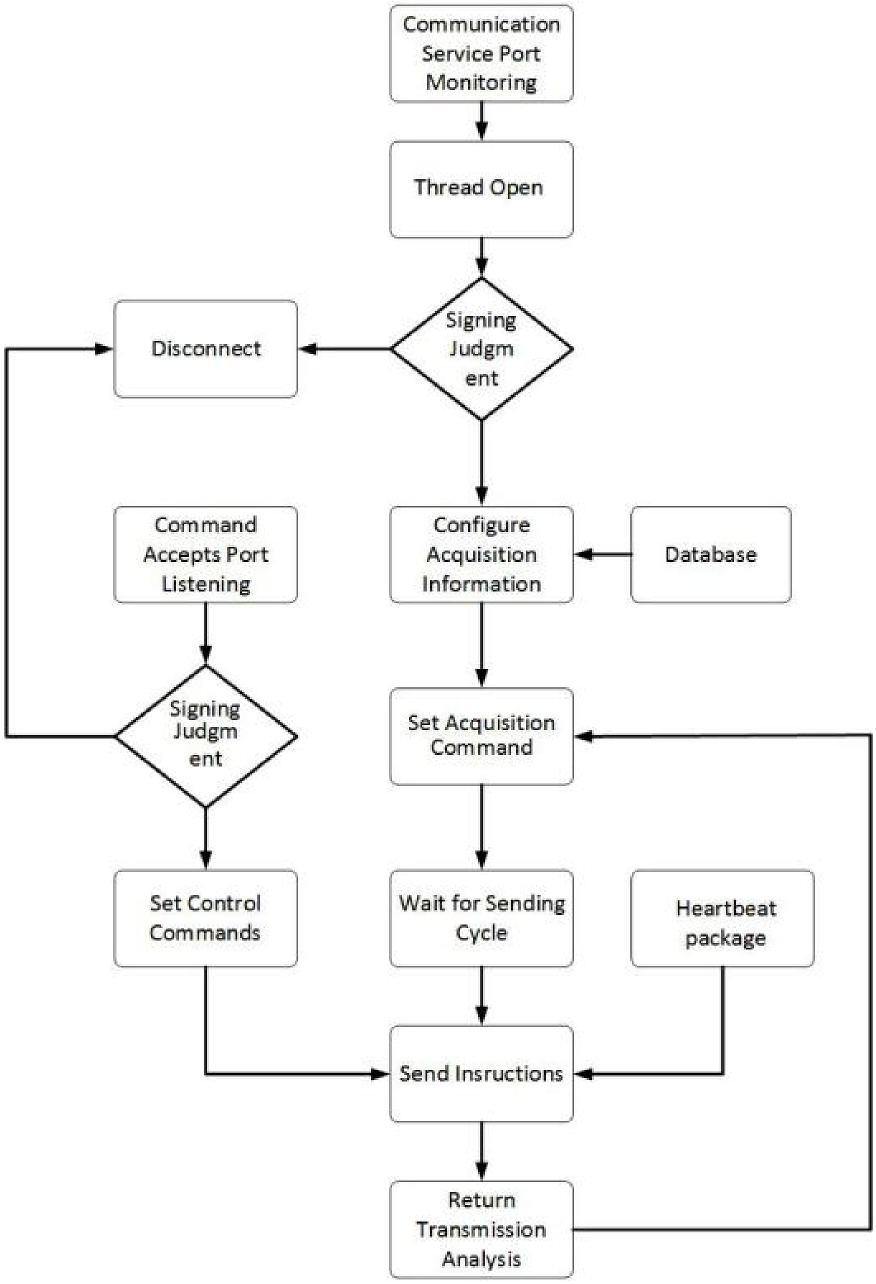

Figure 4. Flowchart of communication attendant service procedure

The .NET and open source easyUI front-end boxes are used in the web server, and the model–view–controller (MVC) architecture is used to set up the front-end to realize the three-tier architecture (i.e., model, view, and controller), which facilitates the separation and development of front-end and back-end programs. In addition, webApi is used to develop the communication interface using the front-end app software based on MVC. The front-end app can implement personnel log-in, boiler information viewing, device search, and statistical report curve functions.

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6. Pilot application

The boiler monitoring system developed in this study is applied to Chongqing for its pilot test (Figure5). The monitoring target is three natural gas boilers. In consideration of the characteristics of natural gas boilers, an external sensor is used to obtain boiler pressure, exhaust temperature, exhaust oxygen content, carbon monoxide content, and cold air temperature. Other information, such as water level alarm and pressure alarm, are introduced from the boiler and utilized. The gas inlet valve switch introduces the relay of self-developed intelligent collection system equipment. After commissioning and operation, this set of monitoring equipment can intelligently control the start–stop of boiler energy efficiency monitoring according to the working pressure set by the user, successfully connect to the cloud server, transmit valid data, and achieve intelligent monitoring. As of April 2018, the equipment for this pilot project has been successfully operating for 7 months.

Figure 5. Application example of the intelligent monitoring platform for boilers

7. Conclusion

This study is based on embedded intelligent control and IoT technology. We integrate a self-developed embedded intelligent acquisition system and an IoT architecture system to build an intelligent monitoring system for industrial boilers. The platform can perform sample pretesting for the energy efficiency monitoring and early security warning of industrial boilers. It can provides processing, intelligent data collection, remote network transmission, cloud intelligent management, and data sharing applications. The system is implemented through a pilot application. The application results show that the system can intelligently start and stop energy-efficient monitoring according to the user's working pressure without relying on the original hardware system of the boiler. The system can perform intelligent collection and remote monitoring through a mobile phone terminal app. It allows the real-timesharing of monitoring data and warning information. The system exhibits good versatility, high integration capability, and intelligence. It provides certain technical support for the remote intelligent monitoring of industrial boilers.

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