Design of Safety Monitoring System for Container Logistics based on Cloud Platform and IoT Technologies

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Abstract: With the tide of economic globalization, container logistics develops rapidly with its unique preponderance. Meanwhile, people have higher requirements for the modernization and safety of containers. Aiming at the problem that containers and its internal freights are difficult to supervise in logistics process, a safety monitoring system for container logistics is designed and implemented in this paper. Based on cloud platform and Internet of Things technology, the system monitors condition of containers through low-power hardware embedded inside the container. Managers can manage large numbers of containers efficiently through two clients of the system. The system has passed the test of performance and has been successfully disposed in containers.

1. Introduction

Container transportation is the most ideal way to transport bulk goods, and is favored by merchants and customers. At present, most of the global circulation of goods needs to be done by containers [1]. With the development of economy in the world, the frequency and quantity of high-risk and high-value goods in container transportation are increasing year by year. The process of container transportation is complex, the duration of transportation is long, the types of goods carried are diverse, and the internal state of the container is invisible. If the safety status of containers is not effectively monitored, it is likely to lead to containerization accidents. In recent years, various types of accidents such as cargo damage, cargo theft, and fire have occurred frequently during container transportation around the world. There are even criminals who use the loopholes in container security monitoring to smuggle dangerous articles. These accidents have caused enormous economic losses to logistics enterprises and caused great damage to the safety and health of employees. Therefore, it is necessary to effectively monitor the safety of containers in the logistics process.

2. Overview of the System

The "Made in China 2025" plan put forward a clear plan for China's Industrial Development in the new era. The core technology of high-end industrial software, such as industrial Internet of Things system and industrial big data platform, will become the focus of research and investment in the future [2]. This paper designs a container safety monitoring system based on cloud platform and IoT technology. The system consists of two parts: container embedded hardware and cloud platform. It can monitor the geographical location of containers, internal condition of containers and other information. After fully investigating the market demand of "safety monitoring systems for container logistics", it can be known that the logistics enterprises have different emphasis on container safety monitoring. Therefore, the hardware of the system is divided into two parts, so that the user can select the module according to his own needs. The first part is BOARD-A, which can collect temperature, humidity and geographic location information in the container. The second part is BOARD-B, which can collect temperature, humidity, particle concentration and human body information in container. The hardware program is embedded c programming language, which processes the collected information and transmits it to the cloud platform. Considering that the

Alibaba cloud platform is powerful, secure and reliable, the cloud platform of this design uses the Alibaba cloud platform.

In order to help container managers and related technicians get monitoring information conveniently, this paper designs data visualization and mobile interaction, so that they can monitor containers on cloud platform, Visual Web interface and mobile APP. The system can send managers alarm information based on hardware events. This paper only sets alarm events for temperature and particulate matter concentration. When a container occurs an alarm event, the system can not only be an acousto-optic alarm itself, but also send alarm messages to managers through the DingTalk APP developed by Alibaba.

Managers can get information rapidly and conveniently through cloud platform, Web interface and mobile APP. The system can help them to timely judge whether the temperature and humidity values will affect the quality of the cargoes, whether the sudden increase in particulate matter means the occurrence of initial-stage fire, whether the container has been illegally invaded, whether the container vehicle is traveling according to the regulated route. Through comprehensive testing, the system is fully functional, reliable and stable. Through comprehensive testing, the system is functional, reliable and stable. It can meet the monitoring needs in the container logistics process and greatly improve the safety level and quality of container logistics. The overall of system is shown in Fig. 1.

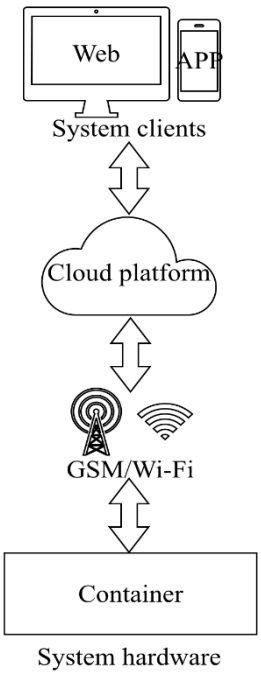

Fig. 1 Overall of the system

3. Design of Hardware

Hardware devices installed inside the container need to be powerful, power-efficient, and be miniaturized in size. It is crucial to choose a powerful and economical module for them. In this design, both BOARD-A and BOARD-B adopt ESP32-WROOM-32 module developed by Espresssif company. It integrates Bluetooth, Bluetooth LE and Wi-Fi. The module supports a data rate of up to 150 Mbps, and 20 dBm output power at the antenna to ensure the widest physical range. generic This Wi-Fi+BT+BLE MCU module is very suitable for low-power sensor networks. The sleep current of the chip is less than 5 μA, making it suitable for battery-powered container safety monitoring system. In this paper, only a few key parts are introduced.

3.1 BOARD-A

Because container transportation has a large space-time span, it may involve land transportation and land and sea transportation. It is not reliable to use GPS only during transportation. In order to improve the accuracy of geographical location data, BOARD-A uses the M6313 communication module developed by China Mobile. This GSM/GPRS/GNSS industrial communication module has four operating bands of 850/900/1800/1900MHz, and GNSS supports GPS/BDS positioning systems. The GPS/BDS dual-mode positioning technology and GSM used in this system greatly enhance the reliability and accuracy of container positioning, and ensure the container position monitoring in the complex logistics process. In addition, BOARD-A is equipped with four LED lights to indicate its working status.

The high temperature inside the container causes the deterioration of refrigerated and fresh-keeping goods, the accidental fire of inflammable goods in the container, and the immersion of goods caused by the leakage of water in the container. This kind of accident can monitor the internal environment in real time by installing sensors in the container [3]. In this design, both BOARD-A and BOARD-B use the SHT30 humidity and temperature Sensor. The functionality of this sensor includes enhanced signal processing, two distinctive and user selectable I2C addresses and communication speeds of up to 1 MHz. Its monitoring range and accuracy meet the needs of cargo monitoring.

3.2 BOARD-B

Both BOARD-B and BOARD-A adopt ESP32-WROOM-32 module and are equipped with SHT30 humidity and temperature Sensor. Since many companies already have positioning systems installed in their containers, BOARD-B does not have positioning functions, instead, it enriches the internal monitoring functions of containers. It can upload data to the cloud platform with Wi-Fi, helping people fully grasp the container internal information.

The traditional container transportation mode is characterized by many cargo theft accidents and lack of transparency in transportation. How to reduce the loss of containers in logistics links and improve the transparency in transportation links so that the cargo owners can get the latest information of cargo in real time is undoubtedly of great social and economic value [4]. BOARD-B adopts HC-SR501 pyroelectric infrared sensor, which is based on the automatic control module of infrared technology, with high sensitivity, high reliability and ultra-low operating voltage. It can monitor a cone angle of 120 degrees and a range of up to 7 meters. When the human body enters the detection range, it will output a high level of 3.3 V. For a 20ft ISO container, one sensor is enough.

In general, except for dangerous goods containers, the probability of fires occurring in the port loading and unloading and storage is low, but there are still many factors that cause fires to spread and spread. Once a fire happens in container yard, it is very difficult to extinguish it because of the interweaving of various complex factors [5]. In order to prevent fire effectively, BOARD-B is equipped with PMS7003 particle sensor. The sensor calculates the concentration of particulate matter with different particle sizes in the air using algorithm based on Mie theory, and then outputs the data in the form of universal digital interface. The sensor has fast response and accurate value. When initial-stage fire happens inside the container, the flaming area of the material is small, the thermal radiation is not strong, but the smoke is dense. Container managers can respond in time to the data collected by the sensor to avoid the expansion of fire scale and causing severe economic losses. In addition, BOARD-B is equipped with buzzers and alarm lights. Different alarm events trigger different types of sound and light alarms. The operation effect of hardware is shown in Fig. 2.

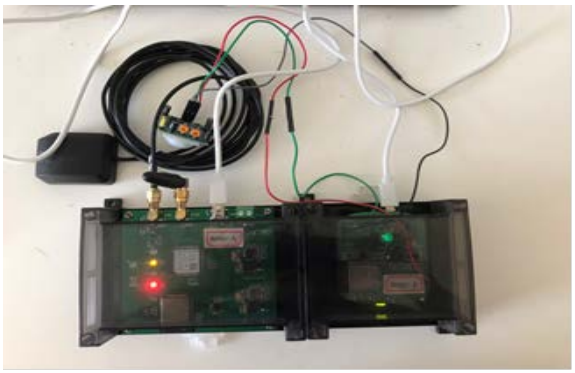

Fig. 2 System hardware

4. Program and Client Design

The program in this design is written in embedded C language. JSON (JavaScript Object Notation) is a completely language-independent text format, but uses conventions familiar to programmers of the C-family of languages. It is a lightweight data-interchange format. It is not only easy for developers to read and write, but also easy for device parsing and generation. So, it is an ideal data-interchange language in this system. MQTT (Message Queuing Telemetry Transport) is a “lightweight" publish/ subscribe messaging protocol-based TCP/ IP [6]. It provides real-time and reliable messaging service and that is very easy to implement. Therefore, the system connects the cloud platform through it.

4.1 Programming

There are some overlaps between BOARD-A and BOARD-B programs. In order to reuse the code, the system adopts modular programming. Modular programming facilitates the maintenance and function expansion of the system. This paper only introduces two important programs: particulate matter monitoring program and human body detection program. Their flow charts are shown in Fig. 3.

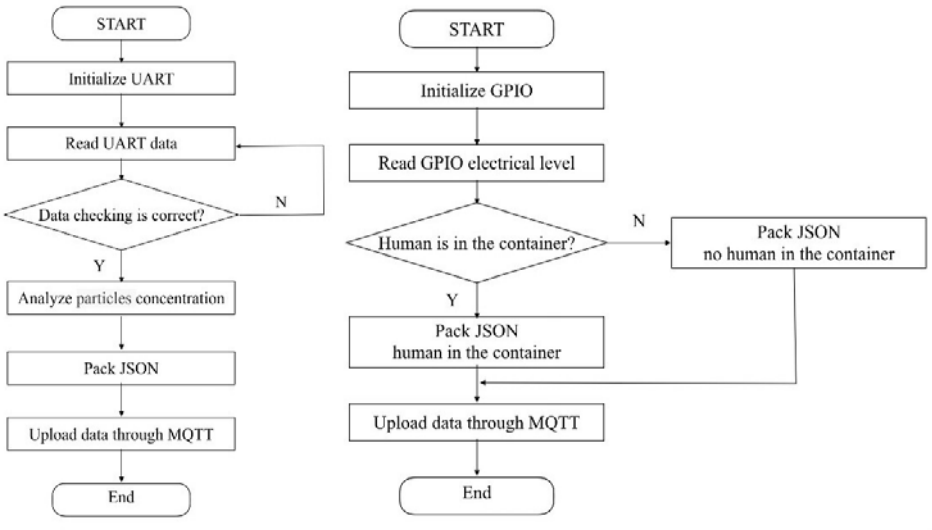

Fig. 3 Flow charts of two programs

4.2 Client Design

After the system is created on the cloud platform and the function is defined, two hardware are connected to the cloud platform by programming the serial numbers provided by the Alibaba cloud platform. The individualization requirements of users are also the focus of cloud computing

technology [7]. Alibaba cloud platform provides aplenty development services, this paper designed and built service solutions to meet diverse needs of clients.

In the cloud platform, the corresponding alarm function can be realized through the alarm logic design. In this system, when the concentration of particulate matter in the container is greater than 300 μg/m³ or the temperature is higher than 353 K, the system will send alarm messages to the user's DingTalk APP. After receiving emergency messages, managers can take effective measures in time to ensure the safety of personnel and commodities in transportation. In addition, the system develops Web applications based on B/S architecture and APP based on Android in a visual way according to requirements of clients. After authorization by the developer, clients can monitor the status of the container or query the historical data directly through the Web or APP. Of course, clients can also use other functions provided by cloud platforms. The clients of the system are shown in Fig. 4 and Fig. 5.

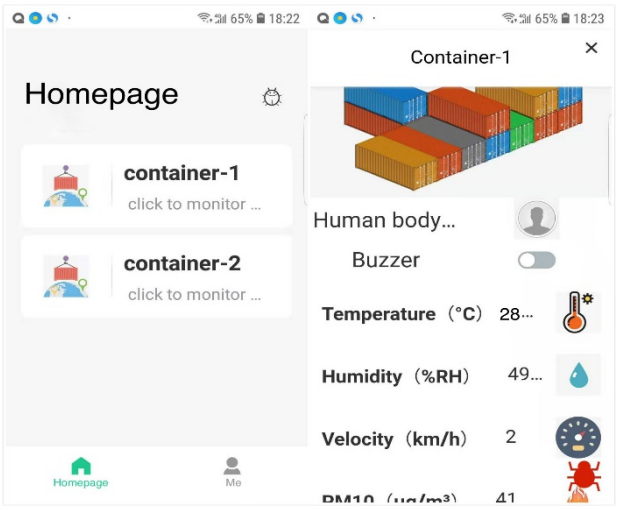

Fig. 4 App of the system

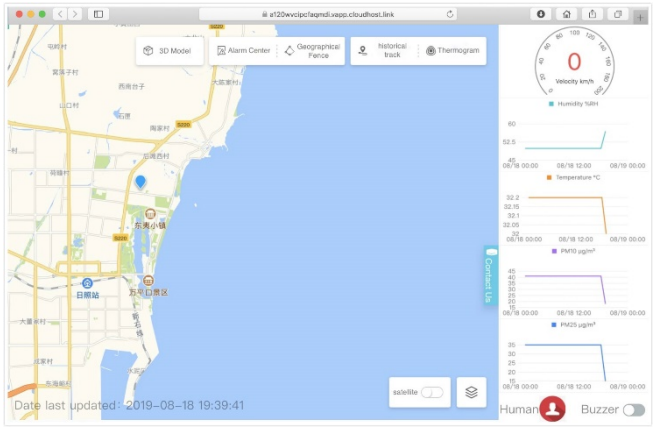

Fig. 5 Web of the system

5. System Test

System test is an important section of system design. In order to know whether the system can achieve the expected goals, it has been tested under the real environment. System test is consisting four functional tests.

Positioning function: The hardware is loaded into the container of the transport vehicle. Test the real-time positioning, track query and electronic fence accuracy of the system through a real transport process.

Temperature and humidity data acquisition function: Put the hardware into the container and compare the system data with the data obtained by the thermometer and hygrometer in the container. Place the device in a high temperature environment at 353 K to test the alarm function.

Human detection function: After the hardware is placed in the container, the person walks into the container and stays for 1 minute. View the accuracy of time nodes and time intervals after the experiment.

Particle detection function: put the equipment into the container and burn wood products. Compare the system data with the data of particulate matter detector in container, and determine whether the DingTalk APP alarm messages can be delivered in time

Test results: The system has accurate historical trajectory and electronic fence. The positioning error is less than 2 m. The temperature error is within 0.3 K and the humidity error is within 2 %. The system can quickly respond to temperature and humidity changes. Alarm messages is normal and there is a delay of about 2 s. System can accurately detect the time people stay in the container, and the time node has a delay of about 8 s. The measurement data is very accurate.

Test results show that the system has high accuracy of data and high stability of information transmission. The system has low total energy consumption and can operate stably for a long time after equipped with batteries. The system can meet the monitoring needs of container logistics enterprises.

6. Conclusion

Intelligent container transportation will become an inevitable trend in the future development of containers [8]. Safety monitoring system makes full use of cloud computing technology and Internet of Things technology to improve the intelligence of containers. It guarantees the safety and efficiency of container in the process of logistics, and promotes the development of modern logistics.

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