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Design and Implementation of Logistics Storage and Transportation System for Dangerous Chemicals Based on Internet of Things

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In recent years, China has witnessed an incredible surge in economy, bringing with it greater demand for chemical products. In order to minimize the potential risks of these dangerous goods during storage, transportation and management, this paper designs a storage and transportation safety supervision system for dangerous chemicals based on the Internet of Things. The system includes three parts, among which, the terminal equipment consists of the “Warehouse Intelligence Security System” and the “Vehicle Beidou Navigation and 4G Broadband Transmission System”; the computer monitor part is made up by the “central monitoring and management platform”. This system enables the powerful database storage across applications, and artfully integrates 4G wireless network transmission, wireless location, smart sensor, intelligent electronic map network technology and other technological means. It fully wraps up an intelligent and modularized supervision and management model for hazardous chemicals in the course of storage and transportation, thus greatly improving the management capacity of dangerous chemicals and reducing the threat to the environment and life.

1. Introduction

In recent years, a number of dangerous chemical explosion accidents arose in China. The finding by analysis on the causes of various accidents is that these explosion accidents are rooted in human errors and improper storage in the course of management for dangerous chemicals (Goh et al.,1995; Bluff,1997). The explosion of dangerous chemicals poses a great threat to the personal safety of workers. Various types of hazardous substances produced by the explosion have ruined the environment (Xu et al., 2011; Matindoust et al., 2016; Hu, 2012). According to relevant regulatory data, the current domestic storage and transportation of dangerous chemicals are ill-governed and there are a number of potential risks and seriously inadequate supervision (Grabowski and Sanborn, 2003; Gardner et al., 2012; Zhang and Zheng, 2012). Automated management model and logistics systems serve for reduction of human errors in the course of management so that the storage and transportation safety of hazardous chemicals can be guaranteed (Sun et al., 2012; Luo and Ren, 2016; Xiao et al., 2017). Therefore, it is of great social and economic significance for us to develop a set of management systems for the storage and transportation supervision over hazardous chemicals in China.

2. Integrated architecture

With the dramatic development of communication technologies, frontier technologies such as mobile network, smart sensor and wireless network have sprung up one after another. The effective integration of multiple technologies has provided a new idea for expanding the application range of the Internet of Things (Potyrailo, 2016; Xia et al., 2016).
The hazardous chemical storage and transportation supervision system designed in this paper mainly includes two sets of terminal devices, namely the “Warehouse Intelligence Security System” and the “Vehicle Beidou Navigation and 4G Broadband Transmission System”, managed by the “central monitoring and management

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platform". The above three constitute a complete system, the general framework of hazardous chemical storage and transportation management systems is shown in Figure 1.

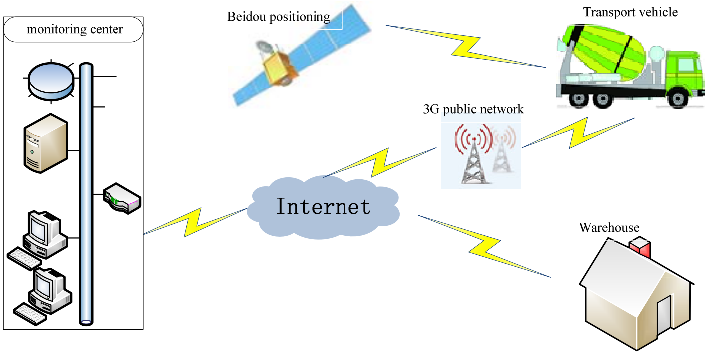

Figure 1: System general structure diagram

The system effectively manages the storage and logistics of dangerous chemicals by the following three procedures:

Step 1: Identification phase. This phase is implemented using RFID widely used now as an electronic tag to mark dangerous chemicals, that is, the hazardous chemicals can be labeled as liquid or gas states on the outer package. When the finished products are stored in the warehouse, the basic information about chemical products will be available by long-distance label scanning and sent to the "Central Monitoring and Management Platform" for storage.

Step 2, in the management phase, 360 HD cameras, free of dead corner, should be installed in the warehouse for dangerous goods and in key transportation arteries to ensure full coverage of surveillance. The camera should have night vision shooting function. Some sensors, such as temperature, pressure, and smoke, should be installed in the warehouse and used to send real-time information to the supervision and control center and compare with the normal values to determine whether there are some dangerous factors in the environment where hazardous chemicals are stored. The schematic diagram of the security part of this system is shown in the Figure 2:

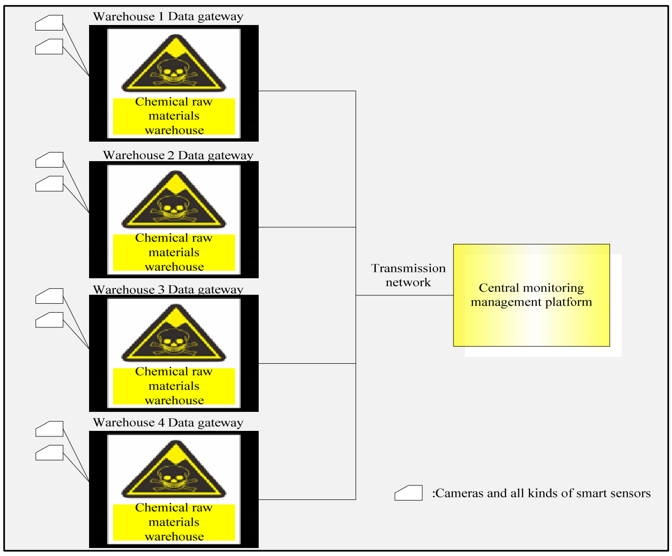

Figure 2: Library intelligent management security system diagram

Step 3, for the sake of safety when transporting dangerous chemicals, first, the RFID tags on the outer package of chemicals should be scanned with information transmitted to the supervision and control center which uses Beidou Navigation System and 4G wireless transmission network to timely locate transport vehicles. The navigation information is recorded in the electronic map to form the vehicle's driving route track. According to the nature of dangerous chemicals, pressure, vibration or temperature sensors installed on the vehicle may be used in conjunction with a high-definition camera to ensure that the supervision and control center can promptly grasp the implementation data in the vehicle transportation warehouse.

3. Technological architecture

The system consists of three parts, i.e. the "Central monitoring and management platform" and the "Warehouse intelligence security system", the "Vehicle Beidou navigation and wireless broadband transmission system".

3.1 Warehouse and vehicle-mounted intelligence security system

Functions and basic features required in the warehouse intelligence security system are given as follows:
(1) Environmental monitoring function, the system needs to implement supervision over the storage environment in the warehouse, according to the characteristics of different chemicals, environmental supervisions include smoke, humidity, temperature, pressure detections, etc.;
(2) Sound and light alarm and access control can be achieved;
(3) Realtime transmission of images can be monitored. It also supports the zoom-in and -out of image surveillance;
(4) ARM A8, 11 or 9 is used as the processor core in Linux.
(5) Wave frequency of RFID technology is 900MHz or 2.4GHz, which supports multi-channel long-distance scan identification.
The system hardware configuration parameters are listed in the Table 1:

Table 1: Hardware configuration of warehouse and vehicle-mounted intelligent security system

Configuration Name	Type	Explain
CPU	STM32F103ZET6	Operating frequency 72MHz
Flash	M29W128FH	128Mb NAND
SDRAM	IS61LV5116-8TI	8MB
USB	USB SLAVE	To communicate with the computer or as a device power input
UART	Two RS232	Three-wire serial port, serial port 2 can be realized.
Debug Interface	JTAG	20

3.2 Vehicle Beidou navigation and wireless broadband transmission system

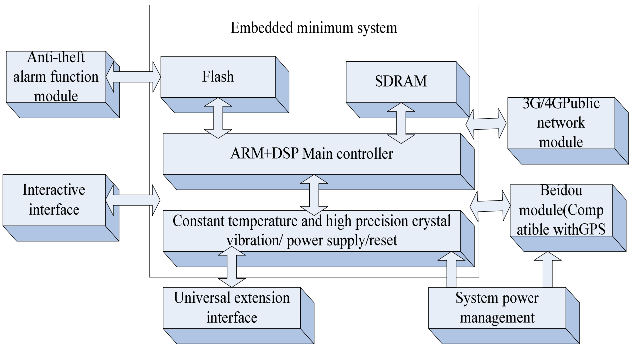

Figure 3: The principle block diagram of beidou positioning and 4G broadband transmission system

The Beidou navigation wireless broadband transmission system needs to implement several functions as shown below:
(1) The Beidou navigation system used in this system can achieve accurate location within a range of 20 meters. Velocity measurement and time service reach 120km/h and ms respectively. It has a good compatibility with GPS.
(2) The system uses a standard PCIE interface to support multiple wireless data link transmissions such as 3G/4G and broadband.
(3) The system uses ARM A8, 11 or 9 cores for efficient data processing;
(4) In the mobile network, it can always maintain a bandwidth of more than 1M, thus ensuring the reliability of system data transmission;
(5) The system can achieve intelligent and modular transportation supervision and management;
(6) The system is equipped with a number of interface circuits to support the expansion of multiple functions;

(7) The system is configured with multiple function indicators, etc., which can indicate the input and output states of current information during the operation or prompt errors occurred in the system.
The schematic diagram for the architecture of Beidou navigation and wireless broadband transmission system is shown in Figure 3.

3.3 Design of embedded software

This system chooses to use Linux2.6.28 as the main OS. The operation process of Linux-based system is shown in Figure 4:

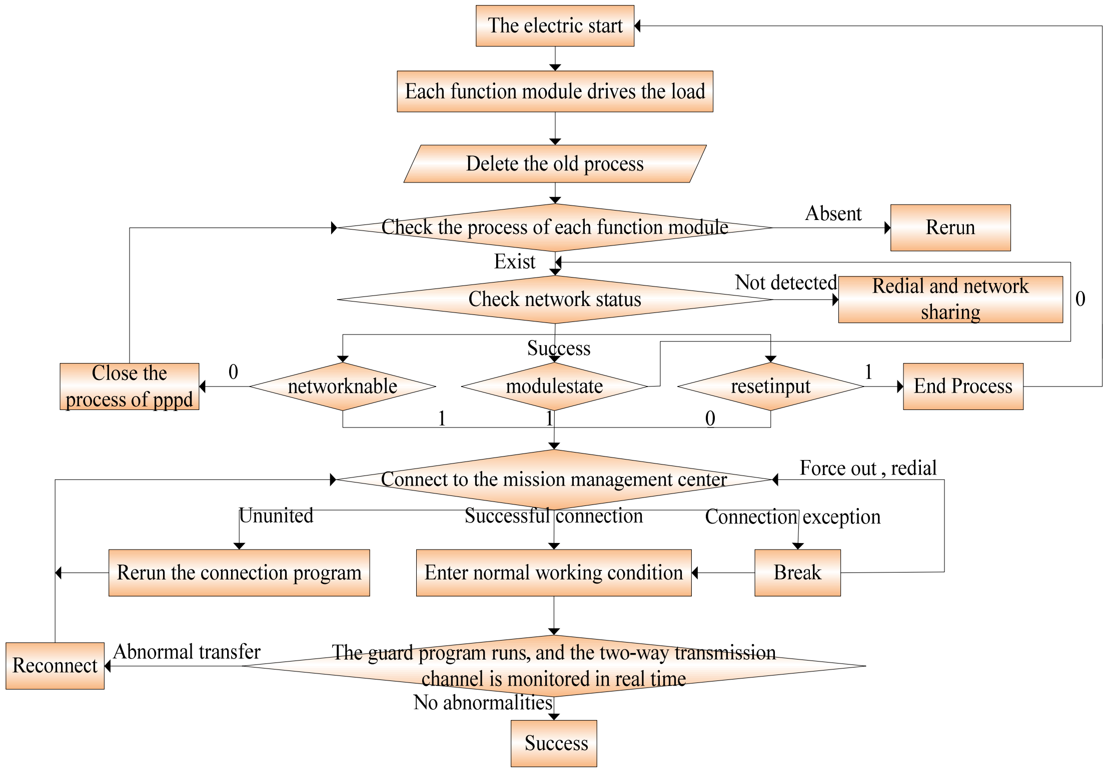

Figure 4: Operation flow chart of software

After the system module process starts up, the system automatically skips to the working directory interface, loads the module driver and executes the PPP dialer. The wireless module is turned on to create a valid connection with the 4G public network that gives the system a random IP address; the configuration of network card information is completed, execute specific instructions, realize the sharing of wireless network ppp0 in wired network card eth0, the main program in the system starts up to access the task management center; based on the dynamic domain name resolution (DNS), create the socket connection and ensure the stability of the data transmission channels; all types of information data acquired by the system sensor side are uploaded to the monitoring center for treatment via transmission channel. In addition, the RFID electronic tag scanning information and the Beidou navigation information are transmitted via this channel.

3.4 Central monitoring and management platform

(1) Performance and features
The system can seamlessly integrate Baidu's electronic map, by which accurate location and real-time supervision in the transportation process can be achieved. Baidu electronic map is embedded in the positioning information module on the platform; the system is connected to the Beidou navigation system and supports 3G/4G mobile network and broadband wireless network information transmission; real-time supervision over CIF and 1080P high-definition video, and simultaneous access to videos in multiple channels; allow simultaneous access to 50 front-end acquisition devices at most.
(2) DB design
The schematic diagram of DB paging is shown in Figure 5. The database of this system mainly includes several web pages such as administrator, mobile device, and image acquisition information storage.

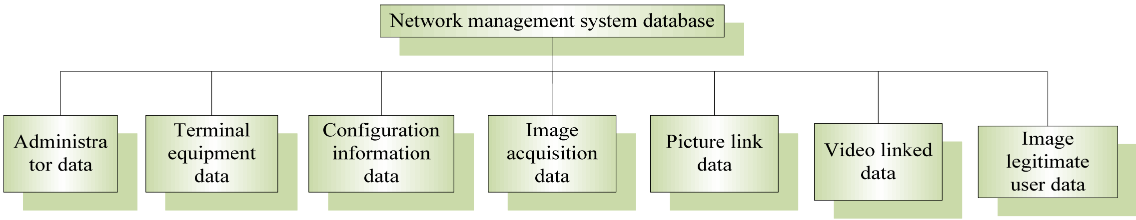

Figure 5: Schematic diagram of database paging

(3) Design of login interface
Note that there are IDs for alerting dangerous chemicals in the log-in interface. The schematic diagram of login interface is shown in Figure 6. User enters the login ID and corresponding password in the dialog box. After the background authentication, the system automatically skips to the main interface of the network management center, if the user ID and password do not match, the system will automatically pop up the error message and return to the login interface again.

Figure 6: The login interface diagram of the chemical dangerous goods monitoring system

Figure 7: Network test interface diagram

3.5 Communication protocol

For the sake of the reliability of dangerous chemical storage and transportation management, transmission channels in the system must be maintained to operate stably and smoothly so as to ensure the safety and veracity of data transmission. In this system, data protection and supervision are carried out by the following three procedures:
(1) Introduce CRC check mechanism to provide guarantee for proper transmission of instruction information in the system;
(2) Introduce a response confirmation mechanism to provide guarantee for the correct reception of instruction information in the system;
(3) The transmission quality is encapsulated in the format of a data frame.

4. System debugging test

4.1 Sensor test

After the device is connected and accessed to power supply, the system starts up. The real-time status option is selected in the network management platform. Data collected in the sensors of the two terminal systems will be transmitted to the network management center, and temperature and humidity information are displayed in the platform interface. When there is excessive poisonous gas in the storage room, equipment vibration, or an unknown object enters, the system will automatically issue an alarm in the management interface.
After the warning information generates, the corresponding sensor status display will automatically change to a red font. Therefore, it is possible to determine whether there is an uploading of alarm information currently based on the font color.

4.2 Network test

The PC and the device are connected via the RJ45 connector, the network connection is started after switching them ON. When setting up the local connection of the computer, the computer IP is manually configured in the same network segment as the mobile device is. The communication between the PC and the network is tested. Record the upstream and downstream data rates during the network transmission. The effect of system test interface is shown in Figure 7.

5. Conclusions

(1) Based on the test results, the system designed in this paper can effectively manage the storage and transportation processes for hazardous chemicals, relieve the burden of manual management, and improve the level of management and transportation of hazardous chemicals.
(2) With this project, it is feasible to realize the intelligent management for storage and transportation of hazardous chemicals. The system adopts a modularized and intelligent development model with good feasibility.
(3) The system integrates mobile network technology, smart sensor, and wireless network, and introduces frontier technologies such as cloud storage to further expand the application of the Internet of Things, playing a certain role in driving the development of China's Internet of Things technology.

Acknowledgments

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