A scheme for logistics tracking and monitoring based on internet of things

Chong Dong*

Huazhong University of Science and Technology; Hubei Wuhan 430074, China

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Abstract

This paper proposes an IOT-based scheme to solve the problems of long transportation time, low transparency degree and high operation costs for logistics vehicle monitoring and tracking system. At the vehicle terminal we adopt integrated sensor techniques with SunSPOT platform. It integrates the information of temperature, humidity, light intensity and so on to make real-time and multi-dimensional control for rapid response and locating. All the collected parameters or audio-video information can be uploaded and sent to the monitoring centre via 6LoWPAN. For the controlling centre, we provide the processes of design and implementation for key modules. The scheme in this paper is proved to offer defamation and informatization for vehicle transportation, with stowage optimization of vehicles and effective monitoring control.

Keywords: IOT and ITS theories, Sun SPOT mechanism

1 Introduction

With the rapid development of logistics industry, the level of automation and informatization for logistics equipment and facilities becomes higher, which brings many problems at the same time. The tracking and monitoring demand for logistics network becomes diverse and complicated. They put forward new challenges to network monitoring system so there are higher requirements for generality and customization of the system. Nowadays, the logistics scale is expanding and the logistics vehicles are increasing fast. Traditional logistics tracking and monitoring measures cannot meet the demand of development of enterprise gradually due to absence of new technology. There is a large turnover of staff, wide area and other characteristics in logistics industry, so the information interaction among the staff has higher requirement on mobility [1]. It is necessary to establish an informatizational, graphical and networked service platform to provide supervision on vehicles and staff, increasing benefit and reducing waste and cost of the resources at the same time. The appearance of Internet of Things (IOT) promotes the third wave of information industry. One of the popular implementation in IOT system is logistics industry [2, 3]. It aims to make intelligent logistic to provide informatizational management for logistics industry. As the critical phase of logistics industry, intelligent transportation plays a big role in the construction of intelligent logistics. IOT offers automatic recognition, intelligent management and control for the cargos and transportation process. The cloud computing of IOT has powerful ability in data processing and it can provide technical support for social production and living systems. IOT also processes and analysis the logistics information by auto-sensing and acquisition, to effectively manage and control the logistics business. So it’s useful to make accurate, intelligent and collaborative operation, as is very helpful to improve the management level of modern logistics and supply chains, and to reduce the cost of transportation.

In literature [4], MA introduces his monitoring system of grain reserve storage and 3G remote centralized monitoring management systems. The techniques such as automatic collection, alarm processing and unified management of monitoring equipment are implemented via IOT system network, so that the monitoring efficiency can be improved. Briand in literature [5] designs and establishes IOT-based logistics vehicles monitoring system. It adopts FID, GPS and GPRS technologies to effectively solve the monitoring problems of transport vehicles during logistics distribution. CHEN [6] applies IOT system to the monitoring system of highway traffic. It monitors and manages the vehicles by electronic tag to perform effective operation on security management of expressway. ZHU [7] adopts the sensing equipment network to monitor real-time status of crops growth environment in remote area. It collects and analyses the monitoring data to provide production monitoring and early-warning for crops, which can improve agricultural output and efficiency. JING [8] introduces a modular composition and optimized method of networked information retrieval in library information monitoring system based on IOT, to improve quality and efficiency of retrieval service. Thomas [9] designs a novel type of data acquisition monitoring system with IOT and achieves obvious effect on communication network. It performs

* ***Corresponding author’s*** e-mail: dongchong1030@163.com

management between sensor and terminal by multiple communication modes. Li and Zhang [10] apply RFID and sensor to the transportation of refrigerator vehicle, providing temperature and humidity monitoring for refrigerator vehicles. It improves the transportation efficiency by monitoring position and intelligent recognition of the cargos.

For the trends of intelligent logistics, this paper integrates the technologies including database, communication, GPS and RFID to the key modules of logistics monitoring system. Then a real-time monitoring of logistics transport vehicles based on IOT is put forward in the whole transport process from output to input, which promotes the information construction of logistics transport. Our research focuses on the following:

1) It proposes the overall project of IOT-based logistics tracking and monitoring system. It requires that the framework be flexible and easy to be integrated with perfect expansibility and the system configuration and deployment environment should have higher heterogeneity.

2) It adopts embedded sensor to integrate the RFID information collected by sensors with warehouse, transportation environment, transportation container, etc. A SunSPOT platform-based active sensor is used to provide real-time GPRS which sends information such as humidity and temperature to the monitoring centre of system.

3) It introduces the design and realization process of several key modules such as data communication, web access, tracking location and system display platform in detail.

We design the test schemes by systematic function analysis and monitoring platform design, to test the functions of monitoring system.

2 Requirement analysis and overall design

Vehicle terminal completes data collection and transmission include IOT-based intelligent transportation system (ITS) [11] logistics vehicle monitoring system aims to provide in-transit monitoring and transportation control, so the whole process can be controlled. The technologies and factors involved in logistics vehicle monitoring system are very broad. The logistics vehicle system studied in this paper focuses on vehicle tracking, early-warning, reappearance of track, landmark setting, and command control in the monitoring system. All the information in the process of logistics must be obtained through vehicle terminal collection. The vehicle terminal is in charge of real-time information acquisition, formatted transportation, communication, etc. The main function of vehicles is transmitting real-time information of distributing vehicles to the monitoring centre. The vehicle terminal also performs monitoring command at the same time with certain processing ability. Therefore, we currently summarize users' demand and the functions of pre-realization system as follows:

A. Vehicle terminal:

1) Vehicle terminal should have basic functions of system initialization;

2) Vehicle terminal should have functions to collect real-time spatial information of logistics vehicles. Transport staff will send vehicle status to the monitoring centre via wireless sensor network including internal temperature of vehicles, humidity, vehicle speed, etc. Meanwhile, they can receive control command from the monitoring centre to complete the task based on command content.

3) There is an alarm function. Therefore, if some emergent case affecting the logistics distribution occurs, it can alarm towards the monitoring centre.

B. Monitoring centre:

1) Monitoring centre have basic functions of data management, including collection and management of basic materials, historical path replay of vehicles, vehicles alarm data and system reports. The basic materials management includes basic information of logistics vehicles, goods and staff monitoring, and real-time update of the basic information. The historical track replay function of vehicles refers that the monitors can select one time segment to replay vehicles route.

2) The monitoring centre has ability of vehicles monitoring. According to longitude and latitude from the vehicle terminal, the vehicle position is displayed on an electronic map of backgrounds to perform visual tracking and positioning of logistics vehicles.

3) The monitoring centre must have basic functions of vehicle terminal communication to obtain real-time status information and position information of vehicle.

4) It has visualization function and users can search current geographical position of transport vehicles by inputting corresponding vehicle information or cargos number.

5) It supports users' web access and real-time query.

C. Other requirements.

With above analysis, we propose the whole framework in this paper. As Figure 1 shows, the logistics tracking and monitoring system is composed of vehicle terming real-time positioning of logistics vehicle, alarm information, etc. The tracking and monitoring system of the whole vehicle terminal is totally based on SunSPOT. It contains a vehicle control sensor module which is used to monitor light intensity and temperature inside the vehicle. The tail integrates a RFID recognizer, which efficiently recognizes incoming and outgoing registration as well as the position of cargos inside the vehicle by EPC code. In comparison with other current structures, the sensor nodes integrated in this system are mutually independent and they can provide technological application in different types. However, it also increases the complexity during deployment and configuration. In order for remote access, the deploying nodes adopt IPv6 protocol on IEEE812.15.4. The communication module completes data transmission between vehicle terminal and monitoring centre. The data processing module analysis data and save them in server database. A GIS display platform stores the received data in local database, so the data can be read and saved easily for visualization and interaction functions.

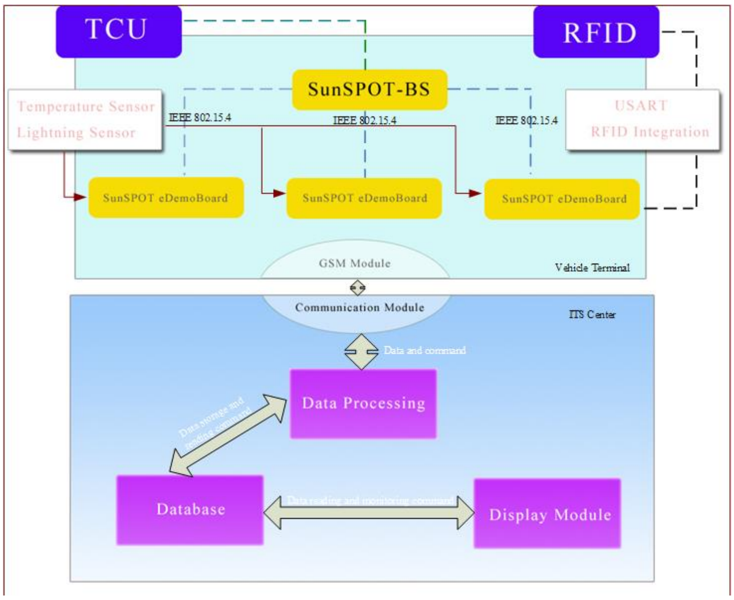

FIGURE 1 Overall architecture of the logistics tracking and monitoring system

3 Function integration based on SUNSPOT

SunSPOT (Sun Small Programmable Object Technology) is Java-based wireless equipment developed by Sun Labs [12]. This development tool contains three kinds of equipment and a set of Java tools. Each device has an ARM9 chip-based processor board, wireless equipment and a user interface for data transmission. One of its functions is working as base station which communicates with the other two sensors, to measure light and temperature. Three equipment all adopt battery driver. ARM9 is taken as the core of Sun SPOT with embedded Squawk VM. It can be developed by NetBeans, so the hardware access and SPOT board control are executed in Java.

The main board takes one ARM920T chip of Atmel as the core and its peripherals are controlled via ATMega88v 8bit AVR SCM. It provides IEEE 802.15.4 ZigBee-based wireless communication module which support functions like miniUSB downloading programs, communication charging, etc. It also provides one DF-17-30 interface and SPI bus is adopted among Mega88Vs to perform data transmission. EDemoBoard is an experiment board with sensor and simple peripheral equipment, which contains one Mega88V and one AD7411 control chip. Default sensor and peripheral equipment also include 8 three-color LEDs, 2 Swithches, 1 light sensor, 1 temperature sensor and 3 axis 2G/6G gravitational acceleration sensors. Meanwhile, eDemoBoard offers 6 analog extended interfaces, 5 digital input/output interfaces, 4 digital interfaces with driver chips. It connects eSPOT by DF-17-30 interface.

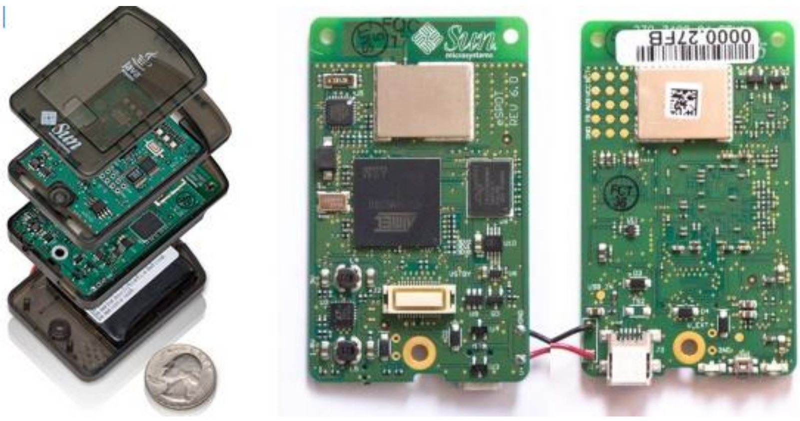

FIGURE 2 Hardware structure of SunSPOT

SunSPOT adopts 6LoWPAN (IPV6 over Low Power WPAN) communication protocol to make IPv6 function on WPAN [13]. 6LoWPAN also expands IP to wireless industry network and it saves the electricity power both in hardware and software. So it is widely applied in Ethernet and WIFI. Figure 3 shows the protocol stack of 6LoWPAN:

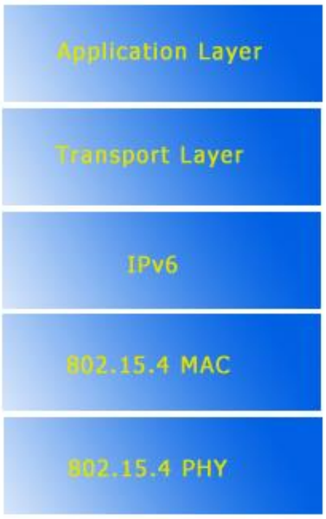

FIGURE 3 Protocol stack of 6LoWPAN

The wireless communication frequency of SunSPOT is 2.4GHz. Each SunSPOT node has the only IEEE MAC address, which is identified by ARM920 processor to access SunSPOT nodes.

RFID system has strict format to collect and transmit data. The direction to send out a command is set fixedly, that is, the program-reader-electronic tag, and the direction of response information is completely opposite. After activation, the electronic tag will send its coding information by antenna built in the card. The receiving device receives the carrier signals from electronic tag and it will transmit it to the reader by antenna regulator. Then the reader begins demodulating and decoding according to given rules. The decoded signals are sent to back stage of the system for relative process. RFID is usually installed at tail to detect the cargo position, while the structure of SunSPOT simplifies the deployment [14]. When a new tag inside the vehicle is found, we can read and register by OBID i-scan and connect RFID node of SunSPOT via USART. The communication message format is depicted as the following Figure 4:

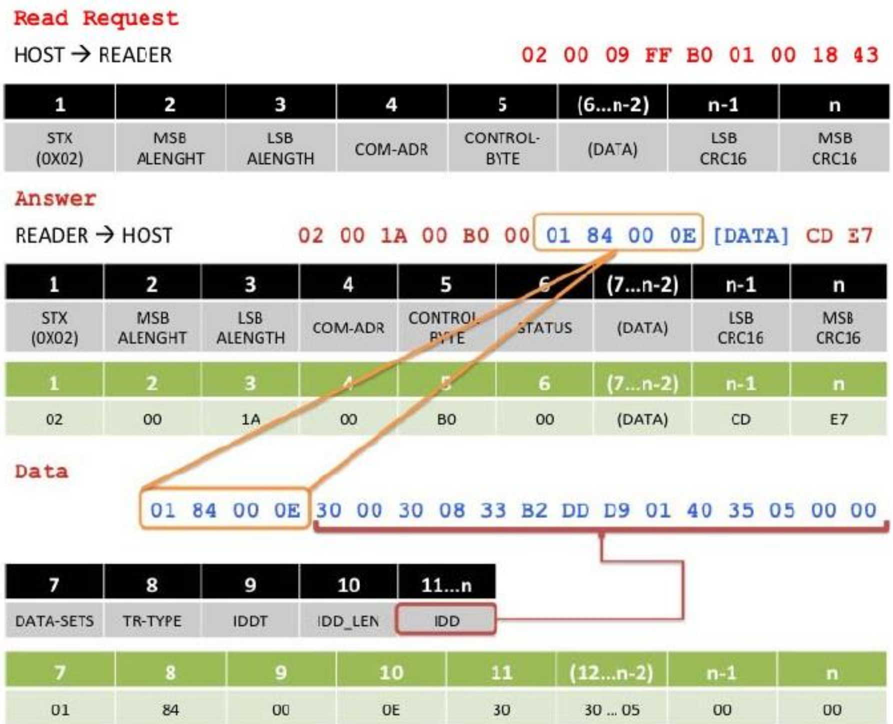

FIGURE 4 Packet format of SunSPOT-integrated RFID

Table 1 shows the important interest fields during information retrieval. When a new tag is read in the system, all the related information will be extracted for later access. From this we can see that when information is extracted, the correlative items such as DATASET, IDDT, TR-TYPE, except EPC code, respectively represent reading data quantity, recognition kinds, and the conveyors types are totally read into the system.

TABLE 1 Code of data types

Value	TYPE
0×00	SNR
0×01	EPC
0×80	ISO 1800-6 A
0×81	ISO 1800-6B
0×83	EM4222, EM4444
0×88	EPC class 0/0+ Gen 1
0×89	EPC class1 Gen 1

We adopt the temperature and light sensor integrated in SunSPOT sensor node to record temperature, humidity and illuminating value inside vehicles regularly. ADT7411 converts the speed measuring instrument, the luminous intensity sensor and the simulation signal of internal temperature measurement sensor to digital signals at the same time. However, the powerful.

Compatibility of SunSPOT provides possibility for more functions to be integrated in internal nodes, to provide more attributes monitoring. For instance, in our scheme, ADT7411 contains an internal temperature sensor and its temperature range is 40~125 degrees Celsius. Actually, temperature sensor is part of ADT7411 chip. When SunSPOT is awakened, it can accurately read current temperature even in non-charging status. TPS851 photovoltaic sensor is deployed at the top of eDemo, the output voltage range is 0.1~4.3V and the resistance value of emitter is 4.7K. The maximum sensitivity of light sensor is 600nm>3dB and the switching time is about 30ms. At present, there are studies which integrate multiple external sensors via communication port of USART. In addition to the mentioned light sensor, the temperature and humidity sensor, the single-chip multi-sensor modules, TSL2550 and SHT11 included, have been widely implemented [15].

4 Designs and implementation of key modules

4.1 COMMUNICATION MECHANISM

The fundamental function of communication module is communicating via GSM between vehicle terminal and monitoring centre. The communication data includes alarm information of vehicle terminal, GPS data, monitoring command, etc. After the data of vehicle terminal is verified, the communication module will process different data according to their types. Before the data transmission, analytic encapsulation will be performed at first. Figure 5 depicts the sequence diagram of vehicle terminal when sending data to the server. It explains the interaction among objects and the transmission process of messages.

The monitoring centre server connects vehicle terminal through GSM and sends corresponding control instructions. The vehicle terminal returns collected data based on SIM signal and the server terminal is used to receive data, that is, validity verification of vehicle terminal data: if it is normal the message will be resolved and saved in database; otherwise we will determine whether it is registered at the centre and ignore this message.

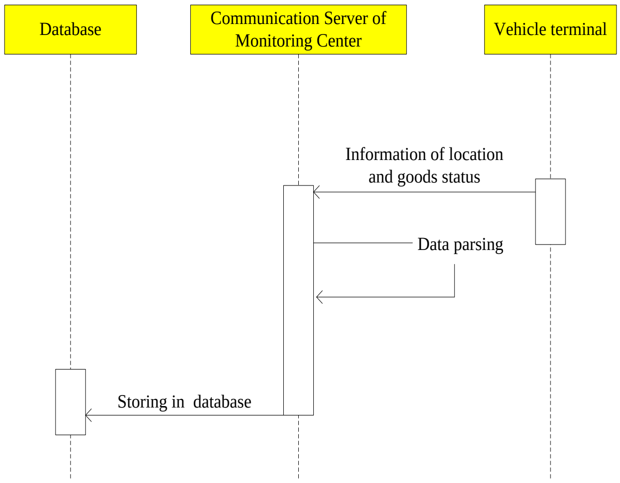

FIGURE 5 Sequence diagram of sending data to servers

The sequence diagram of monitoring centre to send control command is depicted as Figure 6. The communication module sends analytic instructions to vehicle terminal and returns ACK message from vehicle terminal. The process in detail: the managers send control command to the vehicle terminal and this message is encapsulated and saved in the database according to given format. The server checks whether there is command that is not sent by records of the timer. If there is command to be sent, it will send this information to vehicle terminal which will execute this command and return ACK message.

As the communication module class diagram shows in Figure 7, DataRevTran sends and receives data in communication module. The detailed operation contains data storage and extraction. Therefore, this class needs many database operations, that his, it depends on database access class ADOdatabase, class ADO item, class GSM and data processing modules for message transmission. When the message of vehicle terminal is received, DataRevTran run Listening () to monitor all arrived data. Function Listening () uses the timer to read the information in SIM card. Once the newly arrived data is discovered, functions ReceivingStart () and ReceiveData () start data analysis, processing and preservation at the same time. When the monitoring centre sends commands to it, DataRevTran adopts Command Listening () for database monitoring. Similarly, the timer is used to regularly read control command from the database. Once a new command arrives, command Receive () and Message sending () are called to send this data.

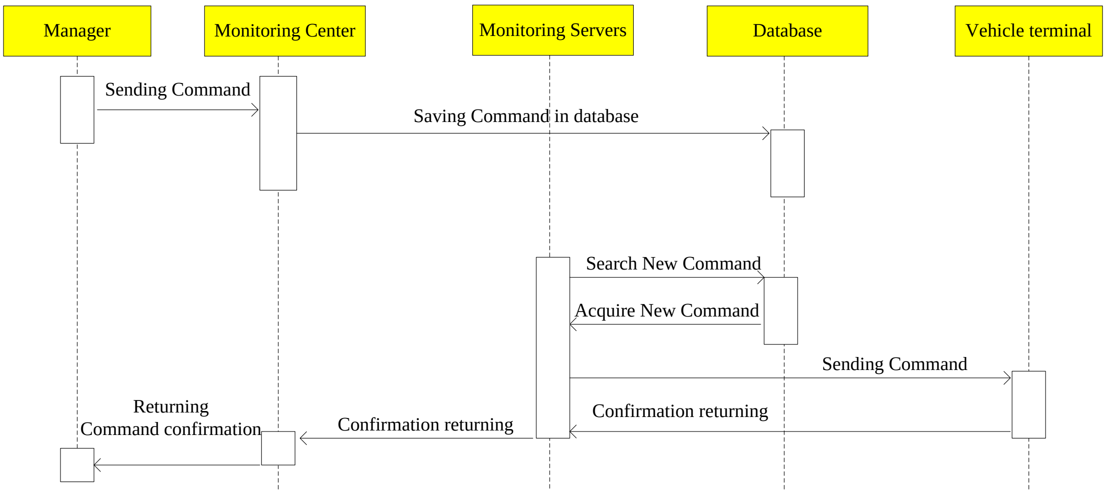

FIGURE 6 Sequence diagram of sending command to vehicle terminal

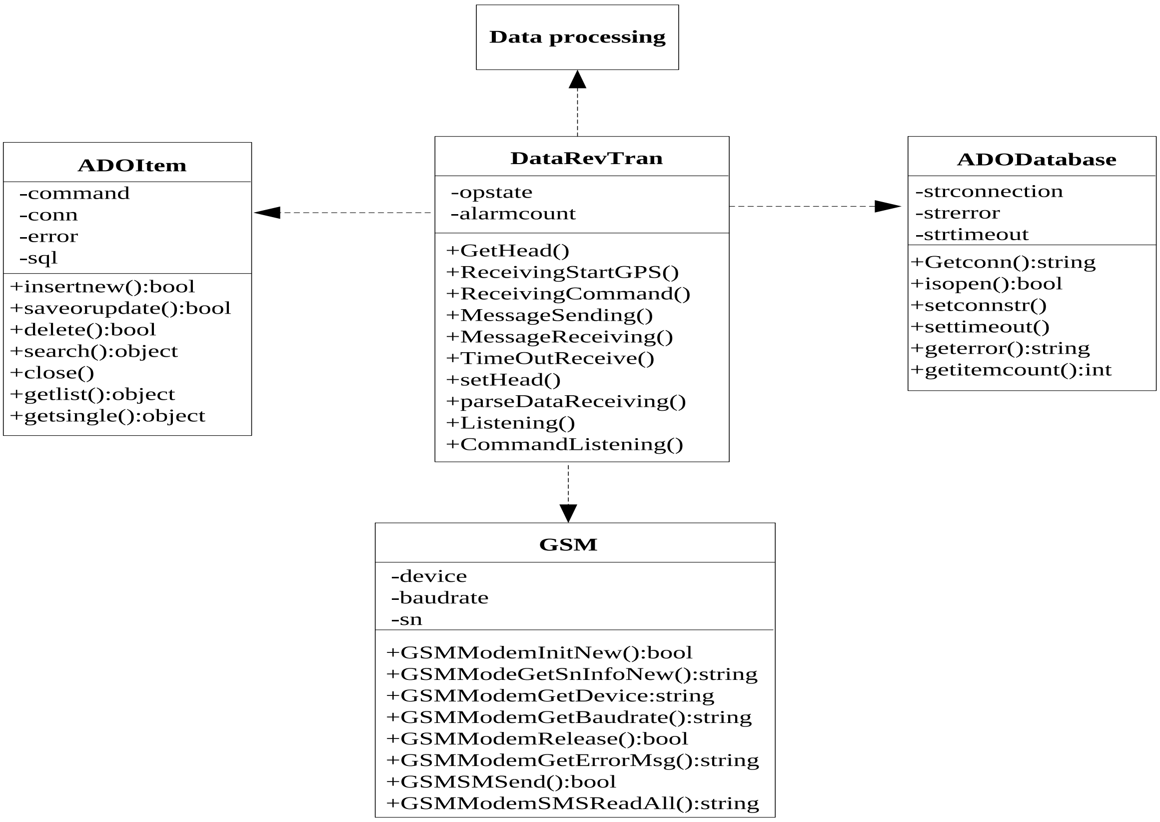

FIGURE 7 Class diagram of communication module

4.2 DATA PROCESSING

Based on the conditions of actual logistics demand, we use existing information to establish database and data model. The most important parts are data structure, data operation and data restriction condition. For our system, vehicle position status information table, temperature and humidity table and cargos information table are very essential. When we design these tables, the relationship among tables should be also concerned and the data is acquired by the incidence query of database tables [16]. All business data is saved in established relational database. We provide key structures of tables such as environment information table, basic information table of cargos, vehicle position information table, alarm information table, monitoring command table, user table for system management, system function table, operation record table, security log table, etc. Figure 8 depicts the logic structure design of the key tables. Parts of the important attributes are listed as follows:

1) RFID information

RFID information includes the records of each cargo which is scanned by reader. The detailed logistics information is discussed in above sections such as name of goods, cargo location, reader recognition, GPS object, loading content, etc.

2) Fundamental information

This attribute includes the fixed information such as ID code of vehicle, delivery line, street name, province code, reader equipment type, etc. The information is usually unchanged within certain period. But it also needs regular update to guarantee the information accuracy as external environment changes.

3) Logs Record.

Similar to most systems, it mainly records system operation information of managers and users including sign on information, operation type, remote access, query record, on-line data analysis and statistics, alarm logs, etc.

4) Logistics tracking information.

It saves real-time information, transitional status, call-in and call-out record, record information, during logistics distribution.

5) User Information.

It saves the fundamental information of users and managers including name, address, E-mail, telephone number, authority, etc.

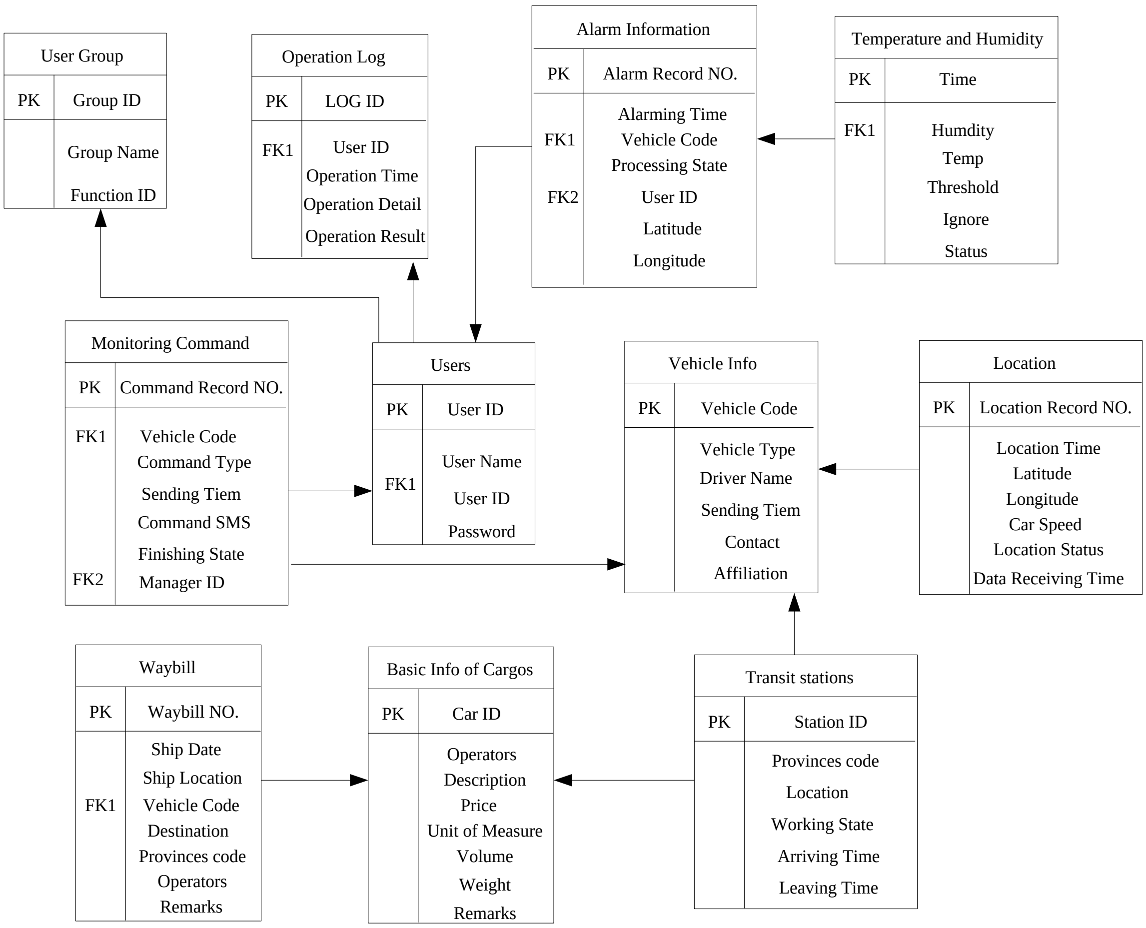

FIGURE 8 Related tables of database model

4.3 VISUALIZED TRACKING AND MONITORING

The logistics process starts from warehousing and ends as cargo's arrival and acceptance, bypassing multiple transition and transport channels. Figure 9 describes the general process of one cargo from delivery to arrival sign [17]. After the logistics system receives the sending command, the distributed cargos are all embedded electronic tags (This tag will not be changed until it arrives at the destination). Within this period, multiple readers will confirm the cargo information by tag identification and they are transported to the monitoring centre for management and web query. User query system provides replay track function based on RFID tag or customers' effective certificate. It can quickly find and locate the cargo in demand according to the needs, providing convenience for users to learn and track the transportation status of their cargos. During the RFID-based query, the tag number and the identity information can also be used. A case of testing results is shown as Figure 10.

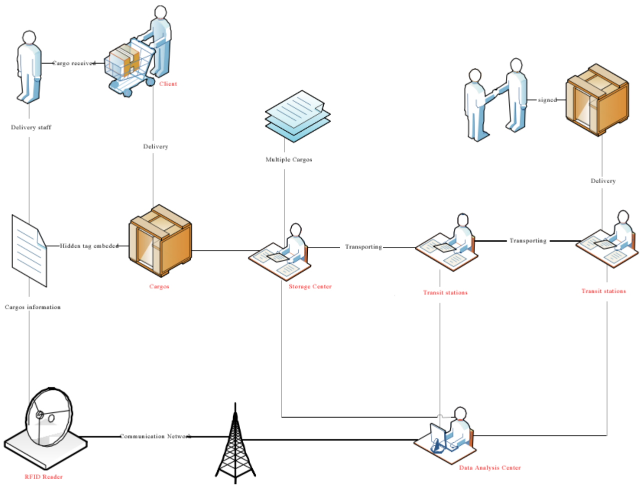

FIGURE 9 An example of general delivery process

FIGURE 10 User query interface of cargos

To ensure in-transit risk of important cargos is controllable, the video capture function is used to transmit real-time images of cargos from the vehicle terminal. It avoids the damage caused by objective factors during transportation. Meanwhile, the temperature and humidity status inside vehicles can be displayed by means of curve form, as shown in Figure 11, to determine the effect caused by environment change by tendency within a certain period.

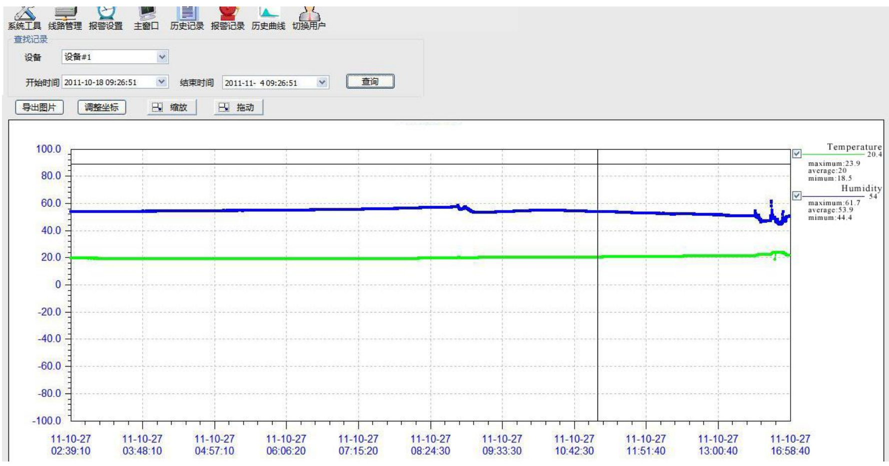

FIGURE 11 Vehicle environment status inquiry

Tracking replay can check the paths of vehicles actually passed. It is used to determine whether the vehicle is in normal trails. We can read the latitude and longitude coordinates from database by replayed intervals and vehicle license plate number. If input time is earlier than its start time of database, it starts from the first record of selected vehicles in database; if input time is later than its ending time in database, the track will be replayed to select the last record of vehicle in database. If the start time is between the segments in database, it starts from the most approximate record time in database till the record of the most approximate ending time. In addition, the vehicle track is displayed according to these records on an electronic map, as is shown in Figure 12.

FIGURE 12 Tracking of cargos transport trajectories

5 Conclusions

With the development of IOT, ITS system is getting more intelligent. It is possible to provide real-time monitoring for vehicles and in-transit risk control of cargos. So this paper analysis current structure of IOT based on existing IOT and ITS theories, and proposes an IOT-based logistics system. It is composed of intelligent transportation, vehicle monitor, dynamic distribution and information control under IOT environment. In addition, we further study EPC system in network-based framework of logistics information platform. We summarize the operation mode and application scope of existing logistic information platform. Then based on the development status of domestic IOT technology and logistics public information platform, the collaborative operation mode under IOT environment is put forward. This paper also discussed the vehicle terminal mode based on Sun SPOT and the communication mechanism with the monitoring centre. The actual operation effects of system are also provided in our actual tests. The research shows this scheme can adapt to the specific needs under IOT environment and it effectively improves the management efficiency of information system.

References

[1] Giannopoulos G A 2004 The application of information and communication technologies in transport *Eur. J. Oper. Res* 152 302-20

[2] Du J, Wang R, Xie X 2012 Precision and profits: Solutions based on the IOT to the problem of agricultural products circulation *Advances in Information Sciences and Service Sciences* **4**(16) 390-9

[3] Gao J, Shi F,Cui Q 2009 Process Reengineering of Logistics & Distribution Businesses Based on the IOT *Logistics Technology* **23**(12) 25-7

[4] Ma Z, Skiing X, Fu X 2013 The architecture and key technologies of internet of things in logistics *Proceedings of IET Conference Publications Beijing China* 464-8

[5] Briand D, Molina-Lopez F, Quintero A Vz, Mattana G Printed sensors on smart RFID labels for logistics *Proceedings of IEEE 10th International New Circuits and Systems Conference Montreal QC Canada* 449-52

[6] Chen J 2012 Research on Maintenance Support Schedule for Carrier Aircraft Based on Genetic Algorithm *Science Technology and Engineering* **12**(35) 9773-87

[7] Zhu X 2010 On Application of Internet of Things in Modern Agricultural Informatization *Journal of Shenyang Normal University* **28**(3) 391-3

[8] Jing X, Zhang J 2012 Computer Engineering and Applications. Automatic book inventory in library based on Internet of things *Computer Engineering and Applications* **48**(26) 11-6

[9] Thomas K, Katerina P, Georgios D 2007 RFID-enabled traceability in the food supply chain *Ind. Manag, Data Syst* 107 183–200

[10] Liu X, Sun Y 2012 Information Integration of CPFR in Inbound Logistics of Automotive Manufacturers Based on Internet of Things *Journal of Computers* **7**(2) 349-55

[11] Jorna R, Foraison K, Thirkell M 2012 ITS: Supporting sustainable logistics flows in Europe *Proceedings of 19th Intelligent Transport Systems World Congress Vienna Austria* EU-00080

[12] Smith R B 2007 SPOTWorld and the Sun SPOT *Proceedings of IPSN 2007: Proceedings of the Sixth International Symposium on Information Processing in Sensor Networks, Cambridge, MA, United states* 565-66

[13] Jara A J, Moreno-Sanchez P, Skarmeta A F 2013 IPv6 addressing proxy: Mapping native addressing from legacy technologies and devices to the internet of things *Sensors* **13**(5) 6687-712
[14] Xiu X, Liu H 2013 Mechanical Vibration Monitoring System for Water Turbine Based on Sun SPOT Wireless Sensor Network *Journal of Jianghan University* **41**(6) 56-9
[15] Hamada S, Kanazawa F, Sawada Y 2012 A study on low-cost logistics support service utilizing ITS spot *Proceedings of 19th Intelligent Transport Systems World Congress Vienna Austria* AP-00177
[16] Diallo O, Rodrigues J J P C, Sene M 2011 Real-time data management on wireless sensor networks: A survey *J. Netw. Comput. Appl* 35 1013–21
[17] Wang L 2012 Research and Design of Intelligent Warehouse Logistics System Based on IOT *Logistics Engineering and Management* **34**(8) 55-7

Authors

Dong Chong, 1981.10, Pingdingshan County, Henan Province, P.R. China.

Current position, grades: a civil servant Tourism Administration of Pingdingshan City, Huazhong University of Science and Technology, China.
University studies: MSc from Ningxia University in China.
Scientific interest: logistics management.
Publications: more than 6 papers.
Experience: teaching experience of 1 year, 3 scientific research projects.