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Quality Monitoring Traceability Platform of Agriculture products Cold Chain Logistics Based on the Internet of Things

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In order to realize quality tracing of cold-chain logistics and real time temperature and humidity data acquisition and transmission, based on analysis of the current method for cold-chain logistics data acquisition and transmission, a new method which integrating radio frequency identification (RFID) with wireless sensor network (WSN) was put forward. The system scheme design and network communication protocol was investigated. The RFID based quality traceability platform was designed. This platform can be used to monitor the quality of products and the environment in real time. It can realize all the way traceability of agriculture products and temperature and humidity monitor on cold chain from transport and storage. By comparison with the previous management system about the cold chain logistics, this quality traceability platform can reduce product loss and ensure product quality better.

1. Introduction

Nowadays, with the level of economic development, the living standards of people are improving. People are seeking for a higher quality of life and a higher health caring period. In recent years, the food safety issues appear continuously, People pay more and more attention to this field. Cold chain logistics is closely related to food safety issues, demand for cold chain logistics in China is increased dramatically which was confirmed (Hu (2010)).

Cold chain logistics is one kind of supply chain system which maintain a given temperature range. It is used to ensure the food quality. With the progress of science and technology and the development of cooling technology, cold chain logistics is developing rapidly which was confirmed (Wu (2011)). In China, cold chain logistics is in high demand. This industry is developing fast, but there are still a lot of problems. Compared with foreign advanced level, cold chain technology in china is backward. The key information in circulation links cannot be effectively used. For fresh, dairy products and some special products such as drugs and vaccines, cold chain logistics cannot guarantee a good quality. In a word, at present stage, cold chain logistics in china cannot meet the social demand.

In our country, food logistics mainly focused on normal temperature logistics. A quality traceability management system that can covered producing, packaging, transporting and selling has not been established which was confirmed (Zhao (2010)). Because of the poor technology, transporting and warehousing stage lack an effective and timely record of temperature and humidity, it unable to form a seamless cold chain after leaving origin and before the sales.

It is well known that in the process of transporting and warehousing, due to complex environment factors, long time period and various unexpected situation, environment temperature may be changed, then products would go bad. Meanwhile, circulation information of cold chain logistics without a systematized management, it makes the tracing of products' quality and status become difficult and imprecise. If we cannot realize the seamless and real-time temperature-and-humidity data acquisition and transmission of cold chain logistics, it is liable to cause the products to deteriorate. Once food quality problems occur, if we cannot discover and handle it in time, these problem products would enter the marketplace. Not only would this damage consumers' health, but also cause huge economic losses of the food enterprise. So, it is necessary to build a seamless and real-time cold chain logistics system.

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Our country falls far behind the developed countries in the cooling technology. At the same time, quality monitoring of the frozen products, control for environment temperature and cleanliness and packaging technology also have a big gap compared with the foreign advanced level which was confirmed (Gao and Qin (2006)). After years of development, foreign cooling technology has very mature already. Many countries, such as the United State, Canada, Japan and Australia have established the complete cold chain logistics system. RFID technology and WSN have been widely applied in cold chain logistics. Automatic temperature monitoring device and automatic temperature control device are mostly used in the process of transporting and warehousing. These advanced technologies and devices guarantee the quality of products.
This article presented two methods. One is integrating traditional RFID tag with temperature and humidity sensor. The other is integrating RFID with WSN. The network communication protocol based on ZigBee was also discussed. In this way, we realize the quality traceability of cold chain logistics and real-time temperature-and-humidity data acquisition and transmission.

2. Design scheme

2.1 Classification of RFID tags

Radio frequency identification technology is a kind of wireless communication technology and it has widely applied in manufacturing, logistics, identification and many other fields since it has born. With technology progress, RFID is gradually shows its great potential. RFID technology can realize non-contact long distance identifying for objects. It has the properties of practicality, universality, high-efficiency and security. RFID tags are small, variety, waterproof, anti-magnetic, heat-resistant, reusable and long service life which was confirmed (Ren et al (2010)).
According to the different way of power supply mode, RFID tags can be classified into passive tags, semi-passive tags (also known as semi-active tags) and active tags. Passive tags have no battery. When tag out of the read range of reader, it go into sleep mode. Only when entering into the read field, it would receive the radio frequency given by the reader and send out the information stored in the chips with the power generated by induction current. It is small and cheap. Active tags are different from the passive tags, they have the built-in battery. Rely on the power provided by the battery, an active tag can periodically transmit the information. Active tags have many advantages, such as long operating distance, large capacity memory and strong anti-jamming. Semi-passive tags are something in between. Although the semi-passive tag have a battery, it still uses the power transmitted by the reader. Compared with the passive tags, Semi-passive tags have a faster response time and higher efficiency.

2.2 The method that integrating traditional RFID tag with temperature and humidity sensor

2.2.1 The construction and working principle of active RFID system

These tags have different features. Rely on the advantages in operating distance and storage capacity, active tags are widely used in cold chain logistics, warehouse management, medical system, etc. This article integrate temperature and humidity sensor into the traditional active tags.
Active RFID system is comprised of electronic tag, reader (it can be divided into the stationary and the hand-held) and application system, as shown in Fig 1. Active tag has a unique identification code. It would automatic sending the information stored when entering the operating range of reader. After received the information, reader store them in its storage device. The reader can transmit the information to the application system by many ways. Then, application system can use them for further processing which was confirmed (Meng and Zhang (2011)).

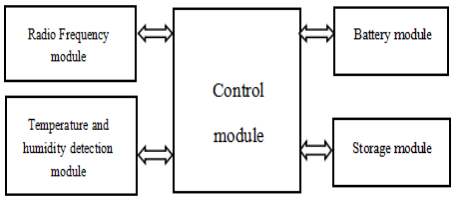

Figure 1: The consist of active RFID system

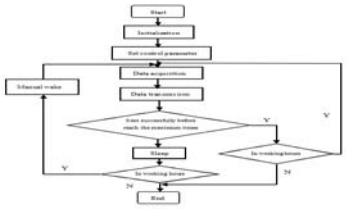

Figure 2: Work flow of the tag

2.2.2 The overall structure of the tags

The design of the active RFID temperature and humidity sensor tag as follow: battery module, storage module, temperature and humidity detection module, radio frequency module, control module and so on. Each one has an independent function**.** Battery module provides power for each module. Storage module stores the identification code of the tag and the product information. Temperature and humidity detection module use to detect the environment temperature and humidity. In order to simplify the design, we use the integrated

temperature and humidity sensor. RF module transmits the data via antenna. As the core of the tag, control module controls the sensor by setting control parameters. It can also used to check battery power.

2.2.3 Work flow of the tag (Fig 2)

The tag is closed when it in the non-working state. Before detecting the environment data, we should set the transmission gap and the working hours by the control module. After requiring the data what we need, tags send the data according to the setting transmission gap. If the data send successfully and the tag still in working hours, it goes to sleep and awaked by timer until the next interval is reached. If the sending is failure, the tag would continue sending the data until reach the maximum times, then it goes to sleep. We can manual wake it if it still in working hours.

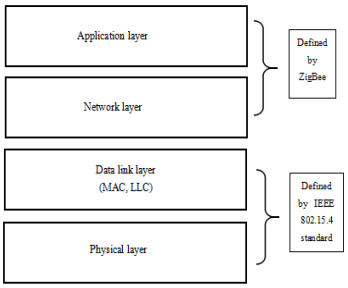

Figure 3: ZigBee protocol stack

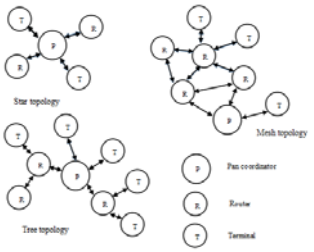

Figure 4: ZigBee network topology

2.3 ZigBee protocol architecture and its characteristic

2.3.1 ZigBee protocol architecture

In order to meet the requirement in small data traffic, the ZigBee Alliance establish the ZigBee protocol. ZigBee is a kind of short distance, low complexity, low power, low data rate, low cost wireless communication protocol which was confirmed (Ren and Yu (2007)). It is based on the IEEE 802.15.4 standard. ZigBee works in the 915MHZ ISM frequency band in USA, 868 MHZ ISM frequency band in Europe and 2.4GHZ ISM frequency band in worldwide. Its transmission rate is 20kb/s-250kb/s and the transmission distance is between 10m to 75m. Although there are many wireless transmission technology, such as Buletooth and Wi-Fi, ZigBee is simpler and less expensive, so it is widely used in automatic control field, remote control, etc.

ZigBee protocol stack has a structure that is simple and compact and its concrete implementation method is easy, so it is low cost. ZigBee protocol stack including the physical layer, data link layer, network layer and application layer, as shown in Fig 3. The physical layer of ZigBee follow the IEEE 802.15.4 standard and data link layer can be divided into Media Access Control (MAC) layer and Logical Link Control (LLC) layer. In the network layer, ZigBee mainly adopt three network topologies: star topology, mesh topology and tree topology, as shown in Fig 4. ZigBee defines two device types: Full Function Device (FFD) and Reduced Function Device. There are three different roles in ZigBee network: coordinator, router and terminal. Only the FFD can be a coordinator. In a star topology, communication process occurs between the device and the PAN coordinator and each device can only communicate with the PAN coordinator. Star topology can easy to change the number of nodes and realize the remote control. Any FFD can be the coordinator in a mesh topology. Tree topology is a special case of mesh topology which can extends the network coverage area and transmit the data in multi-hop and accompanied with the expansion of the network range, the message latency is inevitably.

2.3.2 The advantages of ZigBee

Compared with the other wireless transmission technology, ZigBee has the following advantages: (1) Power Efficient: low transmission rate, low transmission power and low power consumption. If the device out of the working mode, it goes to sleep. According to estimates, the device can last 6-24 months only by two AA batteries. (2) Low Cost: the initial cost of a ZigBee module is about $6 and the cost is reduced year by year. Besides, ZigBee protocol is patent free. (3) Low Delay: the communication time delay and the activation time delay are very short. So, ZigBee technology applies to the wireless control field which has the strict delay requirement. (4) Greater Network Capability: A ZigBee network can hold 100 RFD and one FFD in maximum which is in a star topology. There can be 100 overlapped ZigBee network at the same time. (5) Reliable: ZigBee technology uses the collision avoidance mechanism and it reserves the free time slots for the communication service which need the fixed bandwidth. The MAC layer of ZigBee uses the completely confirmed data transmission mode, so each packet be sent need to wait the confirmation message from the receiver. If something goes wrong during the transmission, it would start again. (6) Secure: ZigBee provide the packet integrity checking feature based on Cyclic Redundancy Check (CRC) and it support authentication.

ZigBee use the encryption algorithm based on Advanced Encryption Standard (AES), so that each application can determine its security properties flexibly which was confirmed (Zhou and Ling and Wu (2005)).

2.4 The method that integrating RFID with WSN

Wireless sensor network is composed of a large of sensor nodes. It can form a multi-hop self-organized network system through the wireless communication which was confirmed (Pang et al (2011)). Wireless sensor networks (WSN) is an important part of Internet of Things which is a synthesis of microelectronic technology, embedded computing technology, wireless communication technology, distributed information processing technology, etc. WSN can realize the real time monitor, awareness, acquisition for the information of monitored objects in the network coverage area cooperatively and after processing send to the observer through the wireless network which was confirmed (Si and Yang and Wang (2011)). Passive tags widely used at present exist some disadvantages, such as poor anti-jamming, short operating distance. WSN can monitor the information in a large range and the effective operating distance can reach 100m, but its identification ability is poor compared with RFID.

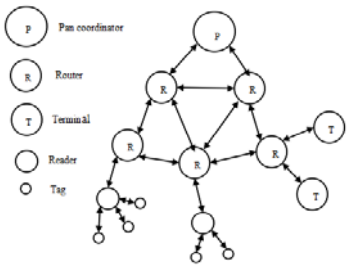

Figure 5: Network architecture

Figure 6: Reader and Sensor

Now, the way integrate RFID and WSN can be divided into three part: the integrate of RGID tags and WSN, the integrate of RFID reader and WSN, the integrate of RFID and WSN in system level which was confirmed (Nie et al (2011)). In this paper, we adopt the second way: the integrate of RFID reader and WSN. Through the network architecture based on ZigBee, we would build a real time information transmission network. Based on comprehensive analysis of the characteristic of these three topology structure of ZigBee, the actual effect of integrating RFID and WSN and the demand of monitoring of warehousing, we design the network architecture integrating RFID and WSN based on star topology and mesh topology, as shown in Fig5.

3. The analysis of the quality monitoring traceabiliy platform

3.1 The preparatory work before leaving the origin

RFID tag uses the binary storage, so we should encode it. EPC has the advantages of uniqueness, permanency, and expansibility which can ensure the information is unique and precise. It is widely used in RFID encoding. We need to store the product information. Product information mainly includes product name, item number, origin, manufacturer date, quantity. We can also store the specific information into the tag according to the mode and type of production and many others feature. The information can provide evidence for quality traceability and play a role in inspection of production. Before loading, we also need to initialize the set of temperature and humidity detection module and set the control parameter such as transmission gap and working hours by the product features. Before the products leave the origin, refrigerated truck across through the large-scale RFID reader then the information is read and uploaded to serve.

3.2 The monitoring and management of cold chain transportation

The products in cold chain transportation are high demand to transportation environment, and the transit time is long, so it is necessary to ensure the appropriate temperature and humidity in transportation environment all the time. On the basic of above research, we adopt the active RFID temperature and humidity sensor tag to realize real time monitoring for temperature and humidity. We put these tags into truck in accordance with the amount and location of the products in certain density in certain density. During the transportation, active tags send the data to the hand-held reader in cab. Reader has the threshold for the environment parameter predefined, which would send a warning to the crew in the cab if the data received over the threshold. So they can take the appropriate measures in time. The temperature and humidity data store in the SD card, when the truck arrive at the destination, we upload it to the serve.

Figure 7: The application in Cold Store

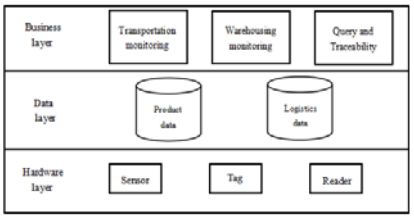

Figure 8: The system level of the platform

3.3 The monitoring and management of cold store (Fig 6, 7)

In the entrance, we put the large-scale RFID reader for reading the data in tags and writing the warehousing information to the tags when the truck in and out the cold store. Using the large-scale RFID reader, we can realize the registration of products automatically and reduce the manual work. We adopt the method that integrating RFID and WSN to monitoring the temperature and humidity in cold store. We have get the product information when the truck into the cold store, according to these information we can set the control parameter. Sensor sends the real time environment data to the local management center through the wireless network which is build by themselves and local management center uploads the data received to the server at the same time. If there are some abnormity data, management center would give a waning, then the staff can take the appropriate measures in time.

Because the space of cold store is large, considering of the cover range of the sensor, we divide the cold store into many small field and put the sensor in each field. In this way, staff can find out where the problem is, and reduce the influence to the environment and products in cold store.

3.4 Platform system level and function structure

This quality monitoring traceability platform mainly has three parts: hardware layer, data layer and business layer. Hardware layer provide the function of data acquisition and transmission. The data stored in data layer including the product data and business data. Business layer is used to deal the data. Depending on the different form of business. it can be divided into transportation monitoring business, warehousing monitoring business and query and traceability business as shown in Fig 8.

After planning the system level, the platform includes product information module, transportation monitoring module, warehousing monitoring module, environment data analytical module, query and traceability module, management and accountability module. Product information module stores the basic product information and logistics information. Transportation and warehousing monitoring module mainly used to monitor the environment in these two process. With the analysis of environment data, the analytical module can be used to optimize the cold chain. Management and accountability module record personal information. If there is a problem in cold chain logistics, we can use it to take the accountability.

3.5 The characteristic of platform

All data in cold chain logistics have stored in server, the data flow of platform. The staff in different stage can know the logistics information at any time. This quality monitoring traceability platform can give the cold chain logistics more transparency by the quality tracing in real time. In summary, this platform can reduce product loss, ensure product quality, discover problem in time and defined the responsibility.

4. Conclusions

This paper adopt RFID technology, temperature and humidity sensor, WSN and ZigBee and research the integrate mode and performance feature of these technologies. Through the combination of the hardware and software, this quality monitoring traceability platform solve the problem that the temperature and humidity data cannot be monitored and transmitted in real time and provide data support for maintaining the environment of cold chain logistics. Using this platform, we can strengthen supervision and management of the products. Through this research, we can get the following conclusion:(1) We can get the real time temperature and humidity data during transport without influencing the cold chain environment by the active RFID temperature and humidity sensor tag. (2) A larger coverage and longer communication distance transmission network is designed to monitoring the cold store environment by integrating RFID with WSN based on ZigBee. (3) All data are stored in the server. Any staff in cold chain logistics can view the product information by using this platform so that it can improve the product quality and safety.

Acknowledgments

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