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Design of Chemical Industrial Park Integrated Information Management Platform Based on Cloud Computing and IOT (The Internet of Things) Technologies

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Abstract

Chemical industry is the fundamental strategic industry in national economy and one of pillar industries in China. A wealth of chemical industrial parks has been built one after another in many places, where lots of chemical enterprises are established. In the normal operation of those enterprises, their raw materials or products manufactured, transported and stored are usually featured by flammable, explosive or toxic properties, resulting in frequent occurrence of pollution and personal accidents and causing great threats to surrounding environment. This thesis realizes an integrated information management platform based on currently advanced cloud computing and IOT (The Internet of Things) technologies, so as for integrated management of chemical industrial parks. This thesis designs the architectural structure of said integrated information management platform, expounds the roles and realization approaches of the basic support platform and the business service platform, analyzes the principles and methods for realization of regionally coordinate emergency management operation mechanism based on the information management platform, that of IOT architecture technology and that of RFID and Wireless Sensor Network (WSN), and discusses that the standard unification of heterogeneous data under cloud computing is realized by means of multi-source data integration middleware. The said platform can accomplish the whole-process, real-time and dynamic follow-up and control of chemicals and hazardous materials and also provide effective service for users' decision-making by mining and analyzing tremendous data of a chemical industrial park with Agent-middleware technology. The information management platform is capable of assessing the safety factors of chemical enterprises at peacetime, giving necessary warning before accidents and offering effective technical support for rescue via expert system, emergency plan system, monitoring system and positioning system. The realization of chemical industrial park integrated information management platform based on cloud computing and IOT technologies will greatly improve the management level of chemical industrial parks, intensify surveillance, achieve information resource sharing and lower the probability of accident occurrence.

Keywords: *Chemical Industrial Park, Cloud Computing, IOT (The Internet of Things), Information System*

Chemical industry is the fundamental strategic industry in national economy and one of pillar industries in China. Currently, existing large chemical enterprises are undergoing large-scale industrial restructuring; at the same time, with a wealth of chemical industrial parks established one after another, Chinese chemical enterprises tend to clustering development in chemical industrial parks and a round of chemical industrial park development upsurges under rapid development. Many localities rush to construct

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chemical industrial parks in a bid to seize the new round of chemical industrial restructuring. On the other hand, there are so many chemical material plants, organic chemical plants, bio-pharmaceutical plants and the similar in chemical industrial parks. In the normal operation of those enterprises, their raw materials or products manufactured, transported and stored are usually featured by flammable, explosive or toxic properties, resulting in frequent occurrence of pollution and personal accidents and causing great threats to surrounding environment. This thesis intends to build an integrated information management platform based on currently advanced cloud computing and IOT technologies so as for integrated management of industrial chemical parks and to provide pre-accident warning and post-accident rescue necessary with service support and decision-making support.

1. Cloud Computing Technology

Cloud computing is an Internet-based service addition, use and delivery mode, which generally involves the supply of dynamic, extendable and often virtual resources via Internet. Cloud computing in narrow sense refers to the delivery and use mode of IT infrastructure, which is to obtain the required resources on the basis of need and in the extendable way via Internet; and that in broad sense refers to the delivery and use mode of services, which is to obtain the required services on the basis of need and in the extendable way via Internet. Such services may either be pertaining to IT, software and Internet, or others. It means that computing power also can circulate as a commodity via Internet. Actually, cloud is a metaphor for network and Internet. Cloud computing is a combination of multiple technologies, instead of merely one technology, which makes information technology (IT) as a service concept possible and recognized by the public.

Cloud computing emerges after centralized computing, distributed computing, desktop computing and grid computing, as shown in Figure 1.

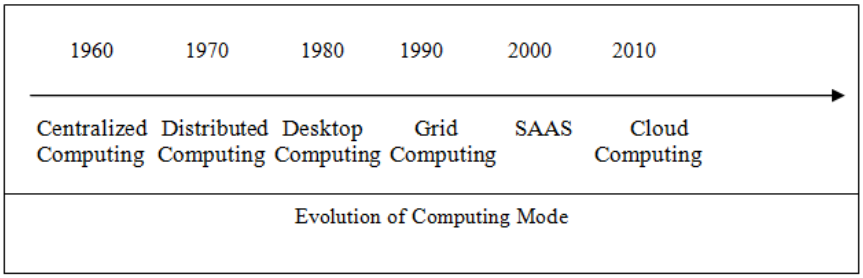

Figure 1. Evolution of Computing Mode

Cloud computing is characterized by: (1) that computing resource integration improves the computing power; (2) that the distributed data center ensures the system disaster tolerance capacity; (3) that separation of software from hardware reduces the device dependence; (4) that platform building block design shows high extendibility; and (5) that virtual resource pool provides users with flexible services.

2. IOT (The Internet of Things) Technology

IOT (The Internet of Things) is an important component of a new generation of information technology. It has two levels of meaning: (1) the core and foundation of IOT is still Internet and IOT is a network extending on the basis of Internet; (2) the user end of IOT extends to anything for information exchange and communication. Therefore, IOT is defined as a network that connects anything with Internet for information exchange and communication via information sensing equipment, like Radio Frequency Identification (RFID), infrared sensor, global positioning system and laser sensor, according to agreed

protocols, so as to realize the intelligent identification, positioning, follow-up, monitoring and management of things. Compared with conventional Internet, IOT is featured by:

(1) That IOT is the extensive application of various sensing technologies; (2) that IOT is a ubiquitous network established on Internet; (3) that, in addition to providing sensor connection, IOT itself is capable of intelligent processing and can conduct intelligent control over things.

3. Current Domestic and Overseas Research Conditions

In 2010, ZHAO Jun had an article named Construction of IOT Operation Platform Based on Cloud Computing published, which started with the analysis on IOT architecture, researched the construction needs of IOT operation platform and the cloud computing features reflected in such needs and further proposed the strategies for construction and implementation of telecom operator IOT operation cloud platform. In 2011, WANG Jing and QUAN Chunlai, *et al.*, wrote a paper titled Research on Architecture of IOT Public Security Platform Software, which established a hierarchy model for IOT public security platform in combination with the structure of IOT and designed the architecture of IOT public security platform software. In 2013, HE Chao and SONG Xuefeng, *et al.*, presented a thesis namely Research and Discussion on Coal Mine Safety Surveillance Information Management System, which analyzed the application advantages of IOT in coal mine safety surveillance, put forth the possible construction of a coal mine safety surveillance information management system covering provincial and national safety surveillance based on IOT and discussed the challenges that the said system would face in information standard, safety factor rating, safety surveillance system and information collection contents *etc.*, during specific implementation. In 2014, CHEN Hao and CHEN Hongling proposed the application of coal mine safety management intelligent mobile information platform based on cloud computing and IOT technologies and introduced the architecture and function characteristics of said platform in their dissertation Research on Coal Mine Safety Management Intelligent Mobile Information Platform Based on Cloud Computing and IOT Technologies. In 2012, according to the work with a title of Research on Chemical Industrial Park Accident Emergency Management Information System, HE Yanwei and LIU Penggang built a chemical industrial park accident emergency management system based on ArcIMS platform development by utilizing the principles and architectures of ArcIMS and exerpt system, which provided the effective auxiliary means for safety planning, emergency management and accident rescue work of chemical industrial parks. After literature search, it is found that so far there has been no research in applying IOT and cloud computing technologies to management of chemical industrial parks or designing an information management platform with systematic theories for chemical industrial parks to accomplish the work from routine management, goods logistics monitoring, data mining, decision-making support to pre-accident warning and in-accident rescue decision-making support.

4. Architecture of Information Management Platform

4.1 Architecture of Information Management Platform System and General System Structure Diagram

The chemical industrial park integrated information management platform based on IOT and cloud computing technologies collects data by means of terminal data collecting sensors, such as RFID, infrared sensor, temperature and humidity monitoring sensor and concentration monitoring sensor, shares data via cloud through wired and wireless data transmission networks, realizes the whole-process monitoring on vehicles, hazardous materials, chemicals and other resources, conducts real-time monitoring and warning of environmental conditions before the occurrence of accidents, monitors the site conditions after the occurrence of accidents, implements rescue technical support via expert system,

emergency plan system, monitoring system and positioning system etc. on the cloud and offers necessary commanding support by dint of rescue cooperation commanding system. The platform architecture provides all kinds of service principals inside and outside parks with SaaS software, offers various Web platform services inside and outside parks with PaaS platform and presents complete computer infrastructure service to users in parks with IaaS infrastructure service. Such architecture design brings into full play the advantages of IOT and cloud computing technologies. The platform architecture and the general system structure diagram are as shown in Figure 2 and Figure 3.

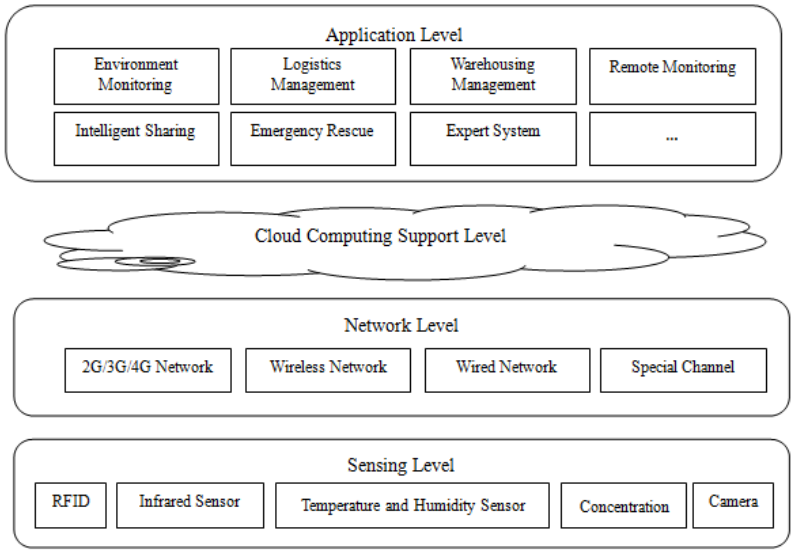

Figure 2. Architecture of Chemical Industrial Park Integrated Information Management Platform Based on Cloud Computing and IOT Technologies

The said platform is divided into three levels, namely sensing level, network level and application level, and supports sharing of data at higher and lower levels via cloud computing support level.

Sensing level: It is mainly responsible for sensing the world, *i.e.*, to collect physical events and data occurring in the physical world technically and to convert physical properties of things in chemical industrial parks, such as current location, ambient temperature and humidity data and concentration data, into machine data for transfer in the perspective of application;

Network level: It is mainly responsible for data transfer and transmission, i.e. to transfer data at the sensing level and the control information at the application level in a barrier-free, highly reliable and highly efficient manner, and to transfer data at the sensing level upwards via cloud in the perspective of application, wherein the application level makes decisions with information converted from such data and gives orders downwards via the network level;

Cloud computing support level: By dint of cloud computing support level, it is possible to transfer data conveyed from the network level into “cloud”, so as to realize the sharing of resources and the cloud processing of data.

Application level: It is mainly responsible for influencing the world, *i.e.*, technically to mine tremendous data and convert into information, conduct the subsequent efficient utilization, make decisions and transform decisions into management to influence the chemical industrial park. This architecture possesses a number of features like all-inclusive sensing, reliable utilization, high sharing of resources and intelligent processing.

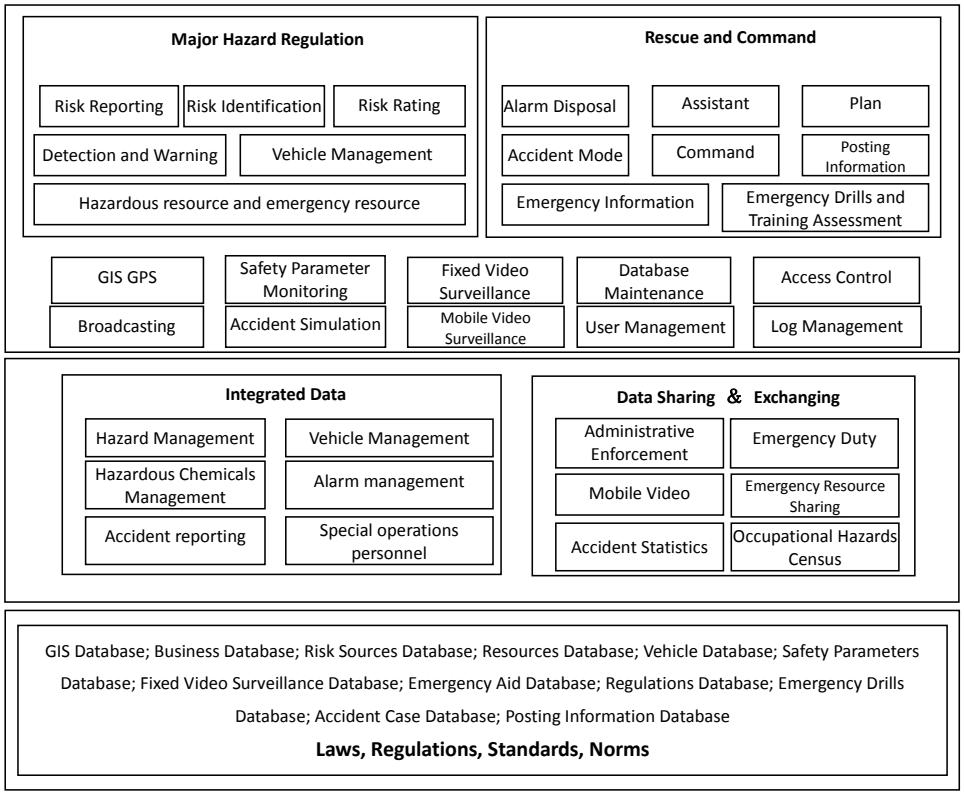

Figure 3. General Structure Diagram of Chemical Industrial Park Integrated Information Management Platform Based on Cloud Computing and IOT Technologies

4.2 Platform software architecture

The scope of research on software architecture of chemical industrial park integrated information management platform based on IOT and cloud computing technologies covers the application service level and the fundamental support level, as shown in Figure 4.

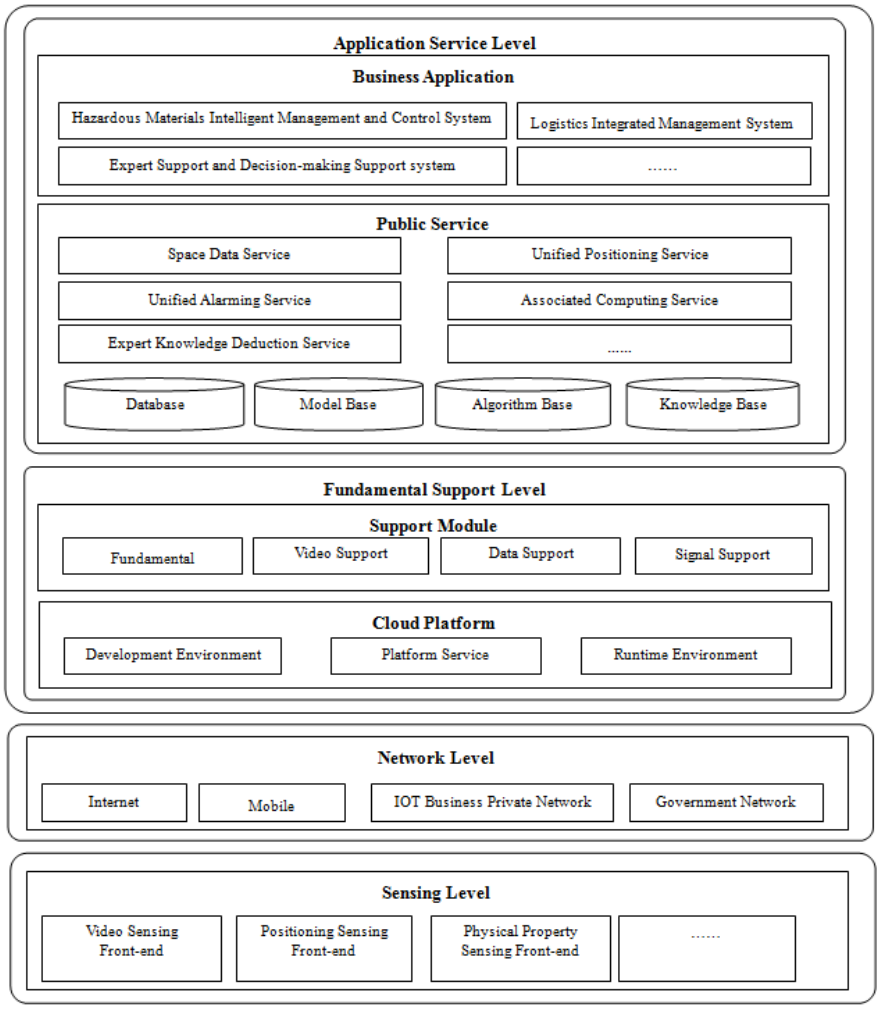

Figure 4. Software Architecture of Chemical Industrial Park Integrated Information Management Platform Based on Cloud Computing and IOT

4.2.1 Basic Support Platform

As shown in Figure 4, the basic support platform is consisted of cloud platform and basic service. Herein, cloud platform offers the entire platform strong computing power, storage space and business support, accomplishes almost all computing processing work and storage work, builds the unified data virtual runtime support environment for the data center, carries the business system by providing application with virtual machine, and lowers the quantity of physical service and the complexity of management. Cloud platform is composed of the development environment, the platform service and the runtime environment. Therein, the platform service reflects the SaaS feature of cloud service and is made up by the runtime dynamic creation module, the service dynamic management module, the coordinated scheduling module, the batch-job scheduling module and the runtime disaster tolerance migration module; the development environment shows the PaaS feature of cloud service and provides the development environment for development tools including cloud environment system architecture tool, general service packaging tool, member/element packaging tool and cloud environment testing tool; the runtime environment reveals the IaaS feature of cloud service and mainly offers runtime environments like coordinated service server cluster, application server cluster and database server cluster.

Basic service provides some fundamental services for platform operation. So-called "basic" refers to that these services are common business components extracted from the IOT platform according to the features of IOT, different from services supplied by the application service level. Its front-end access information includes access management, information pre-processing like normalization and conversion, information exchange and sharing and these modules constitute information exchange service. Basic service realizes the distributed storage and unified management of large data like video information via cloud storage technology; establishes the unified intelligent retrieval service for tremendous data; sets up the unified equipment control service to realize the control and management of various different front-end sensing equipment; and constructs a secure management system integrating use and access management, basic resource information management, equipment and system operation status management and security authentication management etc. for complex sensor types and enormous data users. Basic service is composed of basic management, signal support, data support, video support and so on.

4.2.2 Business Service Platform

The application service platform is consisted of public service and business application. Therein, public service is the core of comprehensive application of sensing information in IOT and it achieves the comprehensive application of sensing information sent by the basic support platform and realizes the technical support for establishments in parks, park administration centers and government surveillance departments by storage, integration, intelligent analysis and judgment of all-inclusive sensing information. It is a common function module extracted from specific business and business flow etc. of public security domain and mainly covers database, model base, algorithm base, knowledge base, thing physical property data, video analysis service, volatile concentration monitoring data, unified positioning service, unified alarming service, short message release service, expert knowledge deduction service. Business application is an application system developed based on existing service composition according to basic needs of chemical industrial parks at current stage and mainly includes hazardous material intelligent management and control system, logistics function management and control system, key zone 3D prevention and control system, expert support and decision-making support system and emergency rescue decision-making support system.

5. Realization of Key Technology

5.1 Realization of Regionally Coordinate Emergency Management Operation Mechanism based on the Information Management Platform

Principle of integral safety. A unified park production safety surveillance institution is established to take charge of coordinating enterprises to jointly participate in formulating the production safety management planning of the chemical industrial park, finding all kinds of hidden accident troubles affecting the integral production safety of chemical industrial park and making timely rectification, so as to promote the coordinate development of integral production safety in the chemical industrial park.

Principle of information sharing. The park production safety surveillance institution coordinates the production safety information of enterprises and realizes the sharing of production safety information, e.g. distribution of major hazard installations, allocation of emergency resources, recent occurrence of accidents and implementation of safety management regulations and rules, in the park under the precondition of not involving the production secretes of enterprises. Only knowing related information well could better protect enterprises from outside accidental damages.

Principle of resource sharing. Enterprises in the chemical industrial park shall erect the awareness of "helping each other means self-helping", make concerted efforts to accident

emergency rescue of surrounding enterprises, take full advantage of limited emergency resources in the park and avoid unnecessary waste, so as to keep themselves from unnecessary effects caused by accident expansion of surrounding enterprises, minimize the domino effect of accident and relieve the environmental impact of personal casualties and property loss.

Principle of compatibility. The regionally coordinate emergency management operation mode of chemical industrial park is compatible with the individualities of enterprises in emergency management and enterprises are exempted from large-scale adjustment so that they could be guaranteed to participate in the regionally coordinate emergency management operation mode with high efficiency under the current conditions of emergency management of enterprises in the chemical industrial park.

Upon the occurrence of accident in some enterprise, the enterprise emergency management department would notify the park emergency management office immediately, give warning information and alarm according to specified procedures in time, report related information like accident type, name and location of hazard installations to the emergency information integrated management system at the same time, apply the emergency rescue information platform module to determine the scale of emergency response team, start corresponding emergency rescue plan and determine the name list of enterprises offering emergency aid to the accident enterprise and the amounts of emergency resources to be supplied by respective enterprises by means of decision-making of regionally coordinate emergency resource scheduling model. After decision-making, the said system would notify respective enterprises required to participate in rescue and those around the accident enterprise via sharing network, entering the normal emergency response stage rapidly. In the emergency management response stage, the issue of resource scheduling is the component of great importance.

5.2 Realization of IOT architecture technology

The chemical industrial park is featured by large amount of mobile office data, real-time frequent data collection and complicated business. Besides on the basis of real-time automatic data collection as mentioned previously, it is required to realize the data integration of wired/ wireless networks, adapt to multi-condition and multi-barrier data transfer and guarantee seamless data coverage and data exchange in the park. As shown in Figure 4, the transfer of video monitoring, physical property data collected and concentration data collected *etc.*, is through wired network like VPN; while for vehicle movement, supplies circulation and positioning of hazardous materials, substance resource and status data (*e.g.*, current conditions and location of hazardous materials, vehicle information *etc*.,) are collected and exchanged through wireless communication network. Similarly, it is possible to send related information to business subjects via wired or wireless network inside the park.

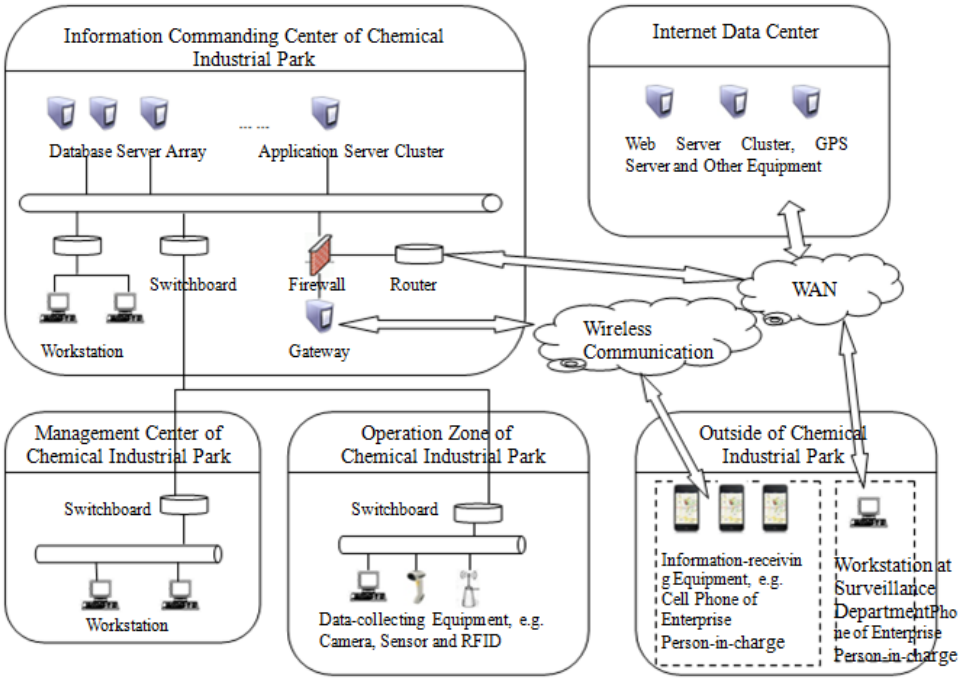

Figure 5. Topological Diagram of Chemical Industrial Park Integrated Information Management Platform

5.3 Realization of Radio Frequency Technology

Radio Frequency Identification (RFID) is a non-contact automatic identification technology rising in 1990's. Compared with conventional magnetic card and IC card technologies, radio frequency technology possesses the characteristics such as non-contact, quick reading speed and no wear. Radio frequency technology conducts non-contact bidirectional data transmission between the reader and the radio frequency card, so as to achieve the goal of target identification and data exchange. In comparison to conventional barcode, magnetic card and IC card, radio frequency card is non-contacting, quick to read, not wearable, free of environmental influence, with long service life, easy to read and anti-conflict, capable of processing multiple cards.

The most basic RFID system is consisted of electronic tag, antenna and reader these three components. Each electronic tag is with the globally unique ID, which is impossible to modify or forge, thus guarantees security. The electronic tag is attached to an object to identify the target; the antenna is used to transfer radio frequency signal between IT tags and the reader; and the reader is used for equipment reading (or writing) electronic tag information and may be designed as portable or fixed type. The working principle of RFID technology is as shown in Figure 6.

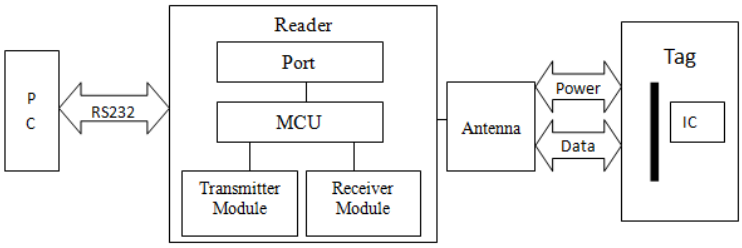

Figure 6. Working Principle Diagram of RFID

In work, RFID reader transmits the signals at certain frequency continuously via the antenna. When RFID tag enters the magnetic field, it sends the product information stored in the chip by dint of energy obtained through current induction or the signals at some frequency of own accord; afterwards, the reader reads information, decodes and transmits data to the central information system for related data processing.

5.4 Realization of Wireless Sensor Network (WSN)

In the process of IOT construction, it is vital to realize sensing. Many sensors capable of communication and computing (*e.g.*, temperature sensor and concentration sensor) can connect wirelessly, interact with the physical world, accomplish specific application tasks together and form the sensor network. The sensor network integrates multi-discipline cross technologies including sensor technology, embedded computing technology, distributed information processing technology and wireless communication technology. In the sensor network, a multi-hop self-organizing system comes into being autonomously via wireless communication, in a bid to sense, collect and process sending information the area covered by the network, monitor and process such information flexibly and transmit detailed information to users concurrently. IOT connects all things with Internet via RFID, temperature sensor, concentration sensor and other equipment to realize intelligent identification and management.

In the sensor network, lots of sensor nodes scatter in specific zones and they are divided into different clusters according to geographic coordinates. In each cluster, there is one sensor as main node to take charge of communication routing and other management in that cluster; and among all nodes, there is one sink node to take charge of communication with trunk networks like Internet and LAN (Local Area Network). Therefore, compared with conventional sensor, the sensor network is easier to deploy, with low network deployment maintenance cost and high flexibility; it is consisted of many cheap nodes, which can be placed within the effect range of physical phenomenon, thus resulting in high observation accuracy and high price/performance ratio. There are a lot of redundant nodes in the sensor network and the function of entire system would not be affected even if some of them fail; therefore, the sensor network is robust. Besides, nodes in the sensor network are capable of computing and collaboration to complete tasks that convention sensors are unable to do.

5.5 Technology Integration

The integration of RFID technology and sensor network technology is a trend of IOT in future. For the effective distance of RFID is within 10cm in general, it is feasible to utilize such feature for positioning and necessary monitoring of some hazardous materials; on the other hand, if RFID is combined with wireless sensors, with the effective radius of wireless sensor at as high as 100m, a wireless sensor network is available for application in logistics management. Generally speaking, the sensor network doesn't care the location of node, thus usually will not attach the overall identifiers to nodes, while RFID has the naturally endowed advantages in node identifier. Both can supplement the defects of the counterpart if combined together and focus the main strength of network on data. When it is required to consider some specific node information, the location of node is easy to find with the identifier function of RFID.

In IOT, constant interactions happen between machines, between human and between human and machine and complicated cost information will encounter difficulties in exchange and sharing. Principal construction can realize the mutual understanding and cognition of information organizational structure among users and among Agent; alternatively, specialized knowledge can be applied to make the assumptions in the specialized field more specific and be analyzed. Meanwhile, the principal may serve as communication media to assist in obtainment, expression and operation of knowledge.

Such assistance is realized by providing a core with consistent basic concept and language structure; similarly, helps build and organize the knowledge base and interpret the input and output of knowledge processing tool module. Principle architecture is the most important work for this platform to realize unambiguous interaction.

5.6 Realization of Multi-source Data Integration Middleware

There are diversified data access and interaction modes in chemical industrial parks; hence there are great difference in data definition format, data storage mode and data transfer mode of different resources, i.e. heterogeneous data sources exist, which requires the system to accomplish the maintenance of data consistence, necessary mode conversion and concurrency control and so on in some way and offer unified data operation ports. The information management platform solves this problem by using multi-source data integration middleware in design.

(1) Processing of static data

All static data, such as attributes of chemicals, physical properties of chemicals sent from sensors and codes of chemicals etc., will be redefined via middleware to accomplish data consistence in terms of data analysis and data conversion. The information management platform offers such function and can read in above data in a standardized manner and convert abstract entities into structured distributed databases.

(2) Processing of real-time collected data

Data in this section mainly come from data read by the RFID reader, data read by the code scanner, data sent from sensors, data entered at the workstation and so on, and are featured by high frequency and large quantity, yet also with abnormal data and redundant data existing. In this case, the role of middleware is to mine, sort out and integrate data sent from respective sensors, obtain complete thing status data and introduce this section of data model into the platform.

(3) In addition, some heterogeneous data also can be processed in the way as shown in Figure 7; data from the distributed heterogeneous data source is changed into virtual data warehouse data via XML and interacted into standard data via XML format before entering the processing system.

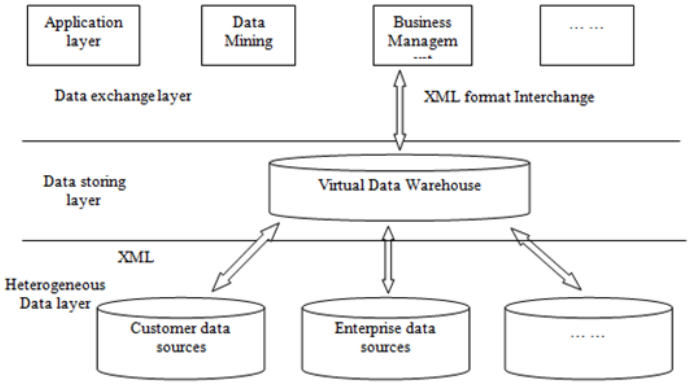

Figure 7. Architecture of Information Management Platform Middleware

Here, middleware can realize the function of packaging the heterogeneous data sources at the data collection level and the requests for respective data sources are in terms of standard XML and eventually converted into standard inquiry language of respective data sources and submitted to corresponding database servers for related processing. After completion of data processing, results obtained are repackaged into data in XML format for sending. XML middleware unifies the data structures of different data sources. The resultant underlying data types and data structure information offer a data specification to

information integration and also support the timely notification of structural changes in underlying data sources to related levels.

The virtual data warehouse in the information management platform processes heterogeneous data sources in the combined virtual and real manner, *i.e.*, to conduct the data integration via virtual network view in the case of data sources not conforming to information system data and to introduce into virtual data warehouse directly via XML middleware in the case of some relational databases conforming to the main data types of information system.

6. Conclusion

This thesis proposes the clews for design and realization of chemical industrial park integrated information management platform based on cloud computing and IOT. The said platform can accomplish the whole-process, real-time and dynamic follow-up and control of chemicals and hazardous materials. It offers related information resource services for respective subjects in chemical industrial parks with SaaS, PaaS and IaaS as support, realizes the information requirements orienting respective subjects of different types and with different tasks and achieves the coordinate management among enterprises and among surveillance institutions in chemical industrial parks and the optimization and control of operation modes and operation tasks among on-chain enterprises and among chemicals with related technologies by promoting the conceptual height of system, accordingly improving the management level greatly. The platform provides effective service for users' decision-making by mining and analyzing tremendous data of a chemical industrial park with Agent-middleware technology. The information management platform can assess the safety factors of chemical enterprises at peacetime, give necessary warning before accidents and offer effective technical support for rescue via expert system, emergency plan system, monitoring system and positioning system. The realization of chemical industrial park integrated information management platform based on cloud computing and IOT technologies will greatly improve the management level of chemical industrial parks, intensify surveillance, achieve information resource sharing and lower the probability of accident occurrence.

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