Research on Integrated Information Platform of Agricultural Supply Chain Management Based on Internet of Things

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***Abstract*—In recent years, accidents in food quality & safety frequently occur, and more and more people have begun to think highly of food quality & safety and encourage food producers to be able to trace the origin of ingredients and process of production along the supply chain. With the development of IT, more and more practices have shown that the supply chain of agricultural products should rely on IT. The using of IT directly decides the degree of agricultural informatization and efficiency of agricultural supply chain management. In this paper, on the basis of introducing the meanings and characteristics of supply chain management and agricultural supply chain management, it also analyzes the information flow's attributes throughout the process of agricultural supply and the technological attributes of Internet of Things, finally, the designing method and architecture of integrated information platform of agricultural supply chain management based on internet of things was discussed in detail.**

***Index Terms*—supply chain management, agricultural product, Internet of Things, RFID**

I. INTRODUCTION

With 9.5% of world arable land and freshwater resource that is only 31% of world average; China has successfully fed 22% of world population From 1978 until 2006, the Engel Coefficients of Chinese urban and rural residents have declined respectively from 57.5% and 67.7% to 35.8% and 43%, and the food of the Chinese has also turned from shortage to abundance. The above development shows that China has contributed greatly to world food supply. However, the developmental process of food supply has the characteristics of “pollution first and then elimination”, which means the process is inevitably accompanied with relatively serious problems of pollution and food safety [1]. Specially, in recent years, the frequency and severity of product recalls has been increasing over the past decade. Notable examples of recent ‘global’ product recalls include the 2008 pork dioxin recall in Ireland, the 2008 melamine tainted milk recall in China, and especially the global recalls caused by Bovine Spongiform Encephalopathy (BSE). More and more people have begun to think highly of food quality & safety and encourage food producers to be able to trace the origin of ingredients and process of production along the supply chain [2]. Agricultural supply chain management is becoming one of the hot issues in the researches on supply chain management and causes wide concern of scholars at home and abroad. The research of agricultural supply chain management would optimize the deploying of agricultural resource, lower the risk of agriculture, improve the efficiency of agricultural production and advance the sustainable development of agriculture. Following the social infomationization, the Internet is often viewed as the means to reduce income disparities between the urban and rural populations in the developing world. Specially, with the development of information technology (IT), numerous innovative of IT based applications have emerged around the world that promise to bridge the digital divide. In the field of agriculture, technological innovation and competition have led to improvements in supply chain management for food products. More and more practices have shown that the supply chain management of agricultural products should rely on network information technology to improve its level of infomationization, internetization and intelligentization.

II. CONCEPT OF SUPPLY CHAIN MANAGEMENT

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. The Council of Supply Chain Management Professionals (CSCMP) defines Supply Chain Management (SCM) as follows: "Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model"[3]. The advantages of supply chain management are numerous, like the reduction of product losses, increase in sales, reduction of transaction costs, a better control of product quality and safety and the dissemination of technology, capital and knowledge among the chain partners. A successful SCM implementation is expected to enhance the relationship between upstream suppliers and downstream customers.

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Its objective is to produce and distribute the commodity in the right quantity, to the right place, and at the right time to minimize overall cost while maintaining customer satisfaction and firm performance [4] (Fig.1).

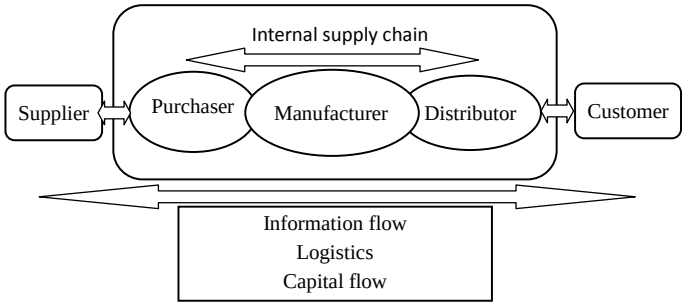

Figure 1. Flow of Supply Chain

Over the past two decades, SCM, emphasizing the interdependence of buyer and supplier firms working collaboratively to improve the performance of the entire supply, has generated extensive interest in both academic and practitioner communities (Shin et al., 2000; Narasimhan and Kim, 2007). A range of new supply chain management tools have been developed over the past decade. For example, 'Efficient consumer response' (ECR) has been developed to increase the consumer orientation and cost-effectiveness of supply chains (Kurt Salmon Associates, 1993). New management systems have been implemented to improve logistics, increase the use of information and communications technologies and boost quality management (Lambert and Cooper, 2000). New generation cooperatives are emerging, strengthening the position of farmers' groups (Cook et al., 2001) and strategic partnering and vertical alliances are cementing sustainable partnerships throughout the supply chain (Zylbersztajn & Farina, 1999). In the side of models, there are a variety of supply chain models which address both the upstream and downstream sides. Such as: Supply-Chain Operations Reference-model (SCOR), American Productivity & Quality Center's (APQC) Process Classification Framework and the Supply Chain Best Practices Framework etc. All of these models address both the upstream and downstream sides, and need use IT to collect, analyze, transmit, manage and visualize their information and results.

III. Agricultural Supply Chain Management

We speak of a 'supply chain' when different actors are linked from 'farm to fork' to achieve a more effective and consumer-oriented flow of products. The ASCM is a branch of SCM and means the research and application of SCM in the field of agriculture; it is a kind of tracking management of "from farm to table". ASCM involves the whole products' flow throughout agricultural production's phase from grow seedlings to customers [5]. In this whole process, the actors of ASCM may include growers, pickers, packers, processors, storage and transport facilitators, marketers, exporters, importers, distributors, wholesalers, and retailers (Fig.2).

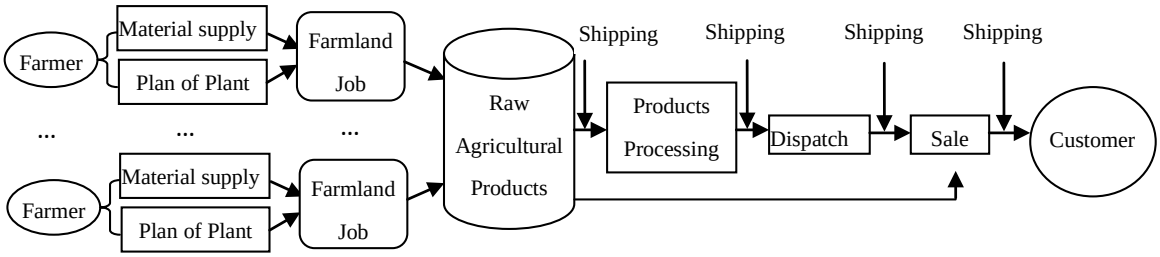

Figure 2. Flow Frame of Agricultural Supply Chain

At present, in many developed countries such as America, Holland, Japan and European Union, the research of ASCM has gotten a very high level. For example, in America, the production of agriculture has been entrepreneurial; the developing mode of agricultural enterprises is "industry + industry + industry". The process of agricultural enterprises' operation has been basically finished. In Europe, people tend to have shorter food supply chain, i.e. sending products from the farms directly to the families so as to ensure the freshness and safety, and avoid uncertainty and information asymmetry. Holland summarizes the successful organization of agricultural chain to: research, service of information and education, high quality and stability of agricultural product supply, and global vision of market.

In China, the research on ASCM begins in 1999 and is currently still in its infancy. Compared with developed countries, Chinese agricultural product supply chains consist of the millions of small scale farmers, who are not well structured and organized in the supply chain. The status quo of food supply chain in China can be summarized as following: A long and unsustainable supply chain, inadequate policy support, limited infrastructure for storage, inefficient information and knowledge flows, the lower level of internetization and intelligentization etc. With the development of Information Technology, specially the development of internet of things technology (such as RFID, Sensor etc.) provides new opportunity for research on ASCM, infomationization, internetization and intelligentization of ASCM would be the new researching content of agricultural modernization and trend of global agriculture development.

IV. ANALYSIS OF INTERNET OF THINGS

In 1995, in the book of "the road ahead", BILL GATES firstly brought up the concept about connection of "thing to thing". In 1999, EPCglobal united more than 100 enterprises and created the International Telecommunication Union and formally brought up the concept of Internet of Things (IoT). In 2005, ITU published "ITU Internet Reports 2005: Internet of Things (IoT)" introduced that we are standing on the brink of a new computing and communication era, one that will radically transform our corporate, community, and personal spheres.

A. Concept of Internet of Things

According to the definition of ITU, The IoT describes a worldwide network of billions or trillions of objects that can be collected from the worldwide physical environment, propagated via the Internet, and transmitted to end-users. Services are available for users to interact with these smart objects over the Internet, query their states, as well as their associated information, and even control their actions [6]. The purpose of IoT is to create a huge network through the combination of different smarter devices (such as RFID, GPS, RS) and networks to realize the information sharing of global things from any place, and any time [7](Fig.3).

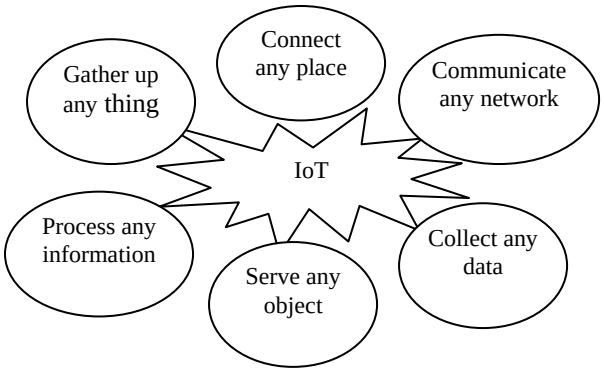

Figure 3. ttributes Frame of IoT

B. The Technology System of IOT

In the field of IT, the IoT is a technology revolution that represents the future of computing and communications. It refers to a network of objects, and is often a self-configuring wireless network. With continuing developments in miniaturization and declining costs, IoT is becoming not only technologically possible but also economically feasible to make everyday objects smarter, and to connect the world of people with the world of thing. Embedded intelligence in things themselves will distribute processing power to the edges of the network, offering greater possibilities for data processing and increasing the resilience of the network. As a whole, in this technology system, the coral technologies mainly include: RFID, sensor, "3S", WSN, and cloud computing etc. (Fig.4).

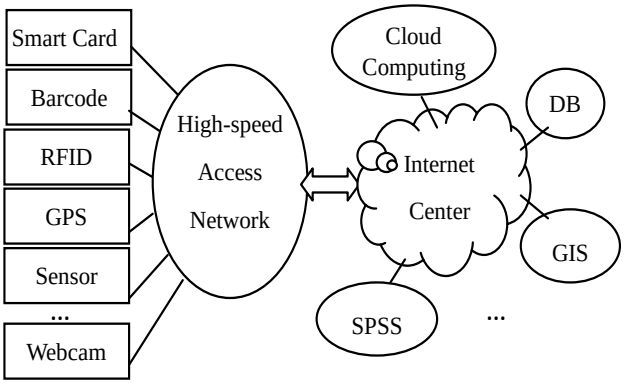

Figure 4. Technology System of IOT

The radio frequency identification (RFID) is a technology that can be used to tag physical objects, allowing them to be detected and identified automatically. RFID has been perceived as a critical technology for improving efficiency and effectiveness in production and operations of manufacturing and service organizations and for improving SCM in various types of organizations RFID technology is classified as a wireless automatic identification and data capture technology which includes bar coding, optical recognition, biometrics, card etc. Basic RFID system consists of three components: antenna, RF tag and reader. The purpose of an RFID system is to enable data to be transmitted by a portable device, called a tag, which is read by an RFID reader and processed according to the needs of a particular application. Using RFID, the IoT can comprise millions of networked embedded devices also called smart items [8].

The sensor is another important technology for acquisition of data, and is mainly used to capture part of the existing data, correlate and synchronize these data, analyze them, and finally, carries out a reactive activity without user intervention. The components of a (remote) sensing node include the following: sensing and actuation unit (single element or array), processing unit, communication unit, power unit and other application-dependent units Sensors can be simple point elements or can be multipoint detection arrays, and it has the capability of large scale deployment, low maintenance, scalability, adaptability for different scenarios etc[9].

The technology of "3S" includes RS (Remote Sense), GIS (Geography Information System) and GPS (Global Position System) and is mainly used to provide the location of a particular tagged object, acquire the information of an object or phenomenon by multiple satellites, aircraft, etc, and finally store, analyze, manage, and present data that are linked to location(s) by GIS software[10].

For the transmission of information, wireless sensor network (WSN) and GPRS/GSM are the mainly used network technology in the field of agriculture. WSN mainly consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, pressure, motion or pollutants. There are four basic

components in a WSN: an assembly of distributed or localized sensors; an interconnecting network (usually, but not always, wireless-based), a central point of information clustering; and a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining.

For the process of information, cloud computing is Web-based processing and is location independent computing, whereby shared servers provide resources, software, and data to computers and other devices on demand, as with the electricity grid. Cloud computing describes a new supplement, consumption, and delivery model for IT services based on the Internet, and it typically involves over-the-Internet provision of dynamically scalable and often virtualized resources[11]. In addition, in the side of integration of information and service, service-oriented architecture (SOA) is a flexible set of design principles used during the phases of systems development and integration in computing. SOA defines how to integrate widely disparate applications for a Web-based environment and uses multiple implementation platforms. It generally provides a way for consumers of services, such as web-based applications, to be aware of available SOA-based services.

V. Analysis about Information Platform of ASCM

In order to react effectively and quick to consumer's demand, supply chain management is consumer-oriented. It aims at coordination of production processes. In ASCM, if all relevant information is accessible to any relevant company; every company in the supply chain has the possibility to and can seek to help optimizing the entire supply chain rather than sub optimize based on a local interest. This will lead to better planned overall production and distribution which can cut costs and give a more attractive final product leading to better sales and better overall results for the companies involved. So, the agricultural data are the vital basis of ASCM, every activity in this chain involves the creation, processing and communication of information. As an important subpart, the integrated information platform of ASCM is to realize integration and seamless access of multi-source information from any place at any time. The terminal target is to improve the level of infomationization, internetization and intelligentization of ASCM, and realize just in time delivery, supply base reduction, supplier integration, efficient information transmission, and collaborative relationships, help firms to trace products along food chains.

A. Analysis of Agricultural Information

Agricultural supply chain is a very complicated process, and involves many different phases and different actors. Every phase involves many kinds of operation, and every operation involves many kinds of factors, from environment to humane, from ecology to economic, from geography to society etc. First, agricultural production is closely related with spatial factors, every farmland has its own geographic location and boundaries. Second, any agricultural system has many factors; each factor also contains many sub-factors. For example, in the crops of biological factor, there are wheat, paddy rice, corn, cotton and other factors etc [12]. Third, agricultural data come from multiple sources, such as on-board sensors, soil sampling, remote sensing, satellite, web-cam and history material etc, the category of data includes text, number, image, sound and video etc. Finally, all of this information is always changing following the time and space. So, agriculture production is a very complicated ecology system and has the attributes of area-decentralization, object-diversify, data-mass creature-mutation and factors-uncertain. So, as a whole, ASCM is closely related with multi-source, dynamic and enormous information, and agricultural supply chain process has the attributes of dispersed collection points, long average collection period, low speed, enormous data, bad conditions of field etc [13]. In addition, during the process of agricultural supply, the flow of information is not single line, every phase has many relationship with other parts or industries, and is carried out by different operators (manufacturers, distributors, service suppliers, consumers) [5] (Fig.5). All of these factors increase the degree of difficulty of agricultural data acquisition and transmission.

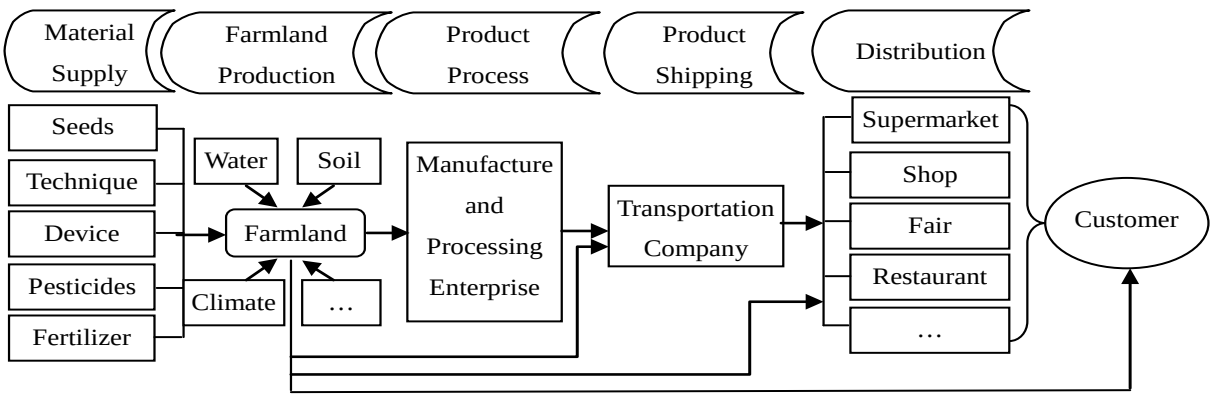

Figure 5. Agri-food Flow of ASCM

B. Designing of Information Platform

The data are the core and basis of ASCM. The potential of using these data will reach its full extent when suitable collecting and transmitting technology and method are developed. So, the main function of information platform of ASCM is to improve the speed and precise of data collecting, ensure the reliable and seamless transmission, enhance the central process ability and advance intelligent service level of ASCM. According to the characteristic of agricultural information flow, from the side of technology, because of the attributes of overall sense, reliable transfer and intelligent process, IoT begins to become the main method of data acquisition and transmission and would become an important technology across the supply chain to collect, analyze, transmit and manage the whole data. IoT can comprise millions of networked embedded devices also called smart items; these devices are capable of collecting information about themselves, their environment, and associated devices and communicate this information to other devices and systems via the all-connecting internet. It can monitor vulnerable environments and prevent or limit natural disasters. In recent years, researchers have begun studying how to use IoT in agriculture. For example, many kinds of sensors have been produced for sensing agricultural objects, such as crops, animals, at the same time, by wireless network; the sensed data can be transmitted to Internet [12].

The information platform of ASCM based on IoT would be an integrated system that integrates all kinds of information which includes the agricultural production, purchase, warehousing, shipment, delivery and retail and realizes the information interchange between different phases. The core function is fast acquisition, seamless connection, reliable transmission and in-time search and trackback of information (Fig.6).

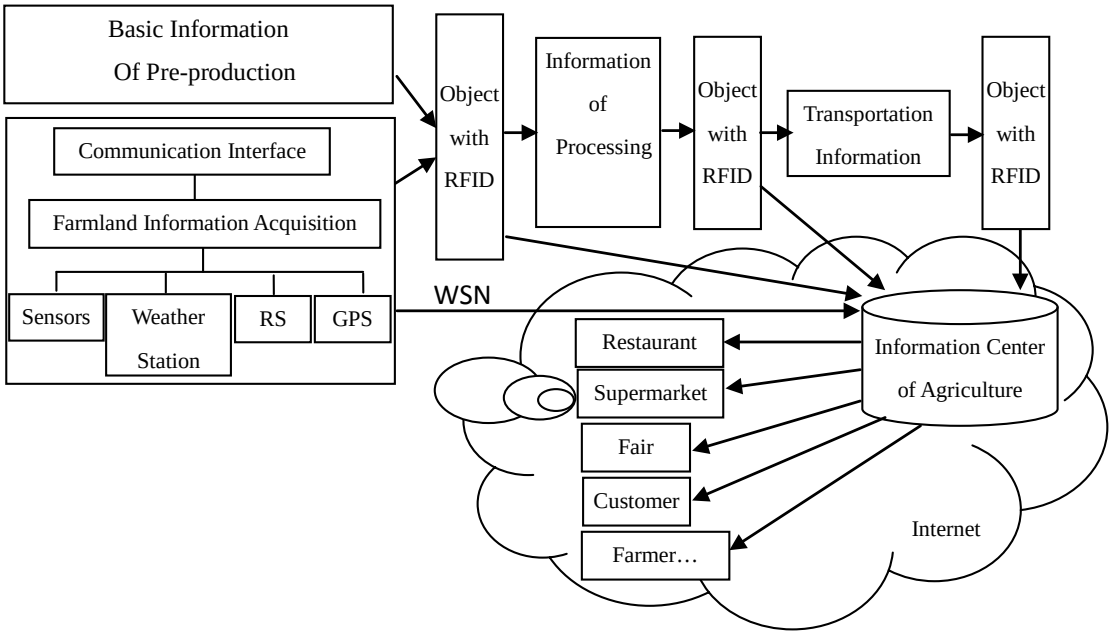

Figure 6. Information Flow of ASCM Based on IoT

1) Fast Acquisition of Data

The collection of data still proves a demanding task and directly affects the efficiency and quality of ASCM. Because of the multi-source of data, we should select different collecting technologies to acquire the data of different phases (Fig.7).

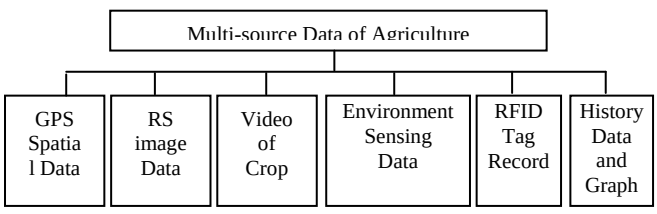

Figure 7. Acquisition of Multi-source Data

For example, during the stage of farmland production, for collecting the data of environmental factor, such as factors of soil (such as PH, CEC, humidity, electrical conductivity etc.), factors of climate (such as temperature, illumination, wind speed etc.), we can deploy different kinds of sensors (such as Temperature Sensor, Moisture Sensor) according to the farmland' attribute of geography and crop's attribute of growth. During the deploying of sensors, we should think of that the in-time dynamic changing of farmland environment would interfere with the transmission of radio signal and diminish this affection as far as possible; for acquiring the environment data of crop's growth, we can deploy web-cam for capturing the image or video of crop's growth, and deploy weather station for getting the environmental climate data of farmland; for acquiring the geographic

information of farmland, we can use GPS to measure geographic location such as, provide data on location in terms of latitude, longitude and altitude of farmland. In addition, airborne data collection systems through RS technologies, such as aerial photographs and satellite remote sensing provide periodic land use, land cover and other thematic information [10].

During the stage of processing and transportation of products, for tracking products status and identify every product, we can use RFID technology. RFID is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. RFID will start linking up the supply chain from the farm gate to the restaurant plate – and every point in between. The RFID tag is dimensioned to approximate a size of an individual product and multiple such tags are deposited in a container of the product at the harvesting stage. At each product handling stage the tags are programmed with the time and location of the event as well as any other attributes relevant to the handling process. Therefore, the entire history of crop handling is stored in the tags and can be detected and identified automatically at any time.

2) Reliable Transmission of Data

In the ASCM, the reliable flow of information is very important for track, manage, collaborate and plan the production of agricultural products. In the part of data process and transmission, the main function is to ensure that the information from different intelligent devices can be reliably transmitted to different users through network infrastructure, such as mobile communications network (such as GSM, GPRS, TD-SCDMA), wireless sensor network (such as ZigBee), and satellite communication network etc.

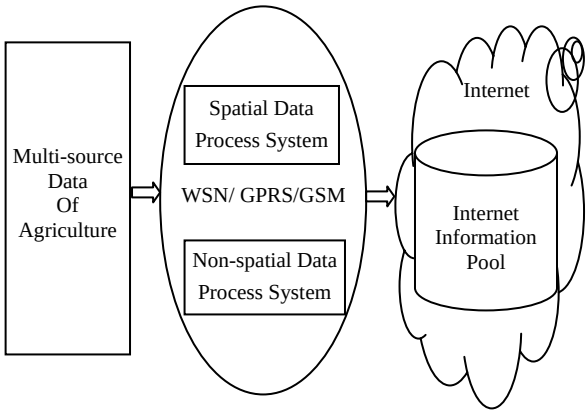

Figure 8. Transmission of Multi-source Data

In the technological system of data transmission, WSN is one of the most suitable technologies for capturing real world data. WSN is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an agricultural administrator the ability to instrument observe, and react to events and phenomena in a specified environment. In addition, connecting WSN to the Internet can standardize contextual data and make them can be shared with other entities, and can analyze these data, take decisions in remote premises, and finally implement these decisions back in the real world through sensors [14].

3) Constructing the Information Center of Agriculture

The purpose of modern ASCM is to improve the level of agricultural information process and enhance the intelligent management and decision of agricultural production. For improving the using efficiency of information, we should use different technology and method to process, analysis, merge, classify and statistic multi-data and create public database and special database, spatial database and relationship database etc. for different users. For example, we can use GIS to store, manage and analyze geographical reference data, and use relationship database to analysis non-spatial data, and use data mining to analyze data from different perspectives and summarizing it into useful information, and use SPSS to realize different statistics of data.

Finally, for further improving the efficiency of on-line analysis and process, the technology of cloud computing has been used. Using the intelligent cloud computer platform can ensure that enormous information of internet are real-time analyzed, processed, managed and controlled and create an efficient and reliable decision service system for the high level management and large-scale industry application. In addition, following the application of service-oriented architecture (SOA) in different industrial infomationization and internetization, many experts begin to research how to realize the application of SOA in agricultural field. Specially, for ASCM, it is consumer-oriented and aims at coordination of different production sub-processes, a system based on a SOA will package functionality as a suite of interoperable services that can be used within multiple separate systems from several business domains. So using SOA can not only improve the level of infomationization, internetization and intelligentization of ASCM, but also enhance the level of service of ASCM.

SUMMARY

Technological innovation and competition have led to improvements in supply chain management for agricultural products. Yet, global market standards are stringent. Consumers demand safe and nutritional food, excellent quality and just-in-time delivery. So, collaboration between trade partners has become increasingly important for the success of cross-border trade in the competitive market. Agricultural supply chain management is a powerful tool to achieve this collaboration. Through supply chains, producers in developing countries and emerging economies can access market information and knowledge to hone their value-added activities. However, developing cross-border supply chains is very complex, and requires a lot of information and expertise about how to build chains, as well as communication and commitment from all the chain partners. Specially, for the ASCM, the research of integrated information platform is the key of improving level of ASCM. The developing of information acquisition and process technology mainly depends on

the development of modern Information Technology, such as computer technology, electronics, satellite navigation technology, RS, sensor technology and network technology etc. In the developed countries, agriculture automation has been applied widely, and the degree of agriculture informationization and networking has attained a very high level. But in China, as a developing country, the research of agriculture informationization still belongs to the beginning level. However, following the occur of IoT, it will advance the developing of digital agriculture, and the research of intelligent agriculture based on IoT will create a huge intelligent agricultural production and supply network and connect the entire farm, farm villages and trade market of a big city such as Beijing together. It can not only improve the quality of agricultural product, the efficiency of agricultural production, the level of agricultural product supply, but also efficiently solve the emergent dispatch of food in special situation.

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