# Smart Agriculture Based on Cloud Computing and IOT

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***Abstract***

*Issues concerning agriculture, countryside and farmers have been always hindering China's development. The only solution to these three problems is agricultural modernization. However, China's agriculture is far from modernized. The introduction of cloud computing and internet of things into agricultural modernization will probably solve the problem. Based on major features of cloud computing and key techniques of internet of things, cloud computing, visualization and SOA technologies can build massive data involved in agricultural production. Internet of things and RFID technologies can help build plant factory and realize automatic control production of agriculture. Cloud computing is closely related to internet of things. A perfect combination of them can promote fast development of agricultural modernization, realize smart agriculture and effectively solve the issues concerning agriculture, countryside and farmers.*

**Keywords***: Cloud Computing, Internet of Things, Smart Agriculture, Virtualization, Agricultural Information Cloud*

## 1. Introduction

Cloud computing and internet of things (IOT) are two hot concepts newly emerged since the 1960s. They are the hard-core of information technology industry of the new generation. Not long after the President of the United States Barack Obama put forward the concept of "smart planet" in 2009, Premier Wen raised the development idea of "sensing China", which mainly emphasized the development of IOT and strategic new industries [1]. IOT is closely related to cloud computing in a way that IOT obtains powerful computing tools through cloud computing and cloud computing finds the best practicing channel based on IOT.

China is a typical agricultural country with productivity of rice, pork, fruit, fresh water product and many other foods ranking first in the world. Agriculture, rural area and farmers are of particular importance when it comes to socialist modernization reform. Our ability to handle these three problems properly has a great bearing on China's development for the future.

## 2. Cloud Computing

Wikipedia defined cloud computing in this way: Cloud computing is a kind of computing method based on the internet, which enables shared software and hardware information to be delivered to computers and other equipment on demand. The end users do not need to know basics of the "cloud" or have professional knowledge concerning this, or control directly. All they need to know is what kind of resource they actually require and how to receive relevant service through the internet [2]. Cloud computing describes a new way of adding, using and exchanging IT service based on the internet which involves providing dynamic, expandable and most of the time virtualized resources by using the internet[3]. Generally speaking, cloud computing has the following five features: on-demand service, internet access, resource polling, rapid elasticity and calculability.

## 3. Iot

Wikipedia defined IOT in this way: put sensors in electricity grid, railway, bridge, tunnel, road, building, water supply system, dam, oil and gas pipes, appliance, etc., and connect the internet, so as to operate certain programs and realize remote control. The central computer can

realize concentrated management and control of machine, equipment and personnel based on the internet and improve production and life through more detailed and dynamic means. This is useful for integration and harmony between human society and the physical world and is regarded as the third wave of information industry development following computer and internet [4]. Major IOT technologies include radio frequency identification technology, sensor technology, sensor network technology and internetwork communication, all of which have been involved in the four links of IOT industrial chain, namely, identification, sensing, processing and information delivery[5].

IOT is an intelligent technology which includes identification, sensing and intelligence. Life and even intelligence of life it self can also be regarded as part of IOT technology. It is used in pattern identification fields like measurement and computing as well as computer and communication fields like sensing, communication, information collection and processing[6-9]. The definition of IOT changes as the time of cloud computing comes. It is now defined as IOT =cloud computing + ubiquitous network + intelligent sensing network. Cloud computing management platform is the “brain” of cloud computing and relevant data. It involves management of accession of cloud computing customization application by users of this IOT, computing and processing what is involved in customization service; organizing and coordinating service nodes in the data center. Ubiquitous network includes 3G, LTE, GSM, WLAN, WPAN, WiMax, RFID, Zigbee, NFC, blue tooth and other wireless communication protocol technology. It also includes optical cable and other wire communication protocol and technology[10]. The principle of cloud computing for IOT is shown in fig 1.

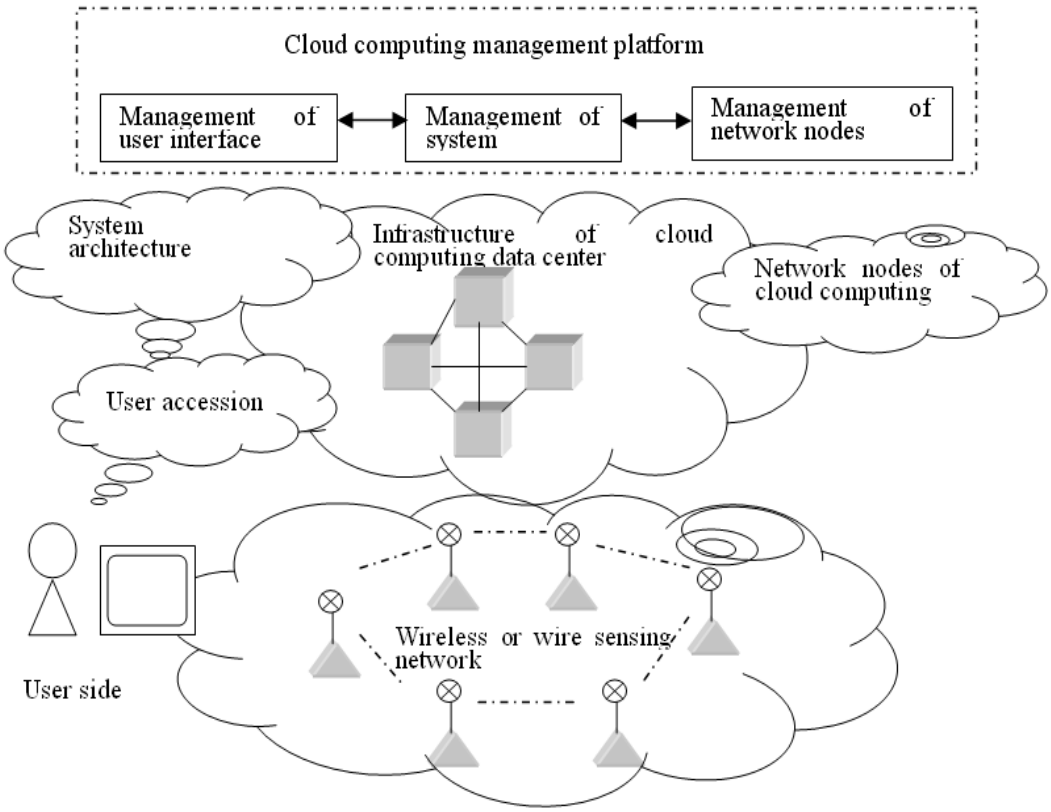


**Figure.1** The principle of cloud computing for IOT

# 4. Smart agriculture

## 4.1 Agricultural informationization

While world agriculture is undergoing industrialization, it is important to develop agricultural informationization at the same time. Agricultural informationization has become the trend of development for world agriculture. As far as China's agricultural development is concerned, agricultural informationization is a major force promoting agricultural development and transformation and a corner stone for maintaining sound and sustaining economic development. In recent years, we have been focusing on agricultural information service and infrastructure development. After years of hard efforts, remarkable results have been seen in agricultural infrastructure development, like "Every Village" project of Ministry of Industry and Information, "Golden Agriculture project" and "Three Dian Project" (computer, TV and telephone network coverage in rural area) of Ministry of Agriculture. These infrastructure provided foundation for agricultural information service. However, problems still exist in China's agricultural information. For example, we put more emphasis on hardware than software and can not provide high quality information to meet production needs of farmers. Moreover, information is not sufficiently used by farmers and the effect of information on agriculture, famers and rural area is not that notable.

To change this situation and promote fast development of agricultural informationization, it is necessary to use cloud computing and visualization technology to construct "agricultural information cloud"[11], combine IOT technology and RFID technology, so as to realize smart agriculture.

## 4.2. Construction of agricultural information cloud based on cloud computing

**4.2.1 Architecture of agricultural information cloud:**The architecture of a agricultural information cloud technology consists of four layers: physical resource layer, resource pool layer, management of middleware layer and SOA[12] construction layer, as shown in Fig.1. The physical resource layer include various kinds of resource servers, memories, internet facilities, database and software in relation to agricultural information; the resource pool layer builds a large amount of resources of the same kind into isomorphic or approximate isomorphic resource pools, like computing resource pool and data resource pool. The construction of resource pool can be regarded as integration and management of physical resource, the main purpose of which is to integrate isomeric agricultural information resources into resource pools of the same kind, so as to create a basis for synergy. Management of middleware layer is the core for agricultural information cloud. It is responsible for management of cloud computing resources and dispatching of various kinds of tasks, so that resources can serve application with higher efficiency and security; the SOA construction layer encapsulates cloud computing capacity into standard Web Services and incorporate them into SOA system for management and using, including service registration, searching, visiting and constructing workflow for services. The management of middleware layer and resource pool are key parts of cloud computing technology. The function of SOA construction layer, to a large extent, relies on external facilities[13].

### 4.2.2 Application of agricultural information cloud:

(1) Cloud computing in planting management

By using cloud computing database, information management of specific processes of plant production becomes possible and this allows cloud computing management of relevant records and storing of data related to production performance shown by individual plant and plant groups, analyze and compute, make production plans, etc. This include automatic analysis of key problems occur in specific process of production, like analysis of potential management defects, measurement and analysis of productivity and property based on productivity curve.

(2) Cloud computing in estimation of productivity effect and management measures

Cloud computing estimates productivity effect of plants with production function constructed by using computer simulation and mathematic modeling. For example, scientists use random model and computer simulation technologies to estimate the benefit of various management strategies adopted in different growing processes of key plants.

(3) Cloud computing in tracing and control of farm produce security

By using information technology of computer network, cloud computing is able to build a tracing system for regional farm produce, thus enhances security monitoring of farm produce "from farm to dinning table" and realize certification of pollution-free farm produce and place of origin.

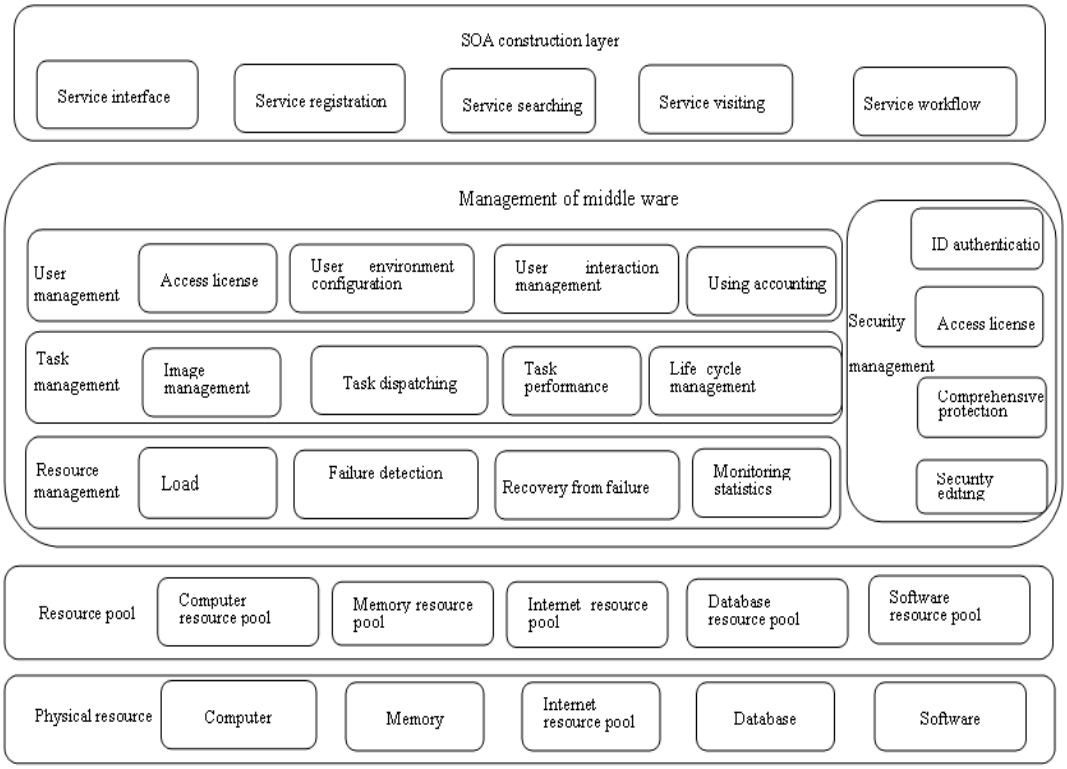


**Figure. 2** Architecture of agricultural information cloud

Cloud computing takes records of quality and security related information in selling and logistics process, like freezing and delivery, going to the market and being put on super market shelves, then uploads such information onto internet server.

Cloud computing takes records of security-related factors in the process of plant production, like information concerning the grower and the field, fertilization, management and environment of planting, disease prevention, etc. and produces electronic files of them.

Cloud computing enables consumers to find out the information in upper reaches of the products through computer network and enterprises to know where the products have gone to by using tracing system. This is of great significance in plant disease prevention, emergency response to food safety events and enhancing competitiveness of farm produce.

(4) Cloud computing in monitor of plant growing

Cloud computing is able to identify the growing of plants by using pattern identification technology and perform dynamic monitor of plant growing with help of other sensing equipment.

## 4.3 Construct plant factory based on IOT

IOT technology in terms of modern farm produce mainly consists of soilless culture and culture solution control technology, artificial photosynthesis technology, growing environment control

technology (carbon dioxide density, humidity, wind pressure and speed), intelligent irrigation technology, etc. IOT technology and method is used in farm produce production with plant factory technology as integration.

Plant factory is a highly efficient agricultural system that achieves continuous production of crops around the year through highly accurate control to environment within the facility. It uses computer to automatically control temperature, humidity, carbon dioxide concentration and culture solution of crops, so as to achieve labor-saving production of crops which are subject to no or little natural condition limitation[14]. In the production of plant factory, IOT serves the plant factory through "comprehensive sensing, reliable delivery and intelligent handling", which corresponds to the three layers of IOT, namely, sensing layer, delivery layer and control layer[5].

(1) The sensing layer mainly consists of environment testing sensor, biosensor, GPS and RFID, which work together for sensing of information in the production process. For instance, lighting sensor can show distribution of intensity of light in real time and video sensor can monitor the size of the plant, from which we can know the stage of growing, whether it is germination period, growth period or other growing periods. With spectral analysis of plant photos, we can get to know health condition of the plants in real time;

(2) The delivery layer is responsible for reliable delivery and the sensing layer collects information and delivers it to control layer and display terminal through delivery layer. In the process of delivery, 2G GPRS, 2.5G CDMA and 3G wireless broadband as well as multi-media techniques are used to achieve remote connection. For short-distance delivery, wireless communication technique developed from combination of non-contacting identification and various kinds of network techniques can be used. This technique can achieve fast and convenient wireless connection of equipment within a short-distance. WLAN802.11 and Bluetooth have been successfully used for such purpose. ZigBee technique fits small-size and low-cost wireless network, like wireless sensor network.

(3) The intelligent control layer consists of PDA, controller, regulation equipment and operating terminal. This layer achieves automatic of equipment in plant factory through comprehensively analyzing information, like intelligent irrigation system. The system can obtain and analyze weather information from the internet, including weather forecast in the previous days. After comprehensive analysis of such information, an irrigation parameter for irrigation plan can be obtained. Meanwhile, another irrigation parameter can be given according to ability of the soil in keeping water and soil after analyzing soil constitution. What's more, the system is able to collect and analyze temperature data obtained from the air and conduct systematic analysis on various conditions that might impact the growth of plants before giving parameters. Finally, an irrigation plan of a specific day is made based on these parameters. This can guarantee the right quantity of water needed by the plant and at the same time avoid too much water which might drown the plant and cause waste.

## 4.4 Smart agriculture

The control architecture of smart agriculture based on cloud computing and IOT is shown in Fig. 3. This data center[15] consists of control platform and database, and the platform further consists of such subsystems as agroecological environment control, agricultural resource control, production process control, farm produce and food safety, agricultural equipment and facility. Data center is a set of complex facilities. It includes not only computer system and other facilities go with it (like communication and memory system), but also redundant data communication links, environment control facility, monitor facility and various kinds of security devices. Data center architecture based on cloud network is shown in fig 4. Numbers in this diagram stand for flow of resource accession. Unitary and highly extendible data center network is good for concentrated servers and memory resources and can achieve better load balance and efficiency of use.

The agroecological environment control subsystem includes:

(1) Water quality monitoring, automatic improvement of water quality

(2) Accurate fertilization saves fertilizer

(3) Monitor soil constituent, soil humidity, light, wind, air, etc.

The agricultural resource control subsystem includes:

(1) Intelligent greenhouse that allows automatic adjustment of temperature

(2) Water irrigation that can automatically control flow and save water

(3) Scientific disease and pest monitoring

The production process control subsystem includes:
(1) Identification of individual animals allows healthy cultivation
(2) Monitoring of animal and plant growth
(3) Product sorting guarantees quality
Farm produce and food safety subsystem includes:
(1) Get informed of the entire logistics process
(2) Rationally arrange storage in warehouse
(3) Traceability system of farm produce supply chain
Agricultural equipment and facility system includes:
(1) Diagnosis of farm machinery breakdown
(2) Remote control of farm machinery
(3) Operation monitoring of farm machinery

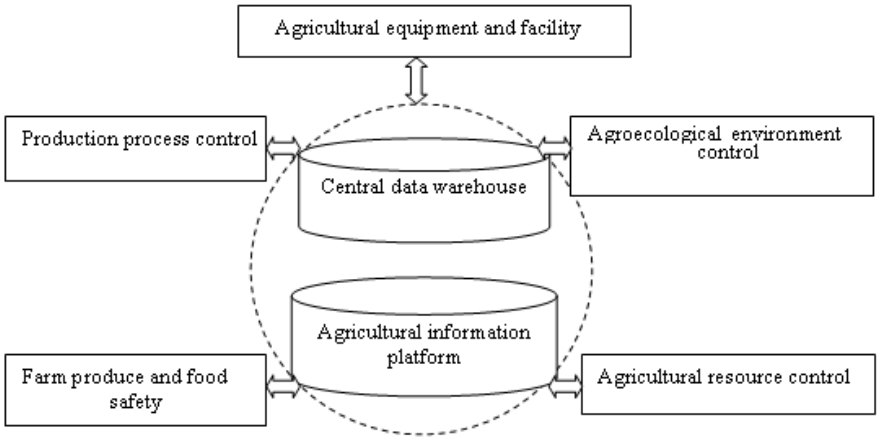


**Figure. 3** Control architecture of smart agriculture based on cloud computing and IOT

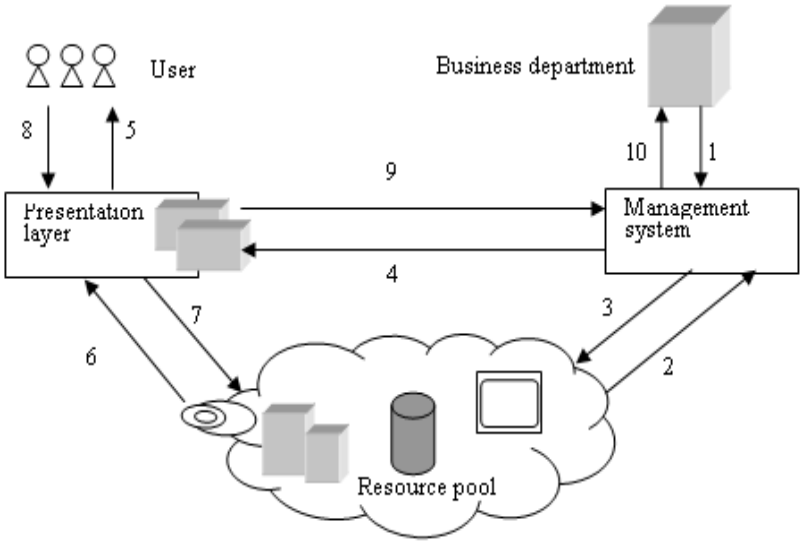


**Figure. 4** Data center architecture based on cloud network

## 5. Conclusion

IOT is closely related to cloud computing in a way that IOT obtains powerful computing tools through cloud computing and cloud computing finds the best practicing channel based on

IOT. Agricultural information cloud is constructed based on cloud computing and smart agriculture is constructed with combination of IOT and RFID. Hardware resources in agricultural information network are integrated into resource pool by using vitalization technology, achieving dynamic distribution of resource and balance of load, significantly improve efficiency of resource using. Large amount of data obtained by using radio frequency identification, wireless communication, automatic control, information sensing techniques of IOT are handled with agricultural information cloud, truly realizing smart agriculture.

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