Research and Application of Agricultural Greenhouse Intelligence Platform Based on IoT (Internet of Things) and Cloud Computing

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***Abstract* — Agricultural modernization is an important guarantee for the agricultural development in China. On the basis of deeply researching relevant technologies, the article aims at independently developing an innovative agricultural network platform based on IoT and cloud computing and with independent property right so as to not only establish a new agricultural production management system integrating data acquisition, digital transmission, data analysis and processing and CNC agricultural machinery, but also compensate for such disadvantages as the relative lag development of agricultural IoT core technology, the low integration of relevant agricultural information technologies, the insufficient maturity of corresponding software design and the shortage of agricultural information standards, thus to guide agricultural production management to be developed towards the following directions: low cost, reliability, energy conservation, intelligence and environmental protection, and improve the quality of agricultural productivity and agricultural products, as well as improve international competitiveness.**

Keywords - gateway matrix arrangement technology; agricultural iot software design module; cloud computing service; intelligent agricultural greenhouse

I. INTRODUCTION

Along with the deepening of global information technological revolution in this century and the construction of 3G network, IoT has been become one of the popular technologies in emerging high-tech industry, thus to be widely concerned by the people in this industry. IoT concept was firstly proposed by Professor Ashton of Auto-ID Center of Massachusetts Institute of Technology in 1999 in RFID research [1]. After being researched for several years, IoT has different definitions. In literature, IoT is defined as a network which adopts such information sensing equipment as RFID (Radio Frequency Identification) device, infrared sensor, global positioning system and laser scanner to connect any articles with Internet according to the specified protocol for information exchange and communication and which meanwhile adopts advanced cloud computing technology and super computer to collate and analyze mass data in order to assist people to make correct action decision in order to realize intelligent identification, positioning, tracking, monitoring and management [2]. As the largest development country in the world, China is also a traditional agricultural country and is currently in the transitional stage of agricultural construction, namely from traditional agriculture to modern agriculture.

In order to comprehensively practice the transformation of this new technical system, the application of IoT and cloud computing will play a key role in providing a new platform for the agricultural development in China and changing the development pattern of traditional agriculture [3].

II. RESEARCH ON AGRICULTURAL IOT SYSTEM ARCHITECTURE

Based on IoT and clouding computing technology, the article mainly aims at designing and implementing a set of agricultural greenhouse information intelligence production system consistent [4-5] with the Chinese agricultural characteristics. At present, a standard, open and extensible IoT system architecture has not yet been established for IoT technology and application. In IoT research and development report submitted by European intelligent system integration technology platform in 2009, IoT is classified in 18 types [6]. Therein, “IoT for agriculture and breeding industry” is one of the most important development directions. According to the report, agricultural IoT includes three layers: information perception layer, information transport layer and information application layer. However, such layered model is too rough to be favorable for guiding the practical specific construction of IoT. Therefore, on the basis of the theoretical research on IoT and the practical application, the system architecture of IoT is necessarily supplemented to refine the functions at each layer, and the system architecture of the whole system is as shown in Fig. 1 [7].

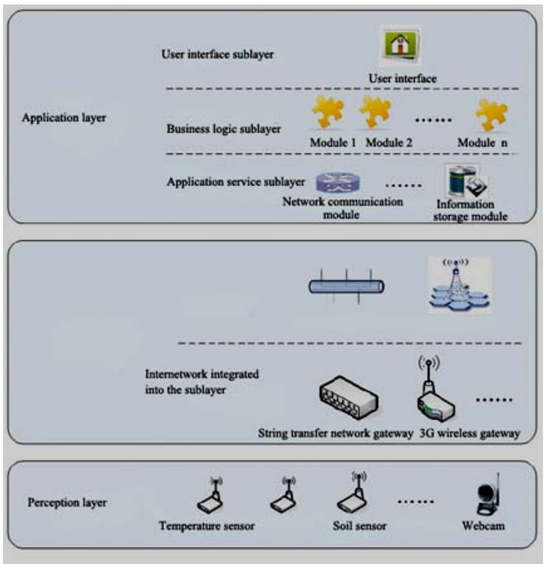

Figure 1. Architecture of IoT on agriculture

Information perception layer: located at the bottom of the whole IoT system, this layer is composed of various sensor nodes and has single functions, namely transmitting such parameters as soil fertility, crop growth condition, animal capacity, health and behavior for fine management in various supporting processes to IoT through advanced sensor technology.

Information transport layer: this layer is divided into internetwork access sub-layer and network sub-layer according to the functions completed thereby, wherein the internetwork access sub-layer, as an important object for IoT research, is mainly responsible for linking the perception layer and the transport layer and can be realized through two ways, namely gateway structure based on serial port access network and gateway structure based on wireless network; the network sub-layer is mainly responsible for completing data transmission tasks in traditional network, and the technology for this sub-layer is relatively mature. Additionally, the wireless network is very likely to become the development direction of agricultural IoT.

Information application layer: this layer includes various functions. Practice shows that unclear function classification during IoT construction can usually cause such system problems as poor flexibility, short duration and expansion difficulty. Based on investigation and lots of tries, this layer is divided into application service sub-layer, business logic sub-layer and user interface sub-layer, wherein the application service sub-layer may be the sharing part for system development in future and can include network communication module, information storage module, etc.; the business logic sub-layer is the core part of the whole application development, and due to the complicated demands of agricultural IoT, it is suggested to adopt module design for this sub-layer in order to improve the reusability and the use flexibility of the modules; the user interface sub-layer, located at the top of the whole system, is the interface for man-machine interaction and external communication [8].

III. System Design And Technological Characteristics

Innovative tries for the design of various layers have been carried out on the basis of deeply researching the system architecture of agricultural IoT, and the achievements are as follows:

A. Gateway of Wireless Iot and Technology of Matrix Arrangement

As everyone knows, the perception layer and the transport layer at the lower part of the whole system are the foundation of the system and the guarantee for the normal operation of the whole IoT. In the article, gateway of wireless IoT and technology of matrix arrangement are proposed according to wireless sensor network and agricultural greenhouse characteristics. According to the technical scheme as shown in Fig. 2, the system is composed of IoT gateway, wireless intelligent sensor, wireless control module and hollow routing equipment. In following figure, the gateway as the core of the system is mainly responsible for receiving the collected information uploaded by the perception layer and controlling the equipment in the greenhouse according to relevant instructions, and for communicating with traditional network according to MODBUS protocol, and actually acts as a connection link; each sensor is mainly responsible for collecting corresponding environment information and providing routing function as follows: when one sensor has difficulty in communicating with gateway, this sensor can indirectly transmit the data to the system gateway through adjacent sensors, and in this way, the reliability of the whole system is invisibly increased; the control module can turn on or turn off corresponding equipment according to the gateway instructions; the hollow router can act as a bridge when the gateway fails to directly communicate with sensors or control modules, thus to ensure that there is no communication blindness in the whole system.

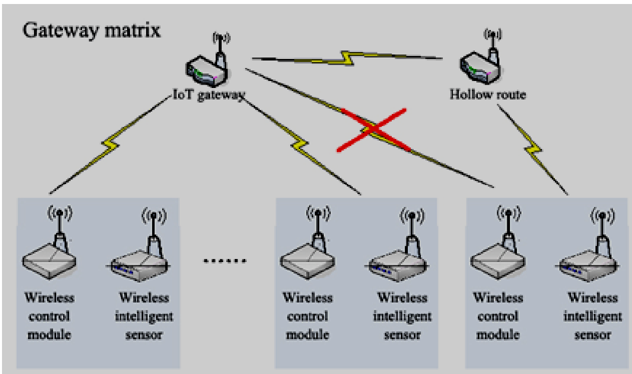

Figure 2. Gateway of IoT and its technology of matrix arrangement

Additionally, the use of the technology has following advantages:

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(1) The sensors can theoretically realize 32-path transmission. In the past, one greenhouse needs several sensor collecting devices, but now, one sensor can transmit multi-path collected data, thus significantly reducing the number of the sensors used in the project and accordingly reducing cost;

(2) Adoption of wireless control module: at present, the control module with wired serial port is relatively mature, the wired communication is relatively reliable, but the wired communication can increase wiring burden, and due to the complicated geographical conditions in farmlands, the cost will be further increased; additionally, the wireless communication does not have any wiring expenses, thus significantly reducing cost;

(3) 64-path gateway of wireless IoT and the technology of matrix arrangement: on the one hand, the gateway adopted thereby can access 64-path collecting and controlling equipment, so one gateway can be used to directly monitor dozens of greenhouses, thus to reduce the number of the gateways used in the system and meanwhile reduce cost; on the other hand, the use of the technology of matrix arrangement can make wireless communication more reliable, and this is particularly important for wireless control module [9].

(4) The gateway designed thereby for IoT not only has passive server requesting mode, but also has “pushing” data client mode, and the latter mode lays a foundation for the connection of IoT and cloud computing service.

At present, this scheme has been realized in several agricultural bases and has also obtained good effect, thus basically realizing the large-scale group measurement and control functions while meeting the practicability and feasibility requirements for construction cost and user experience.

B. Design Model for Application Layer of Agricultural Iot Based on Loose Coupling Layering Technology

According to agricultural production demands and modern software design idea, the application layer in the system is divided into application service sub-layer, business logic sub-layer and user interface sub-layer. Meanwhile, corresponding functions and external interfaces are abstractly defined for each sub-layer, so each sub-layer can be independently developed in any language and the uniform interface can be used for the communication between sub-layers. At present, such inter-process communication technology as shared database and operating system calling is used for the communication between sub-layers. Additionally, the business logic sub-layer is also developed in plug-in form according to different modules in order to be added to the system like “building blocks”. Such design idea can solve the following problem :

(1) IoT technology is continuously developed, especially the integrating technology of the perception layer and the transport layer, but for cost consideration, it is inadvisable to allow the change of the above part to generate global influence and reset the whole system. Therefore, the network communication module shall be designed as an interface in order to abstractly define the logic functions and external interface for the module. The new integrating technology may have different specific communication methods, but if it is compatible with the standard external interface, there is no need to modify the programs of other parts, namely making the business logic realization irrelevant to network integrating technology.

(2) Due to the wide application of agricultural IoT, the demands of different regions or the demands of a same region during different periods may be significantly changed. In consideration of system performance and development cost, the system shall be made into plug type business logic modules in order to have good flexibility. Like this, the system will have great flexibility and extensibility and the system functions can be freely added or deleted in future according to demand, cost, performance, etc.

(3) Due to the adoption of inter-process communication technology, each layer can be developed in different languages to increase system compatibility and meanwhile improve development efficiency.

The overall software design architecture obtained from practical work including this design idea is as shown in Fig. 3:

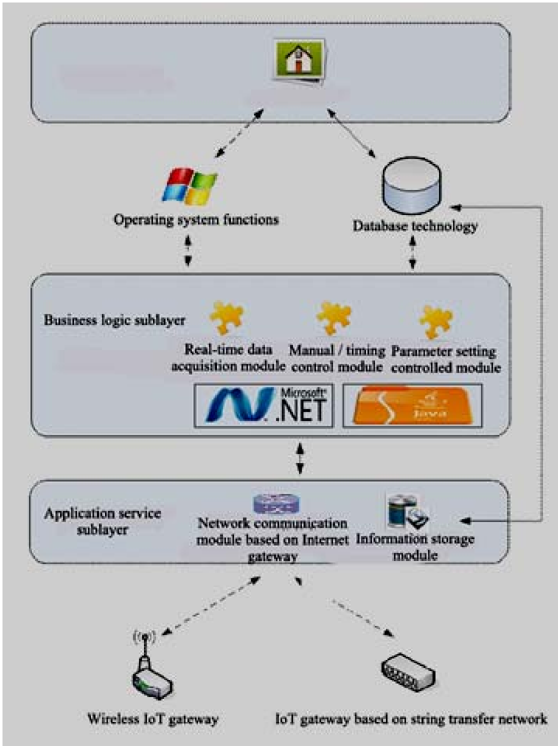


Figure 3. A software design model for application

Use of virtualization technology and cloud platform for establishment of agricultural greenhouse intelligence application platform

The first main problem regarding cloud service access lies in the communication between the gateway of IoT and cloud server. In general condition, cloud server has one real IP address, and if the gateway also has a corresponding real

IP address of public network, then such communication will be simple. However, it is unpractical to allocate one real IP address of public network for each gateway, and accordingly most of IP addresses on the gateway are virtual addresses, namely LAN home addresses. In this way, the cloud terminal cannot actively send data request to the gateway to obtain relevant data. As we know from the previous part of the article that the gateway of IoT designed in the system has active "pushing" data client mode, so the gateway can actively communicate with cloud service system, or upload data, or wait for the cloud terminal to issue equipment control instructions through various Internet access modes (optical network access, 3G wireless network access, etc.). On the other hand, by virtue of the dedicated cloud platforms established by three major mobile operators, it is feasible to rent the virtual machines in these cloud platforms, then use some virtual machines for advanced application, data service, system maintenance and web issuing and use other virtual machines for programming in order to obtain the data "pushed" by the gateway of IoT and meanwhile store them at the cloud platform as well as issue corresponding control instructions to the gateway [15]. At present, data collection and statistics as well as the remote control service for greenhouse equipment, etc. have been completed in the cloud service platform, and meanwhile suitable interfaces are reserved for future development in order to derive more agricultural production services on this basis, such as plant growth process analysis, agricultural expert system, agricultural data mining service, etc.. The architecture of the cloud service platform for agricultural greenhouse based on virtual machines is as shown in Fig. 4.

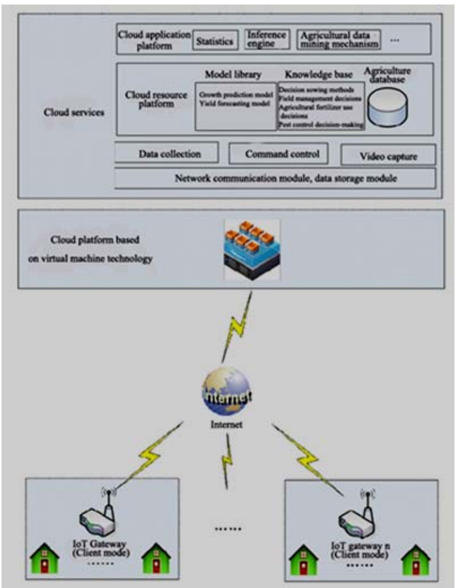


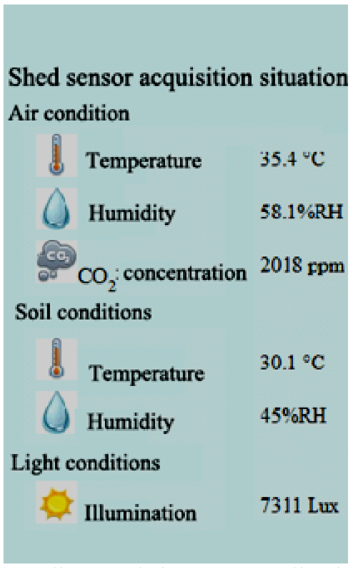
Figure 4. Cloud service platform based on virtual machine technology

IV. SYSTEM REALIZATION

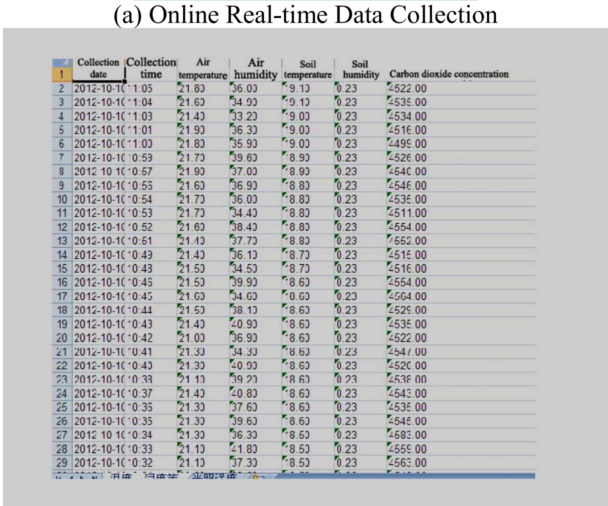
At present, the realized functions include:

(1) Data Collection Function

Such influence factors as temperature and humidity, illumination, wind direction and speed, CO2 concentration, soil moisture and temperature and other soil information can be collected for the greenhouse. The realization effect is as shown in Fig. 5 (the data are obtained by the all-weather monitoring on the solar greenhouses of Tianjin Academy of Agricultural Science, wherein various environment parameters are collected and stored in database every 1~2 minutes for each greenhouse), and different data views can be generated according to different production demands, and these data views not only can be online displayed in a real-time manner, but also can be offline automatically generated into relevant Excel files. Meanwhile, statistical analysis can be carried out for the data in order to predict the development tendency of various parameters, which can be provided to the agricultural personnel as decision reference.



(a) Online Real-time Data Collection



1	Collection date	Collection time	Air temperature	Air humidity	Soil temperature	Soil humidity	Carbon dioxide concentration
2	2012-10-1	1:05	21.80	36.00	9.10	0.23	4522.00
3	2012-10-1	1:04	21.60	34.90	9.10	0.23	4535.00
4	2012-10-1	1:03	21.40	33.20	9.00	0.23	4534.00
5	2012-10-1	1:01	21.90	36.30	9.00	0.23	4516.00
6	2012-10-1	1:00	21.80	35.90	9.00	0.23	4499.00
7	2012-10-1	0:59	21.70	39.60	8.90	0.23	4526.00
8	2012 10 1	0:57	21.90	37.00	8.90	0.23	4540.00
9	2012-10-1	0:55	21.60	36.90	8.80	0.23	4546.00
10	2012-10-1	0:54	21.70	36.00	8.80	0.23	4535.00
11	2012-10-1	0:53	21.70	34.40	8.80	0.23	4511.00
12	2012-10-1	0:52	21.60	38.40	8.80	0.23	4554.00
13	2012-10-1	0:51	21.40	37.70	8.80	0.23	4552.00
14	2012-10-1	0:49	21.40	36.10	8.70	0.23	4515.00
15	2012-10-1	0:48	21.50	34.50	8.70	0.23	4516.00
16	2012-10-1	0:46	21.50	39.90	8.60	0.23	4554.00
17	2012-10-1	0:45	21.60	34.60	8.60	0.23	4564.00
18	2012-10-1	0:44	21.50	38.10	8.60	0.23	4529.00
19	2012-10-1	0:43	21.40	40.90	8.60	0.23	4535.00
20	2012-10-1	0:42	21.00	36.90	8.60	0.23	4522.00
21	2012-10-1	0:41	21.30	34.30	8.60	0.23	4547.00
22	2012-10-1	0:40	21.30	40.90	8.60	0.23	4520.00
23	2012-10-1	0:38	21.10	39.20	8.60	0.23	4538.00
24	2012-10-1	0:37	21.40	40.80	8.60	0.23	4543.00
25	2012-10-1	0:36	21.30	37.60	8.60	0.23	4535.00
26	2012-10-1	0:35	21.30	39.60	8.60	0.23	4545.00
27	2012 10 1	0:34	21.30	36.30	8.50	0.23	4583.00
28	2012-10-1	0:33	21.10	41.80	8.50	0.23	4559.00
29	2012-10-1	0:32	21.10	37.30	8.50	0.23	4563.00

(b) Offline Historical Data Query

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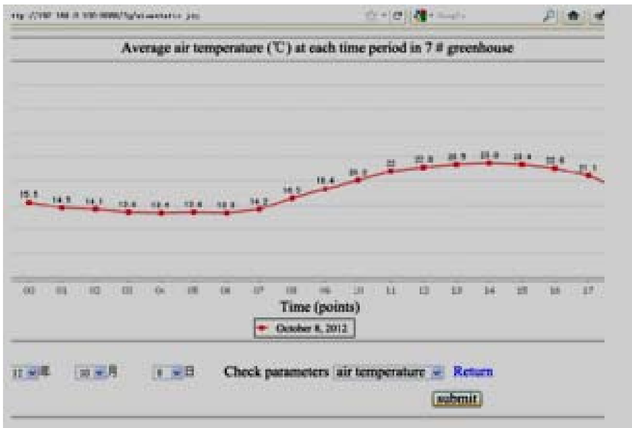

(c) Statistical Analysis for Data

Figure 5. Different display formats of collected data

(2) Remote Automatic Control Function

As proposed in literature, intelligent agriculture shall be a closed-loop system with the intelligent control of the agricultural large system as the core. Besides that the draught fan, the external sunshade curtain, the internal overshadow curtain, the light filling lamp, the water curtain, the sun roof and other relevant equipment in the system can be manually and timely controlled, the strict plant environment closed-loop control system based on loop command list technology is particularly designed and implemented in order to store the parameters set by operators into the command list for loop execution as follows: when the environment condition can be met, the preset action can be activated to automatically control the environment. The working process is as shown in Fig. 6.

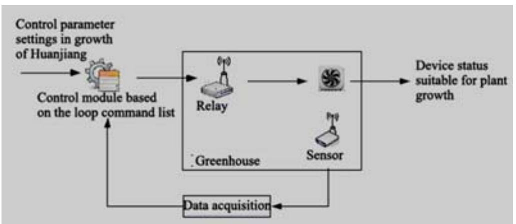

Figure 6. Strict plant environment closed-loop control system based on loop command list technology

(3) Real-time high-definition video monitoring and image capture: the system can monitor the greenhouse conditions in a real-time manner and meanwhile periodically store the high-definition image information for the greenhouse in order to facilitate the agricultural experts to remotely diagnose plant diseases and insect pests.

V. Conclusions CONFLICT OF INTEREST ACKNOWLEDGMENT

In allusion to the problems and shortcomings existing in Chinese agricultural IoT, the article aims at supplementing and perfecting the theory of agricultural IoT on the basis of the in-depth practices in order to further propose a practicably feasible agricultural greenhouse intelligence system design scheme based on IoT and cloud service technology. At present, the scheme is basically successfully implemented and has smoothly passed the expert testimony organized by Tianjin Municipal Science and Technology Commission in 2012 to be identified to have internationally advanced level. In future, expert system technology and data mining technology will be further used for researching agricultural plant growth process model in order to actually realize the intelligent production management for crops.

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