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Internet of Things Monitoring System of Modern Eco-Agriculture Based on Cloud Computing

SHUBO LIU[1], LIQING GUO[2], HEATHER WEBB[3], XIAO YA[1], AND XIAO CHANG[4]
[1]Business School, Central University of Finance and Economics, Beijing 100081, China
[2]Chinese Academy for Environmental Planning, Beijing 100012, China
[3]Higher Colleges of Technology, Dubai Men's College, Dubai 25035, United Arab Emirates
[4]China Land Surveying and Planning Institution, Beijing 100035, China

Corresponding author: Heather Webb (hwebb@hct.ac.ae)

ABSTRACT In order to enhance the efficiency and safety of production and management of modern agriculture in China, problems, such as the quality and safety of agricultural products and the pollution of the environment from agricultural activities, should be unraveled. Based on the new generation of information technology (IT), an integrated framework system platform incorporating the Internet of Things (IoT), cloud computing, data mining, and other technologies is investigated and a new proposal for its application in the field of modern agriculture is offered. The experimental framework and simulation design suggest that the basic functions of the monitoring system of the IoT for agriculture can be realized. In addition, the innovation derived from integrating different technologies plays an important role in reducing the cost of system development and ensuring its reliability as well as security.

INDEX TERMS Management system, modern agriculture, big data, cloud computing, Internet of Things (IoT).

I. INTRODUCTION

The current technological era of promoting and adopting information technologies is the economic and industrial foundation in regenerating China. Agricultural information, as a part of China's information construction, refers to the application of computer science and technology, mobile communication technology and LAN (Local Area Network) communication technology, microelectronics technology, sensor technology, and embedded technology in the process of agricultural production management. The application of agricultural IT can effectively resolve problems such as low management efficiency and high production pollution, as well as significantly improve agricultural labor' financial gains. Thus, improving the development of agricultural informatization infrastructure works to narrow the development gap between urban and rural regions in China [1].

With the development of information technology and the continuous renewal of sensor technology, Internet of Things (IoT) technology is emerging fast. IoT as an extension of the Internet is able to connect any distant items with the Internet through information sensing devices such as RFID (Radio Frequency Identification), infrared sensors, GPS (Global Positioning System), laser scanners and so on in accordance with stipulated agreements for information exchange and communication [2]. Along with the advancement of IoT industry, there are integration and in-depth exchanges with other industries, such as in the field of industrial control, logistics, and financial equipment etc. Therefore, it can be expected that in the future, cross-industrial integration of IoT will increase and the applications of the IoT will become more prevalent in human lives. For this study, an environmentally friendly production mode for agriculture is designed by a simulation integrating IoT and surrounding technologies, such as cloud computing and big data.

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II. LITERATURE REVIEW

A. IoT, CLOUD COMPUTING AND AGRICULTURE

In-depth research on the IoT in the field of agriculture has been previously conducted. The interaction between IT and agriculture created new directions to agriculture. Liu and colleagues found that growing number of companies were investing in research and development (R&D) of the IoT technology in the United States (US) and embedding intelligence and sensors into their products. Farmers and agricultural labors in the US relied on IoT technology to solve a number of problems, such as natural disasters, livestock and poultry diseases, and pest's infection. Existing experiences proved that IoT performed well by effectively reducing farmers' losses [3].

Corcoran and Peter showed that because of the very limited farming land resources in Japan, more than half of Japanese agricultural population chose to apply agricultural IoT technology. The research also pointed that the Japanese government proposed that by 2020, the investment of agricultural IoT would be reaching the scale of 58 billion to 60 billion yen, while the use of the big data platform of the agricultural IoT will occupy 75% of the market. In the meanwhile, the Japanese government planned to use agricultural IoT platform to provide information and data services with agricultural robots. All such technologies could significantly restructure the traditional management mode and enhance the production efficiency of agricultural products [4].

Similar to the case of Japan, after studying cases from European and American contexts, Choumert found that, in developed economies, managers in agricultural production relied on satellite to monitor their land resources and send instant data to information fusion system for overall system analysis and real-scenarios information supported decision-making. In such way, it became possible for the overall planning of large regional agriculture to take place [5].

IoT adoption process can integrate advanced IT infrastructure facilities such as cloud computing. Cloud computing refers to data centers available to vast number of Internet user. Cloud computing-based monitoring system of modern agricultural IoT is expected to promote the development of modern agriculture through the establishment of a complete information system.

B. THE CASE OF CHINA

Based on fieldwork in China, Luong and Hoang found that the majority of the agricultural labor in China still rely on manual operation to carry out agricultural management activities. This mode of production and management features are done with low scientific and technological levels, and, more importantly, with low production efficiency. Nonetheless, benefits from the application of agricultural Internet of Things include reducing the cost of human resources in production activities and negative impacts on environment, and enhancing farmers' access to accurate crop land environment and crop growing information.

About a decade ago, China began to introduce IT into the agricultural industry, and actively drew on experiences from successful cases from developed countries. However, the limitations with benchmarking these cases is that each country has its varying natural environment and technological infrastructure, as well as societal/economic backgrounds, thus the introduction process needs to be carefully considered and further investigated [6].

Facing such challenges, China has allocated more resources on R&D in this industry, and has made an impact. Chen and colleagues claim that the establishment of the Joint Working Group on the IoT in 2010 represents a milestone of China's complete industrial system of the IoT. Moreover, the application of the IoT in agriculture has been developed: with the application of the IoT and its supporting and surrounding technologies, the agricultural soil environmental monitoring system has been widely applied in China [7]. Moreover, great progress has been taken place in a number of fields, such as data acquisition, transmission effective distance, fusion technology, gateway intelligent technology, terminal control and other aspects of intelligent agriculture front-end. However, the overall integration level of IoT and other technologies and fields remains low. It still needs ongoing efforts to achieve the mode of ''intelligent agriculture'' with IoT system and technologies in the process of agricultural production. Therefore, this study tries to bring implication for IoT application in agriculture by proposing and testing an inclusive IT based experimental process.

III. RESEARCH METHODOLOGY

This research is an exploratory and experimental in nature. It is done to focus on how China can increase IoT in their agricultural industry and rely less on humans. Therefore, the following section presents the methods uses to analyze and develop the IoT Agricultural system.

A. SYSTEM ANALYSIS AND SYSTEM DEVELOPMENT

The functional requirement analysis of the system includes the following contents. Water, fertilizer, heat, gas and other related data of agricultural production are collected through a number of different sensor devices. The data was then sent to the intelligent gateway through Zigbee wireless sensor network for further processing.

1) INTELLIGENT GATEWAY

An intelligent gateway is then designed through open source hardware raspberry pie, which uses cooperative information processing technology to process perceived data and send it to cloud platform after local caching. A small resource server is set up on the intelligent gateway, which maps equipment resources into Web Services conforming to Restful standards and provides services to the outside world. Based on the Web Service of equipment resources, some localized applications based on Intelligent gateway can be developed, such as sensor data monitoring, video monitoring, device control, etc. to realize redundancy and complement of the functions of cloud platform system. At the same time, some services that consume network resources, such as video surveillance, can run stably with low latency locally [8].

2) MULTI-PROTOCOL DATA TRANSMISSION

In the device and intelligent gateway end, the connection and data transmission can be carried out through Zigbee, WiFi, Bluetooth, USB and serial port. Meanwhile, in order to adapt to the limited resources of sensor devices, the gateway supports the Coap transmission protocol. For data transmission to the cloud, the cloud supports TCP/IP-based http, MQTT, and websocket application layer transport protocol [9].

3) STORAGE AND REAL-TIME MONITORING OF CLOUD DATA

After receiving the perceived data, the cloud processes and stores the data, and makes decisions on the data values according to trigger conditions. Cloud provides real-time data query interface through API (Application Programming Interface).

4) BIG DATA ANALYSIS AND DECISION-MAKING

Big data analysis, machine learning and other technologies need to be adopted by the decision makers in order to analyze and predict a large number of agricultural product price data, as well as the perceptual data obtained during the process of agricultural product growth.

5) MULTI-TERMINAL APPLICATION

Based on the abundant Web service provided by cloud platform, RIA (Rich Internet Applications) IoT monitoring system running on browser is developed, and the device status is inquired in real time. Sensor data is displayed by chart through visualization technology. The device can be remotely controlled, weather and agricultural product price can be constantly referred and viewed, and data analysis can be instantly conducted.

6) REVERSE CONTROL OF EQUIPMENT

In the IoT system, reverse control of equipment is more complex. To ensure the stability and security of control, while the equipment is in the LAN, the cloud cannot directly connect to the internal and external equipment through the Internet. The system uses MQTT (Message Queuing Telemetry Transport) protocol, sends control instructions to the equipment control gateway through encrypted data transmission mode, and verifies the instructions after the equipment gateway receives them and control terminal equipment [10].

The performance of the system needs to be open, highly concurrent, and secure. Therefore, the supporting features of the system should include mass storage, scalability and high timeliness.

B. SYSTEM FRAMEWORK DESIGN

Based on the above requirement analysis of the system, the functional structure design of the system divides the modern agricultural IoT monitoring system into six modules: intelligent gateway, equipment monitoring, agricultural product management, data information, big data analysis and decision-making, and user center, as shown in Figure 1.

As shown in Figure 2, the system architecture design is divided into four layers: perception layer, network layer, support layer, and application layer.

In this system, it is necessary to develop three functional modules: intelligent gateway in perception layer, cloud computing platform in support layer, and monitoring system of modern agricultural Internet of Things in application layer.

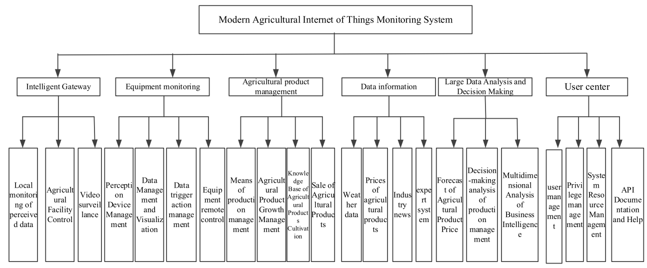

FIGURE 1. System functional structure.

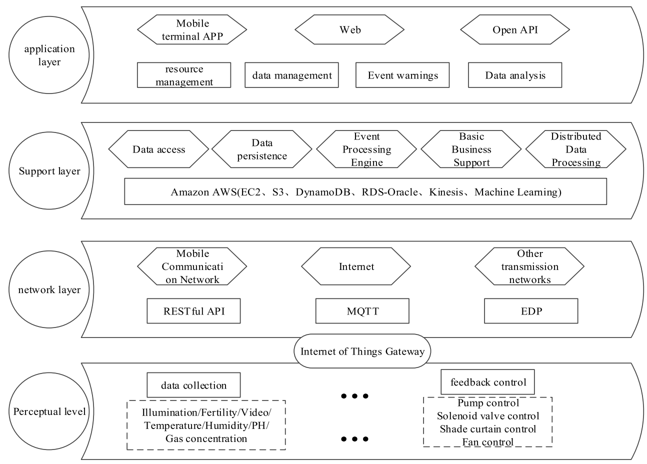

FIGURE 2. System architecture design.

Intelligent gateway in perception layer: Intelligent gateway of IoT is the link between sensor network and Internet communication network. In addition, the intelligent gateway has equipment management commands, which can send the control information to the gateway via remote or local applications. After the gateway verifies the commands, it is able to manage the related equipment. In the design, and in consideration of cost structure, stability, availability of system resources, development cycle, and system scalability, Raspberry Pi is selected as the hardware platform of the intelligent gateway of the Internet of Things and Raspbian as the software platform of the Gateway based on Debian. The sensor network inside the gateway adopts Zigbee sensor network.

For the cloud computing platform in the support layer, the stable and safe operation of IoT monitoring system requires good hardware and software foundation. Through the research of cloud computing platform, the AWS (Amazon Web Service) cloud service of Amazon is chosen as the software and hardware platform of IoT monitoring system. EC2 service in AWS service is used as virtual machine hardware platform for IoT system, and Ubuntu Server based on Linux kernel is used as operating system. The system uses S3, DynamoDB, Rds-oracle in AWS service as file storage and database, and Kinesis and Machine Learning as data analysis tools.

For the monitoring system of modern agricultural IoT in application layer, the application layer is composed of modern agricultural IoT monitoring system. On the basis of the system hardware and software resources provided by the support layer and the data and equipment resources provided by the intelligent gateway, IoT monitoring system is developed. The background of the system is mainly implemented by Spring MVC (Model View Controller) framework based on J2EE platform. By abstracting the related resources and functional logic of the system, Web Service based on Restful specification and Websocket service based on subscription mechanism are designed and developed, which can realize real-time access to perceived data, remote control of devices, data analysis and other operations. The RIA client based on WEB browser is developed on the service interface of related system resources and functions. The human-computer interaction with the monitoring system of agricultural IoT is realized through the web interface.

C. DATABASE DESIGN AND SCHEMA

The design of system database includes external design and structure design. External design: Because the recording volume of sensor data points in the system may be as high as 10 billion orders of magnitude per year, traditional relational database storage cannot meet the demand. At the same time, there are still a large number of relational data storage requirements in the system, such as sensor data points, agricultural product cultivation records, means of production and so on. Therefore, the modern agricultural IoT monitoring system adopts two hybrid storage schemes: Amazon DynamoDB NoSql database and Amazon RDS (Oracle) relational database. For Amazon DynamoDB, ORM framework Spring Data DynamoDB can be used to store and query data. For Amazon RDS (Oracle), Mybatis and Spring Stored Procedure are used to store and query data. Through Amazon's big data analysis tool Elastic MapReduce based on Hadoop platform, the system realizes the statistical analysis of a large number of sensor data, and transfers the analysis results to Oracle for user query.

Structural design: In the modern agricultural IoT system, equipment monitoring module and agricultural product management module are the main functions of the system. The main database table structure design of these two modules is given below.

The main technical framework of the system includes Spring Web MVC, ORM persistence layer framework, NoSql database Amazon dynamoDB, relational database Amazon RDS for Oracle, file storage Amazon S3, big data analysis Amazon EMR (Hadoop), instant messaging protocol MQTT, and RIA client framework Extjs.

The main functions of the system depend on the following eight points: establishment of development environment, integration of related frameworks, MyBatis-based functional interface, Stored Procedure-based PL/SQL functional interface, Spring Data DynamoDB-based functional interface, Paho-based Mqtt message sending and receiving, interface message signature verification, and the main functional interface of the system.

TABLE 1. Relevant tables of device monitoring module.

Name	Instruction	Subordinate database
T_DEVICE	System device table	ORACLE
T_SENSOR	Sensor device (data flow) table	ORACLE
T_DATA	Data point table	DynamoDB
T_DATA_AVG_1MIN	Statistical table of data points, take 1-minute mean	ORACLE
T_DATA_MAX_30MIN	Statistical table of data points, take the maximum value of 30 minutes	ORACLE
T_DATA_AVG_1HR	Statistical table of data points, take the mean value of 1 hour	ORACLE
T_SENSOR_TRIGGER	Data trigger action table setting table	ORACLE
T_SENSOR_TRIGGER_LOG	Data start action execution log table	DynamoDB
T_DEVICE_CMD_LOG	Device remote control log table	DynamoDB

TABLE 2. Tables of agricultural product management module.

Name	Instruction	Subordinate database
T_STOCK_ADD	Production material purchase table	ORACLE
T_STOCK	Inventory table of means of production	ORACLE
T_STOCK_CONSUME	Consumption table of means of production	ORACLE
T_CROP	Main table of crops	ORACLE
T_CROP_RAISE	Record table of crop cultivation	ORACLE
T_CROP_SALE	Record table of agricultural products harvesting and selling	ORACLE
T_CROP_KNOWLEDGE	Table of crop cultivation knowledge	ORACLE

IV. EXPERIMENTAL DESIGN AND PERFORMANCE EVALUATION

A. THE WORK-FLOW OF THE SYSTEM

The work-flow of the system is shown in Figure 3.

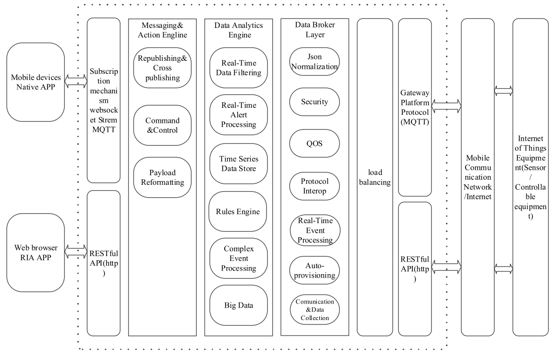

FIGURE 3. Work-flow of the system.

There are many sensors installed in the application of the agricultural IoT monitoring system. These sensors are connected by wireless sensor networks such as Zigbee or wired connection and the intelligent gateway of the Internet of Things, and the data collected by sensors are transmitted to the gateway. After processing these data, the gateway transmits these data to the IoT system platform through the wide area network such as mobile communication network or Internet. The data transmission between gateway and system platform adopts restful api based on HTTP or mqtt based on publish / subscribe mechanism. In order to take into account the security and efficiency of data transmission, two-level encryption mode is adopted for data and information transmission in the system. For interfaces requiring high transmission efficiency, low-level encryption mechanism is adopted. Apikey+time threshold value encryption is used as key for interface verification by using MD5 algorithm for the data interface, and data itself is not encrypted. For high-level security requirements, public and private keys are used to encrypt the data itself to ensure data security [11]. After receiving the data sent by the gateway, the system platform parses and validates the data through the data agent layer. After the data processing of the data agent layer, the data is sent to the data analysis engine. The data is further processed by preset events or rules. For instance, data are stored in the database persistently or triggering commands to control remote device management. From the application side of the system, users can realize on-line monitoring, remote control, intelligent data analysis and assistant decision-making of IoT device through web pages. Users use these functions of the system in their applications by calling the web service provided by the system. Web application servers, such as tomcat, distribute the requests to the message and action processing engine of the system after receiving the relevant requests sent

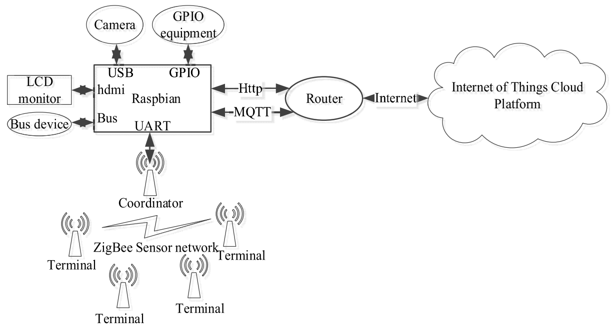

FIGURE 4. Overall structure of gateway.

by the user application, and invoke the related resources of the system according to the relevant request commands to realize the related functions provided by the system.

Cloud computing-based monitoring system of modern agricultural IoT expects to promote the development of modern agriculture through the establishment of a complete information system. The system collects environmental information and crop life information data of agricultural production through sensor network and collects them on the IoT gateway. The gateway processes and transmits the data to the IoT cloud platform system. The cloud platform system then diagnoses crop growth and analyses and processes environmental information by sensing data. Through the analysis and decision information obtained, it guides agricultural production and makes intelligent control of facilities to achieve the goal of agricultural modernization production.

B. SOFTWARE DESIGN OF SYSTEM INTELLIGENT GATEWAY

The hardware design of the system intelligent gateway uses the basic hardware platform, Raspberry Pi and Zigbee-based perception network.

IoT gateway is indispensable in the application system of IoT. As a link between perceptual network and traditional communication network, it needs access capability to multiple perceptual networks, data conversion capability between different protocols, fast access capability to the Internet, and control and management capability of perceptual devices. Combined with the cloud service platform provided by the modern agricultural IoT monitoring system, a multi-protocol compatible IoT gateway device is developed by using the open source hardware system "raspberry pi" with low cost, low power consumption, high performance and high scalability.

The raspberry pie is open source hardware, which is developed as a hardware platform without potential technical barriers and patent rights. At the same time, the raspberry pie has powerful computing power, abundant on-board resources, up to 40 GPIOs (General Purpose Input Outputs), low power consumption and low price, so it is used as the hardware platform of IoT gateway [12].

ZigBee is a low-power LAN protocol based on IEEE802.15.4 standard. ZigBee is translated as "Purple Bee", similar to Bluetooth. According to international standards, ZigBee technology is a short-distance and low-power wireless communication technology. It is characterized by short distance, low complexity, self-organization, low power consumption, and low data rate. It is mainly suitable for automatic control and remote-control field, and it can be embedded in a variety of devices. As a short-distance wireless communication technology, ZigBee has very strong applicability [13] in the field of IoT because its network can easily provide users with wireless data transmission function.

Raspberry pie gateway's operating system uses Debian-based Raspbian and Linux Kernel (the core of the operating system), but most of the basic operating system tools come from the open source GNU project, so they are also called GNU/Linux. It is the first Linux distribution to use package management system, making it easy to install and delete software. Debian GNU/Linux comes with more than 29,000 packages, which are pre-compiled and packaged in a good format for installation on a computer [14].

In addition to the open source operating system, the system gateway also uses a lot of open source software or library files. For the gateway hardware IO, I2C, SPI ports, RPI.GPIO and WiringPi are used; for UART ports, PySerial is used; for motion-based video surveillance, motion is used; for mqtt message transmission and analysis, paho-python is used; for web service framework, WebIOPi is used. In addition, many drivers of the system, http, shal and other modules or functions provided by python are also applied.

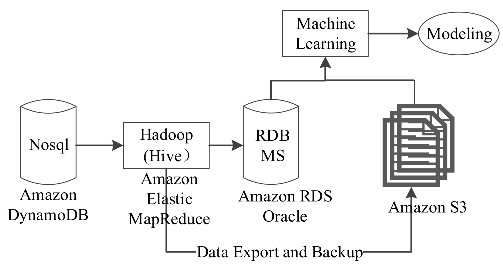

FIGURE 5. System big data analysis and machine learning process.

The overall architecture of the gateway is shown in Figure 5.

Video surveillance module is designed in the monitoring system of IoT of modern agricultural network. Through video surveillance, users can know the growth of crops remotely and real-time, and monitor the actual operation status of Internet of Things device. With the help of raspberry dispatch gateway's abundant expansion ability and strong computing ability, using USB high-definition camera and open source software motion, remote real-time video surveillance has been achieved. Combined with the simple platform made by stepping motor, the function of remote-control rotating camera is realized.

Motion's photos and videos are saved in the folder of the gateway by jpg and swf. These photos and videos are uploaded to Amazon S3 to save through the network. After the upload is successful, the local files are deleted to release the storage space. Users can view these photos and videos at any time through the Internet. The core code to implement this function can be referred in Appendix.

The remote control of equipment is an important function of gateway. The transmission of control message is realized by message based on mqtt protocol. After receiving the user remote control command, the server publishes the control message to the topic specified by the mqtt proxy server, and the gateway subscribing to the topic can receive the message immediately [15]. After the gateway receives the message, it parses and validates it. Then, it sends the message to ZigBee coordinator through serial port. The coordinator transmits the message to the terminal device through wireless network. The terminal device receives the message to parse and control the device.

V. DISCUSSION

A. CHOICE OF CLOUD COMPUTING PLATFORM

In the modern agricultural IoT monitoring system, the background of the system is built into an open agricultural IoT service platform, which provides data storage, big data analysis and processing functions, and also establishes a mqtt message service platform. The IoT platform belongs to the support layer of the hierarchical structure of the IoT. Based on this platform, users can develop low-cost, safe, stable and agricultural Internet of Things applications with big data analysis capabilities. To achieve these functions, the open IoT platform needs powerful computing resources, so cloud computing technology is chosen to develop the IoT service platform.

As early as the year of 2006, Amazon Co. launched its AWS cloud service, which was the largest and most competent cloud computing provider in the world. Based on its abundant cloud computing services, low cost, high security, flexible computing resource expansion capability, and multiple data centers around the world, it was selected as the basic cloud computing platform [16]. Amazon EC2 is a virtual server in the cloud and an IaaS (Infrastructure as a Service) service. It can adjust the hardware and software computing resources of EC2 at any time according to the requirements of system operation [17]. EC2 virtual server is used as the basic platform of this system. The operating system of virtual server adopts centos. On this basis, the web application server tomcatMQTT message proxy server mosquitoo, which is needed for the system to run, is installed.

A number of PaaS (Platform as a Service) services of Amazon AWS are used in the modern agricultural IoT monitoring system, such as NoSql database DynamoDB, RDS-Oracle, file storage service S3, big data analysis service EMR, and machine learning ML. By using these PaaS services, the design of the modern agricultural IoT monitoring system can be transformed into a product faster, which saves the high cost and trouble of building the basic platform, and also makes the system stable and safe to operate [18].

B. BIG DATA ANALYSIS AND MACHINE LEARNING BASED ON CLOUD COMPUTING

In the application of the IoT, the data generated is huge. Thus, if the system has 10,000 sensors to collect data every 5 seconds, then the data volume of the sensor data can reach 100 billion orders of magnitude only in one year. Processing such a large amount of data will be a problem that the system faces. One of the basic functions of the system is to provide users with real-time data query and statistics. It is not advisable to probe and analyze data directly from massive data for each request because that would occupy a large amount of disk IO and computing resources, and the delay caused by it would be unacceptable. Therefore, Hadoop big data analysis hosting platform service EMR (Elastic MapReduce) provided by Amazon, as shown in Figure 5, has been applied. EMR is used to run regularly to analyze and count the big data in DynamoDB database, transfer the results to Oracle's partition table, provide data query services to users through Oracle and improve the quality of system services and response speed.

The huge amount of data generated in the application of the IoT is of great value. The large amount of perceptual data, weather records, crop cultivation management records, price records of agricultural products, crop harvest and price records stored in the system are of great significance for establishing crop cultivation management models and price prediction models of agricultural products [19]. With these models, it is capable of more efficient agricultural production. To build these models, it is necessary to mine these data. Through Amazon Machine Learning, it is possible to quickly carry out machine learning analysis, verify the idea of modeling, and then use the model to predict on a large scale. Amazon machine learning supports three different types of prediction: binary classification, multi-class classification, and regression analysis.

C. DEPLOYMENT AND IMPLEMENTATION OF MODERN AGRICULTURAL INTERNET OF THINGS MONITORING SYSTEM ON CLOUD PLATFORM

Modern agricultural IoT monitoring system is developed based on J2EE platform. The system needs to run on application servers supporting J2EE. There are commonly paid WebSphere and WebLogic, and open source free Jboss, Tomcat, etc. [20]. By comparing these application servers, Jboss is chosen as the application server of the system, which is open source and free of charge, and has low resource occupation, and supports high concurrency. In the application of the IoT, there will be very high concurrent connection requests, so Nginx is used as the front-end web server to separate static resources and dynamic resources, and its reverse proxy function is used to achieve load balancing of the system. Therefore, the function modules of the system are based on session mechanism. It is supposed to consider how to realize load balancing among multiple Jboss instances: ession sharing, session sharing. As a result, memcach technology is chosen.

Algorithm 1 Core Code

```
#-*-coding:utf-8-*-
import os
import boto
from boto.s3.key import Key
import time
def getBucket():
    #connect to amazon s3 server and obtain bucket object
    conn = boto.connect_s3('username-xxxx', 'passwd-xxxx')
    b = conn.get_bucket('swjtu')
    return b
def main(dir,k):
    list_dirs = os.walk(dir)
    for root,dirs.,files in list_dirs:
        for f in files:
        if not f.startswith('A'):
            fd = os.path.join(root,f)
            print(fd)
            try:
                p1 = f.find('-')
                #p2 = f.find('.')
                fn = f[p1+1:]
                k.key = fn#Create file storage objects
                num = k.set_contents_from_filename(f)# upload the file
                if num > 0:
                    print('upload success:' + str(num))
                    os.remove(f)#Delete successfully uploaded files
                    print('rename success')
            except Exception as e:
                print(e)
                pass
if__name__== '__main__':
    b = getBucket()
    k = Key(b)
    while 1:
        if k is None:
            b = get Bucket()
            k = Key(b)
        main('.',k)
        time.sleep(10)# Scan folders every 10 seconds
```

The web server Nginx and application server Jboss of the system need to run on the basic computer hardware and software platform. The hardware platform of the system is Amazon EC2 virtual machine cloud service, and the software operating system is centos. With the high scalability of EC2, our hardware and software resources can be adjusted according to the load level of the system at any time to ensure the normal operation of the system. The deployment structure of the whole system is shown in Figure 6.

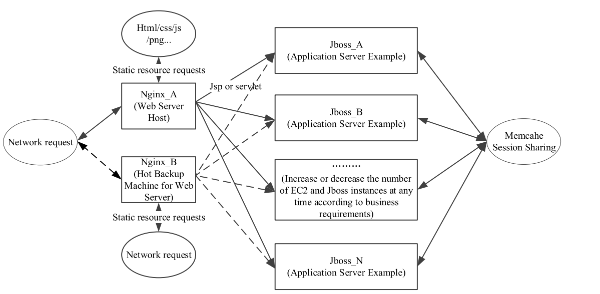

FIGURE 6. System deployment structure diagram.

The modern agricultural IoT monitoring system based on cloud computing designed and developed mainly consists of three parts: the intelligent gateway of the perception layer IoT, the cloud platform of the supporting layer open agricultural IoT, and the Wechat public number of the application layer modern agricultural IoT and the Web monitoring system. The IoT gateway is mainly responsible for sensing data acquisition and device control. The supporting layer open agriculture IoT cloud platform is the core component of the whole system. It provides functions such as device and sensor management, sensory data upload and acquisition, data intelligent analysis, device control message transmission, and agricultural information query through restful style Web Service interface.

VI. CONCLUSIONS

In the era of IT and mobile Internet, agricultural management and production need to incorporate such advanced technologies such as IoT, cloud computing and big data technology. In such background, the current application research has been conducted to show the effectuation and process of IoT system in a simulation. Experimental results show that the development and construction of modern agricultural IoT monitoring system, intelligent gateway of the IoT, MQTT message service, cloud-based big data analysis and data mining projects are validated. The main achievements are listed as below:

The design of combining Internet of Things, cloud computing, big data and modern agriculture is proposed. In addition, a hybrid data storage scheme based on NoSql database DynamoDB, relational database Oracle, and file object storage Amazon S3 is designed.

Using open source hardware raspberry pie, a low-cost, stable and highly scalable intelligent gateway for IoT is developed, and ZigBee module is integrated to build a wireless sensor network. Functions such as video surveillance based on motion detection, acquisition and upload of sensing data, and remote control of equipment are successfully realized.

Public cloud service is used as the basic software and hardware platform of modern agricultural IoT monitoring system. IaaS and PaaS services provided by cloud manufacturers are applied, which reduces the difficulty of system development and makes the system run more stable and lower in cost. According to the research results, it can be suggested that the functions of the modern agricultural IoT monitoring system based on cloud computing can be further applied.

This study is experimental in nature and thus has a number of limitations which future research can address. Firstly, the experiment design needs to be examined with more simulations to test its reliability . Secondly, quantitative empirical studies can further examine the effectiveness of large-scale adoption of IoT into agricultural production and management. In the end, a real-scenario case study would be helpful to investigate different contextual factors and their influences in the application of agricultural IoT.

APPENDIX

See Algorithm 1.

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Authors' photographs and biographies not available at the time of publication.