Research Article

Intelligent Deployment and Development Strategy of Agricultural Farmland Based on Improved Architecture of Internet of Things

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Agricultural modernization has gradually become the direction of future agricultural development. With the improvement of the technical capacity of the Internet of things, a new agricultural development model, namely, intelligent agriculture, has gradually emerged. It can not only improve the production efficiency of agriculture but also improve the efficiency of resource utilization. The main work of the software design of the terminal node is the IoT network connection, the sensor work acquisition, and the packaging of the collected data for transmission and acceptance control to fundamentally alleviate the pressure on food security and ensure the sustainable development of China’s agriculture. The experiment demonstrates that the curve temperature cycle of the agricultural greenhouse monitored by the system in this paper is normal, and the maximum temperature has been constant under different time cycles. For example, the maximum values of 5, 15, and 20 are all 0.67.

1. Introduction

With the change of lifestyle and consumption concept, urban and rural residents’ demand for high-quality, green, safe, and healthy agricultural products has further increased. As food manufacturing involves multiple links/subjects such as production, processing, circulation, and sales, it is restricted by many factors such as inputs, environment, technology, opportunistic behavior of business subjects, and the information asymmetry among producers, consumers, and regulatory authorities, resulting in great difficulty in monitoring the quality of agricultural products, repeated prohibition of food safety incidents, and lack of public confidence in agricultural products. In the context of building a new development pattern of domestic and international double circulation, the development of smart agriculture is conducive to enhancing the market competitiveness of agricultural products in various countries, which is an important aspect of China’s high-quality agricultural development. It is urgent to enhance the value chain of agricultural industry through smart agricultural technology and promote the core competitiveness of China’s agricultural industry to approach the level of agricultural developed countries as soon as possible [1].

Since 1982, the central government has issued many No. 1 documents on the subject of the three agricultural issues, and the National Medium and Long-term Development Plan for Agriculture clearly proposes the development of special agriculture, intelligent agriculture, ecological agriculture, tourism agriculture, and water-saving agriculture [2]. At this stage, as society continues to develop and as technology progresses, the creation of IoT provides strong technical support for the development of smart agriculture, which promotes the smart agriculture to become an important part of modern agriculture [3], to implement the national policy on agricultural development, in order to fundamentally solve the “three rural” problem.

IoT is a network model that uses sensors, global positioning systems, global geographic information systems, gas sensors, and laser scanners to monitor, interact with, and connect processes or objects in real time, in particular by collecting a wide range of information such as light, heat, electricity, chemistry, sound, physics, location, and mechanics, and then integrating them with the Internet [4]. The biggest advantage of the IoT is that it allows all objects to be
connected to the network, thus making them easier to detect and manage. At this stage, the IoT can be divided into 3 levels [5]. First, there is the sensing layer, which is formed mainly based on various sensors that can use information to sensing devices, thus collecting the required information and then carrying out intelligent analysis, and finally enabling the connection between the device and the network. In fact, it is the network layer, which mainly includes the network management system, the cloud computing system, and the Internet system, whose main function is to sense the processing and transmission of the data obtained. Finally, there is the application layer, which can fully realize the sensing and identification between people and things, things and things, so as to complete the research and analysis of the data and play the intelligent function of the IoT itself [6, 7].

Smart agriculture integrates the emerging mobile communication network system, Internet system, and cloud computing system, and uses various sensors and wireless sensors to achieve intelligent warning, intelligent identification, intelligent sensing, and intelligent decision making, thus providing strong technical support for agricultural development and forming visual and refined decisions [8]. The smart agriculture model mainly consists of several systems such as remote monitoring system, expert system, data analysis and collection system, wireless sensor system, and data analysis and processing system, thus being able to solve different kinds of problems existing in agricultural production.

2. Related Work

In the context of the development of the new era, agricultural development urgently needs to face transformation, from the once semimechanized to a modern informatization and mechanization stage of development [9]. The vigorous development of modern agriculture requires the support of modern information technology such as the IoT and cloud computing. The new IoT technology NB-IoT, known as NarrowBand-InternetofThings, is a LPWA technology led by Huawei and has become a 3GPP standard [10]. At present, China’s NB-IoT industrial development is also in a leading position in the world. Reference [11] clearly proposed that the infrastructure of narrowband IoT should be built and perfected to achieve its large-scale application in urban ones. In the five-year plan for the development of the information and communications industry (2016–2020), the Ministry of Information and Communications has clearly proposed to build and improve the infrastructure of narrowband IoT and realize its large-scale application in urban management and key industries, and issued a notice on comprehensively promoting the construction and development of mobile IoT [12].

Previously, Deutsche Telekom announced that its NB-IoT network has been commercially available in eight European markets, and its US company T-MobileUS will also build a NB-IoT network covering the entire US in 2018 [13–15]. To promote the development of NB-IoT, Deutsche Telekom has established a special R&D lab, WARPNB-IoT, to provide technical support to the relevant terminal and product manufacturing companies [16]. As of June 2017, a total of 26 operators worldwide are deploying cellular LPWAN networks, mainly concentrated in Asia, Europe, and North America. It can be seen that NB-IoT technology is currently focused on development and promotion both at home and abroad, and there is still much room for future development, gradually coming into our lives and serving the public [17, 18].

2.1. System Solutions. Today’s agriculture is gradually moving towards an era of unmanned, regionalized, professional, and efficient agriculture, relying on modern technology to develop agriculture so that fields are not manned, digital irrigation is achieved, and computerized automatic control and software data systems are used across the board to ensure production reliability and increase efficiency while steadily increasing returns [19].

The NB-IOT-based agricultural environment monitoring system can remotely acquire the air temperature and humidity, soil moisture temperature, carbon dioxide concentration, light intensity, and video images in the field or greenhouse in real time. Through model analysis, it can automatically control the greenhouse wet curtain fan, sprinkler drip irrigation, internal and external shading, top window side window, heating and lighting, and other equipment. At the same time, the system can also push real-time monitoring information and alarm information to managers through mobile phones, PDAs, computers, and other information terminals so as to realize greenhouse informatization and intelligent remote management, which give full play to the role of Internet of things technology in facility agricultural production, ensure that the environment in greenhouse is suitable for crop growth, realize fine management, and create conditions for high yield, high quality, high efficiency, ecology, and safety of crops, help customers improve efficiency, reduce costs, and increase revenue.

The information collected by sensors in the sensing layer by means of wired or wireless is transmitted to local area networks and wide area networks using a variety of communication protocols [20]. The platform layer is to transmit the collected data to the central server side of the platform and to carry out analysis and aggregation processing of the data, displaying real-time data in a database in the form of graphs and other forms [21]. In the application layer, the manager understands the real-time crop growth condition and makes scientific decisions to achieve remote control of the agricultural production process. The specific system structure is shown in Figure 1.

In-depth understanding of the crop growth environment, and making full use of the advantages of modern wireless sensor network technology, combined with this design specific implementation project functional requirements of the background, the overall scheme of the NB-IOT-based agricultural environment monitoring system is proposed [22].

The hardware sensor collection and transmission terminal are designed, and the software monitoring platform is
designed to make it a complete agricultural environment monitoring system. The design takes into account the actual use of environmental conditions, transmission distance, maintenance difficulties, and power consumption to ensure stable monitoring data collection and transmission, and to achieve synchronous storage and real-time query of the server side, issuing instructions to control and other functions [23].

On comprehensive analysis of the above considerations, the overall system design is ultimately to achieve data collection. The overall system hardware scheme structure is shown in Figure 2.

The whole design consists of three main parts: control part, communication part, and collection part. The IoT platform required plug-ins, profile file writing and IOT terminal device registration and installation, etc [24].

2.2. Node Hardware Architecture. The hardware part of the node is designed mainly around the control circuit, connection SIM module, the step-down circuit, and some peripheral circuits, etc. Figure 3 shows the hardware block diagram of the node.

2.3. Main Software Processes. The main work of the software design of the terminal node is the IoT network connection, the sensor work acquisition, and the packaging of the collected data for transmission and acceptance control. The software works in the following steps: first, the initialization of the configuration microcontroller, closing the watchdog, and configuring SMLK as the clock source to ensure that it can be woken up in the LPM3 mode via the UART serial port [25]. And then initialize each other interface, and initialize variables such as clearing the serial buffer, then it enters the sleep power saving mode and enables interruptions, waiting for the next attempt to turn on the network and carry out data collection and transmission. Software workflow of the specific end node is shown in Figure 4.

3. Nodal Energy Model Analysis

3.1. Cause Analysis. The current IoT technology mainly uses sensors to collect parameters, a wide range of sensors and some of the power is large, but the actual use of IoT nodes mostly use battery power supply such as solar energy combined with battery storage power supply, light and high energy density lithium battery power supply, etc., without the need for cumbersome external utility not only to meet the field production environment requirements but also to reduce development costs to promote the rapid implementation of the project [26].

Most of the nodes in the IoT application are powered by batteries, which also bring its limitations. The key to the research is to balance the energy consumption of the nodes with the energy efficiency of the batteries so that the nodes can work for as long as possible and the batteries can ensure the stability of the monitoring network for a controlled period of time. This requires the selection of the battery energy size according to the energy consumption of the node and the comprehensive calculation of the node’s stable working cycle to ensure the normal operation of the whole monitoring network. The loss of energy in the communication of the end nodes is difficult to measure through the instrumentation and needs to be modeled for analysis [27].

3.2. Communication Energy Consumption Model. The node energy consumption is analyzed here using the commonly used first-order energy loss model, which is also used in the study of clustered routing algorithms. In this design, the node contains both transmit and receive energy losses. The energy consumption of sending a k-bit packet through the transmitter circuit is $E_{TX}(k)$, the wireless transmission distance is $L$, and the energy consumption of receiving data in the receiver circuit is $E_{RX}(k)$. Figure 5 illustrates the energy consumption model of the node [28].

The energy consumption of node communication can be simply represented by the above diagram

$$P_E = P_{TX} + P_{RX},$$

where $P_{TX}$ is the transmitter energy consumption and $P_{RX}$ is the receiver energy consumption, both of which are related to the distance of the wireless signal and the size of the transmitted packet $k$ which can be expressed as

$$E = E_{TX}(k, l) + E_{RX}(k).$$

The energy consumed by the sensor node to transmit $K_{bit}$ of data over a distance of $L$ is
\[ Erx(k, l) = Erx_{elec}.k + \varepsilon_{amp}.l.k, \]  
where \( Erx_{elec} \) is the energy consumption per bit in the transmitter circuit and \( \varepsilon_{amp} \) is the energy consumption of the amplifier in the discharge circuit. The energy consumption can be divided into two cases depending on the threshold value; when the distance is greater than \( l_0 \), the multipath fading channel model is used, while when the distance is less than \( l_0 \), the self-using spatial channel model is used to calculate the energy consumption.

Therefore, based on the relationship between the transmission distances \( l \) and \( l_0 \), the energy required to send \( K_{\text{bit}} \) data is

\[ \begin{align*}  
Erx(k, l) &= Erx_{elec}.k + \varepsilon_{amp}.l.k \quad l < l_0, \\
Erx(k, l) &= Erx_{elec}.k + \varepsilon_{mf}.l^4.k \quad l \geq l_0. 
\end{align*} \]  

The formula for the critical distance threshold \( l_0 \) is

\[ l_0 = \frac{\sqrt{ES}}{\varepsilon_{mf}} \]  

where \( \varepsilon_{fs} \) represents the fading coefficient in the self-use spatial channel model, \( E_{TX} \) represents the fading coefficient in the multipath fading channel model, and \( E_{RX} \) is the energy loss in the circuit [29].

The energy consumption of the received data is

\[ E_{RX} = E_{RX, elec}.k. \]  

From equation (6) above, whether in the free space model or in the fading space model, the received data energy consumption is only related to the amount of data received. The energy loss from channel transmission in the node is much greater than the energy loss from the sensor acquisition and data integration, and the internal energy consumption is relatively small. Therefore, it is necessary to consider reducing the transmission distance and keeping the node location and the base station within a reasonable range.

The energy consumption algorithm can be used to calculate the node placement and a number of nodes in the communication grid in relation to the base station to obtain the best area with low energy consumption for node communication. According to the common selection criteria for wireless sensor networks, the energy consumption of the transmitting circuit is determined, the initialized node energy is 0.3 J, the fading factor in the spatial channel model is 10 pJ/(bim^2), the fading factor \( \varepsilon_{mf} \) in the multipath fading channel model is 0.0013 pJ/(bim^4), the packet size \( k \) is 2000 bit.
the transmission radius of the wireless network is 100m, and the threshold value $l_{Ex}$ is $1.026 \times 10^J$ according to the energy consumption formula, and the capacity of the battery is 169 mAh at 3.7 V according to the transmission time of 5 s per transmission, 12 times per day, and the working life is of at least 1 year [30, 31].

4. Case Applications

This study takes a modern agricultural intelligent park project as the background and uses IoT technology and wireless networking technology to build an intelligent sensor monitoring network in the demonstration area and construct a real-time monitoring system for the rice crop growth environment in the demonstration area. The monitoring parameters of the system mainly include regional meteorological parameters monitoring (temperature, humidity, rainfall, etc.), rice growth soil and fertilizer environment monitoring (groundwater level, pH value, $CO_2$, light level, etc.), and finally build a demonstration area pump station remote computer automation control system integrating data acquisition, image transmission, and automatic control. The field application of this R & D is mainly the field commissioning and application of the nodes based on NB-IoT technology. Figure 6 below is a schematic diagram of the system structure of an intelligent modern agricultural park [12].

After the hardware design is completed, on-site commissioning will be carried out and the collected environmental data and information such as pumping stations of the intelligent modern agricultural park will be gathered in the application platform of the project. The environmental data collected by the nodes will be subscribed to the application data through the IoT platform. The URL of the local system server will be filled in the subscription address field and the subscription will be successful when the platform is automatically detected, and the data will be sent to the local management system server simultaneously. Figure 7 shows the field system platform transfer attempt.

In recent years, after years of development, China’s IoT technology has made certain achievements, taking shape specifically, and Internet of Things technology can detect and control the production environment of intelligent agriculture. This requires farmers to go out to the fields regularly to observe the growth of their crops, which consume a lot of resources, human, financial, and material resources. Use of IoT technology allows for timely and effective irrigation, spreading, sowing, and fertilization of crops, thus eliminating the drawbacks of traditional agriculture, improving the quality and yield of crops, and saving resources.

It can be seen from Figure 8 that the curve temperature cycle of the agricultural greenhouse monitored by the system in this paper is normal, and the maximum temperature has been constant under different time cycles. For example, the maximum values of 5, 15, and 20 are all 0.67. An IoT technology can provide protection for the food safety of agricultural products. The proverb “disease enters through the mouth” shows that food safety is directly related to human health, so the safety and quality of agricultural products need to be strictly controlled so as to provide a safe dining environment for the general public. The use of the IoT technology can be used to measure and control the quality and safety of agricultural products throughout the whole process, from the field to the table management will be transparent, so as to ensure the safety of agricultural products. This technology can be used in greenhouses, highways, irrigated areas, and gardens. This technology can also be used in greenhouses, highway barriers, agricultural irrigation areas, and garden green areas. In addition, IoT technology has been significantly developed in the network management, intelligent computing, and communication protocols of smart agriculture and has received good results in the agricultural fields of electricity, environmental protection, food, transportation, logistics, and medical care, with temperature monitoring as shown in Figure 9.
Logistics network technology in the development of smart agriculture also has certain shortcomings, such as the slow degree of construction of basic information in agriculture, the lack of relevant norms and standards for agricultural development, the lack of professional and technical personnel, the lack of unified technical means in agriculture, the lack of maturity in the development of IoT, the lack of strength in agricultural production, and the inability to enable farmers to receive appropriate technical training, specifically for the application of IoT in smart agriculture technology. There are problems between the standard and cost of the IoT technology; compared with foreign technology, China’s technology still has more drawbacks and needs to be further improved, and the maturity of the IoT technology directly restricts the scale of the development of smart agriculture, the lack of unified technical standards in the reading of information, the transmission of information, and the analysis of data and human–computer interaction, as shown in Figure 10.

This directly leads to the fact that manufacturers cannot organize their production according to uniform regulations and, therefore, costs are increased and can only be applied to some high value agricultural products. At this stage, there is a lack of professional and technical personnel to apply IoT technology. There are not many experts in Chinese agriculture, and there are many computer professionals and technical personnel who do understand the science of smart agriculture, which is an inherent deficiency. The commercial form of smart agriculture is backward. At this stage, the commercial form of Chinese agricultural IoT is by and large the production units of agriculture themselves which pay for the needed projects, and even some large farms need to pay for their own application of IoT projects, which all lead to high cost and low motivation and insufficient multisectoral coordination of IoT technology. The development of smart agriculture using IoT technology requires the collection of a wide range of information, requiring a lot of information analysis and transfer from the environment, government, meteorological offices, farmers and business, etc.
5. Conclusions

IoT, with its ubiquitous information data perception, intelligent information analysis and processing, massive information data storage and analysis, and ubiquitous network connectivity, can not only combine the real world and the virtual network but also promote the transformation of agricultural production methods and improve the efficiency of resource utilization.

Although there are many problems in applying IoT technology to smart agriculture, with the continuous development of science and technology, smart agriculture has become the inevitable trend of the times, and we believe that combining IoT and smart agriculture is an effective strategy to achieve sustainable agriculture. In short, the application of IoT technology in smart agriculture is a long way to go and requires the joint efforts of the party and the state, the agricultural sector, and all sectors of society. [32].

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

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