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An environment safety monitoring system for agricultural production based on artificial intelligence, cloud computing and big data networks

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Abstract

Monitoring the agricultural production environment is crucial for optimal crop growth and resource efficiency. Cloud Computing, Artificial Intelligence (AI), and Big Data have revolutionized traditional agriculture, promising improved output and product quality. The popularity of these technologies drives their application in safety monitoring. This system facilitates data collection and transmission among equipment, overcoming challenges of traditional systems like investment, costs, and maintenance. In this paper, cloud computing-based AI optimization technology and big data network were proposed to monitor the safety of the agricultural production environment, and the shortcomings of traditional distance vector hop (DV hop) positioning algorithms were analyzed in depth. RSSI (Received Signal Strength Indication) technology improved the traditional DV Hop location method. The paper analyses direct and indirect transmission for data transmission between WSN and cloud nodes and favors indirect transmission because it consumes less invalid energy. Finally, the article compares several evaluations of alternative algorithms for monitoring system performance, including data transmission reliability, data reception rate, and data delay. The experimental results in this paper showed that in the data reception rate test, the data reception rate of System 2 was 97% at the lowest and 99% at the highest, both exceeding 95%.

Keywords Agricultural production environment, Cloud computing, Distance vector hop, Big data network, Artificial intelligence

Introduction

These days, cloud computing has revolutionized various industries, and its potential impact on the agricultural sector is significant. The traditional agricultural production model is facing challenges in meeting the demands of modern society, especially when it comes to ensuring the safety of the agricultural production environment. To address this critical issue, integrating cloud computing technology into the environment safety monitoring system for agricultural production has become a priority. With its large population and limited land resources, China has reached a specific limit in developing and utilizing its land [1]. As a result, the excessive use of pesticides and fertilizers has become a prevalent practice to improve agricultural production. However, the current situation in agriculture highlights a pressing issue regarding utilizing fertilizers. The effective utilization rate remains dishearteningly low despite the large amount of fertilizer used annually. Shockingly, approximately 70% of the applied fertilizers flow into the soil and rivers, while

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only 30% are effectively absorbed by crops. This imbalance significantly damages the agricultural production environment to varying degrees. In this context, adopting cloud computing technology can be pivotal in optimizing agricultural practices and reducing environmental impact [2].

Cloud computing provides a scalable and flexible infrastructure for efficient data storage, processing, and analysis. By leveraging cloud computing, agricultural stakeholders gain access to a powerful computational platform capable of seamlessly integrating various components and services required for monitoring and managing the safety of the agricultural production environment. This technology offers centralized data storage, which facilitates the integration of diverse data sources, such as weather data, soil conditions, and pest monitoring information, enabling real-time decision-making and optimization. The integration of cloud computing with artificial intelligence (AI) optimization techniques further enhances the capabilities of the environment safety monitoring system. AI algorithms can analyze large datasets and identify patterns, correlations, and anomalies that may not be immediately apparent to human observers. By leveraging AI optimization algorithms within the cloud computing framework, proactive decision-making and early detection of potential hazards or deviations from optimal environmental conditions become possible [3].

By integrating cloud computing, artificial intelligence optimization, and an extensive data network, stakeholders can overcome the limitations of traditional monitoring systems and significantly enhance the efficiency, accuracy, and timeliness of monitoring the agricultural production environment. This research paper proposes an environment safety monitoring system for agricultural production that addresses the challenges associated with high costs, maintenance difficulties, and limited scalability of traditional systems. The system utilizes wireless sensor networks (WSNs) integrated with AI optimization techniques and big data analytics within a cloud computing framework [4]. To improve location accuracy, we also address the shortcomings of the traditional distance vector hop (DV hop) positioning algorithm by incorporating Received Signal Strength Indication (RSSI) technology. The system's real-time monitoring capabilities are demonstrated through extensive experiments, including evaluations of data reception rates and transmission delays.

Other contributions of the paper are listed below:

- The contribution of this research lies in leveraging cloud computing technology to empower stakeholders in the Chinese agricultural sector to make informed decisions, enhance resource efficiency, and mitigate the environmental damage caused by the excessive use of pesticides and fertilizers.
- Firstly, this paper analyzes direct and indirect data transmission between WSN and cloud nodes, favoring indirect transmission due to lower energy consumption.
- Secondly, it compares an upgraded DV Hop method to the classic technique, showing reduced error as the number of nodes increases.
- Finally, it evaluates various alternative algorithms for monitoring system performance, including data transmission reliability, reception rate, and delay. The test results demonstrate that the data access rate of the system surpasses 95%, indicating that system 2 may significantly enhance data utilization and system use value.

The remainder of this paper is organized into 5 sections. "Related work" section emphasizes the contributions of national and international researchers. "Agricultural production environment safety monitoring system based on big data network and cloud computing" section discusses the agricultural production environment safety monitoring system based on the Big Data network in a cloud environment. "Effect experiment of agricultural production environment monitoring system using WSN in cloud environment" section presents the experimental results of the agricultural production environment monitoring system using WSN in a cloud environment. The final section concludes the paper and suggests future research directions.

Related work

Monitoring the agricultural production environment is crucial in achieving optimal agricultural growth and resource efficiency. With the advent of Cloud Computing, Artificial Intelligence (AI), and Big Data technologies, traditional agriculture practices have significantly transformed, promising improved output and product quality [5]. As a result, there has been a growing interest in applying these technologies to safety monitoring in the agricultural sector. Since the reform and opening up, China's agricultural development has made remarkable progress, but there are many problems in the current agricultural production environment. Finger Robert found that the agricultural production environment was deteriorating rapidly. He believed that targeted safety monitoring could reduce environmental costs, and the progress of safety monitoring technology continued to promote agricultural development [6]. The author of [7] hoped to use safety monitoring technology to track the agricultural production environment to manage environmental problems and improve production efficiency. Therefore, the work [8] found that a healthy agricultural production environment was essential to ensure food production kept pace with population growth. In recent years, the abnormality of the agricultural production environment has led to global environmental degradation. Coordinating and combining safety monitoring technology with the agricultural production environment is necessary to solve these difficulties and guide human beings to a safe agricultural production path. The above scholars believe that with the growth of the population, the food problem is becoming more and more serious. In order to maintain the agricultural production environment, it is necessary to use safety monitoring technology to solve the agricultural production environment problems on time.

With the development of Cloud Computing, AI, Big Data network, and other related technologies, the safety monitoring of the agricultural production environment has ushered in a new era. The early work in [9] found that the modern agricultural production environment safety monitoring system could realize the video monitoring function. He established a corresponding model to use AI and Big Data networks to solve the bottleneck problem of the agricultural production environment, which solved the problem of agricultural product quality safety and agricultural production environmental pollution from the source. According to [10], establishing a security monitoring system based on Big Data networks and AI was crucial for the real-time monitoring of the agricultural production environment. The results showed that the performance of the safety monitoring system was very stable, reliable, and reusable, which was a helpful tool for monitoring the continuous agricultural production environment. Therefore, author [11] analyzed the safety monitoring technologies used in the intelligent agricultural production environment based on Cloud Computing, AI and Big Data networks, which were outstanding in monitoring the environment in the intelligent agricultural production process. The above scholars believe that with the development of Big Data networks, Cloud Computing, and other emerging technologies, the design of agricultural production environment safety monitoring systems tends to be more effective, low-power, and cost-effective.

To effectively improve the agricultural production environment, the development of safety monitoring technology must be ensured to ensure the safe and stable production of agricultural products to fundamentally solve the problem of the agricultural production environment [12]. The environmental problems of agricultural production not only cause significant harm to the human body but also have a significant impact on the ecosystem [13]. Therefore, it is necessary to find out the agricultural production environmental problems and analyze their causes to formulate effective prevention and control measures to improve the environmental pollution situation of China's agricultural production [14].

Agricultural production environment safety monitoring system based on big data network and cloud computing

The agricultural production environment safety monitoring system based on big data network in a cloud environment is a cutting-edge technology solution to improve agricultural production safety and efficiency [15]. By leveraging big data analytics and cloud computing, this system receives and analyses enormous amounts of data from multiple sources, such as weather sensors, soil sensors, and crop monitoring devices [16]. The data is then analyzed in real time to give farmers useful insights and actionable information. It allows them to optimize resource allocation, increase crop yields, and reduce risks. The cloud environment allows farmers and agricultural specialists to access information remotely and make educated decisions by facilitating seamless data storage, sharing, and collaboration. This technology allows farmers to monitor environmental variables, detect possible hazards, and perform timely adjustments, resulting in a safer and more productive agricultural production environment. Before to discuss the general architecture of the suggested agricultural production environment safety monitoring system, we first explore the composition of agricultural production environment challenges.

Composition of agricultural production environment problems

The deterioration of the agricultural production environment has had a particular impact on the survival and development of crops. The agricultural production environment includes natural and human factors, and there are different problems in different periods and spaces [17]. Currently, the main environmental issues of agricultural production in China are environmental pollution and ecological destruction. Therefore, it is essential to monitor its safety in agricultural production [18].

The traditional manual detection method is only suitable for small-scale environmental monitoring, not ideal for agricultural production environments or areas where dangerous gases exist. If it is still carried out according to the traditional method, it results in the cost and manpower consumption of the system. Therefore, new and intelligent monitoring equipment has emerged [19]. Using modern communication technology to combine AI optimization technology and an extensive data network with the agricultural production environment can effectively reduce the cost of maintaining the agricultural production environment and increase land income to promote ecological development [20]. The main environmental problems of agricultural production are shown in Fig. 1.

As shown in Fig. 1, the main environmental problems of agricultural production include pesticide pollution, fertilizer pollution, soil pollution, air pollution and water pollution.

Pesticide pollution

Due to improper preparation and use of pesticides, the drug resistance of crops has increased. The pesticide residues of some agricultural products exceed the standard, which has a particular impact on the quality and safety of agricultural products. Crops are vulnerable to pests and weeds in the growth process, so it is the most economical and quick method to use pesticides to control pests and diseases. Pesticide floats into the air or water during spraying. Although most pesticides are slowly decomposed into non-toxic substances, some are stable and can stay in plants and soil long. Some pesticides are degraded, residual pesticides and some toxic metabolites are also produced when crops are harvested.

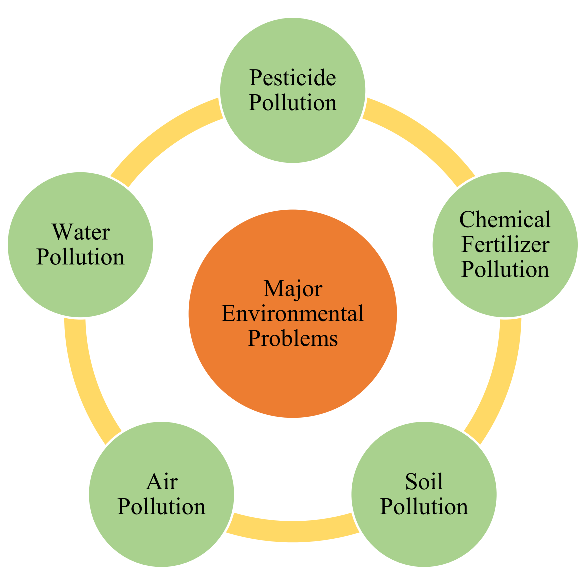


Fig. 1 Major environmental problems in agricultural production

Chemical fertilizer pollution

For a long time, most farmers in China have used chemical fertilizers to increase their grain yield, thus increasing the concentration of nitrate nitrogen in the soil, which has a particular impact on the agricultural production environment. At present, it is recognized that chemical fertilizers can increase grain production. Therefore, the use of chemical fertilizers is rising every year. The amount of various chemical fertilizers applied to soil absorbed by crops is minimal. Many nutrients evaporate from the ground or escape into the air as a gas. Due to unscientific application, organic matter content in farmland soil has decreased yearly, causing severe damage to the soil structure and the emergence of environmental problems in agricultural production.

Soil pollution

Because of the long-term fertilizer application, the quality of the soil has deteriorated, and the fertility of the soil itself has been continuously reduced. In this case, many farmers rely on increasing fertilizer to maintain their farmland, thus forming a vicious circle. In addition, after heavily using pesticides, some toxic and harmful substances remain in agricultural products, causing serious pollution to the agricultural production environment. In agricultural production, the soil is the most important material base, and its quality greatly impacts the agricultural production environment. Currently, the soil quality of cultivated land in China is not optimistic, and soil pollution problems caused by various factors occur occasionally. Therefore, a good soil environment must be created to ensure the quality of agricultural production. The causes of soil pollution are various. The problem of environmental pollution from the source should be solved to provide a healthy environment guarantee for the safe production of agricultural products.

Air pollution

Excessive harmful gas is also an important reason for the poor agricultural production environment. In the process of burning straw, a large amount of smoke is produced, and the harmful substances in the smoke also pollute the agricultural production environment. In agricultural production, the sedimentation of air also causes particular pollution to the soil, so the absorption of crops into the soil also has a certain impact.

Water pollution

Excessive application of nitrogen fertilizer results in many feces, thus causing water pollution. It causes eutrophication of ponds, rivers, lakes, and other water bodies, resulting in anoxia of water bodies, death of aquatic organisms, and excessive algae growth. Toxic substances and heavy metals in fertilizers and pesticides enter the water through different channels, which significantly impacts the agricultural production environment. China is short of water resources, and irrigation still dominates agricultural production. Without effective governance, it is bound to pose a massive threat to the agricultural production environment. Wastewater is widely used in early agricultural irrigation in China. In such an environment, crops cause particular pollution to the water source, thus causing toxins in the soil to enter agricultural products.

The safety monitoring system must monitor various agricultural production settings to solve numerous difficulties in the agricultural production environment [21]. However, the traditional monitoring system is difficult to widely use in agricultural production environment monitoring due to high energy consumption, lengthy duration, and other factors [22]. Using WSN in agricultural production not only overcomes the challenges listed above but also adds cloud computing and big data networks to the monitoring process of the agricultural production environment [23].

Overall design of smart agricultural production environment safety monitoring system based on WSN in cloud environment

The design of the smart agricultural production environment safety monitoring system based on WSN in a cloud environment aims to address the specific needs of monitoring the agricultural production environment. The WSN scheme proposed in this paper enables the system to establish a network quickly and provides a management mechanism that allows devices to operate autonomously, resulting in a network with a robust self-healing ability. By utilizing WSN, the system can effectively meet the real-time monitoring requirements of various aspects of the agricultural production environment. It enables the system to monitor real-time parameters such as temperature, humidity, soil moisture, air quality, and other relevant factors. It ensures that any potential environmental changes can be promptly detected and appropriate actions can be taken to maintain the safety and productivity of agricultural production. One of the significant advantages of implementing WSN in this system is its ability to reduce energy consumption and prolong the system's service life. The WSN devices are designed to operate efficiently with minimal power consumption, allowing for prolonged battery life or even energy harvesting techniques. It reduces the need for frequent maintenance and replacement of batteries, resulting in a cost-effective and sustainable monitoring system.

Furthermore, by integrating the WSN scheme with a cloud environment, the system can leverage cloud computing capabilities to enhance its performance and functionality. Cloud computing provides several benefits, such as real-time data processing, scalability, cost-effectiveness, and security. In terms of real-time data processing, the cloud environment enables the system to analyze and process the data collected by the WSN devices in real time. It allows for timely decision-making and immediate response to detected anomalies or changes in the agricultural production environment.

Scalability is another advantage of the cloud environment. The system can quickly scale up or down its computational resources based on the demands of the monitoring system [24]. This scalability ensures that the system can accommodate increasing data volumes or additional sensors or devices without significant infrastructure investments. Cloud computing also offers cost-effectiveness by eliminating the need for dedicated hardware resources. Instead of deploying and maintaining individual servers, the system can rely on cloud services for data storage, processing, and analytics. It reduces the upfront costs and ongoing maintenance expenses associated with managing on-premises infrastructure. Therefore, the cloud environment provides robust data security measures to safeguard the collected data. The system benefits from the cloud provider's security protocols, encryption, access controls, and backup mechanisms by storing data in the cloud. It ensures that the agricultural production data remains confidential, protected against unauthorized access, and backed up in case of data loss or system failures.

In order to meet the specific needs of agricultural production environment safety monitoring, this paper proposes a WSN scheme in combination with cloud computing technology. The appropriate WSN management mechanism enables the system to quickly build the network so that the devices in the system can work at will and the entire network has a strong self-healing ability. It also reduces energy consumption and prolongs the system's service life to realize real-time and accurate monitoring of the agricultural production environment. The integration of WSN and cloud computing technology can effectively meet the real-time monitoring requirements of all aspects of the agricultural production environment. Therefore, how to design a safety monitoring system that can both reduce energy consumption and improve its life cycle is an urgent problem to be solved. The monitoring function of WSN based on cloud computing technology is shown in Fig. 2.

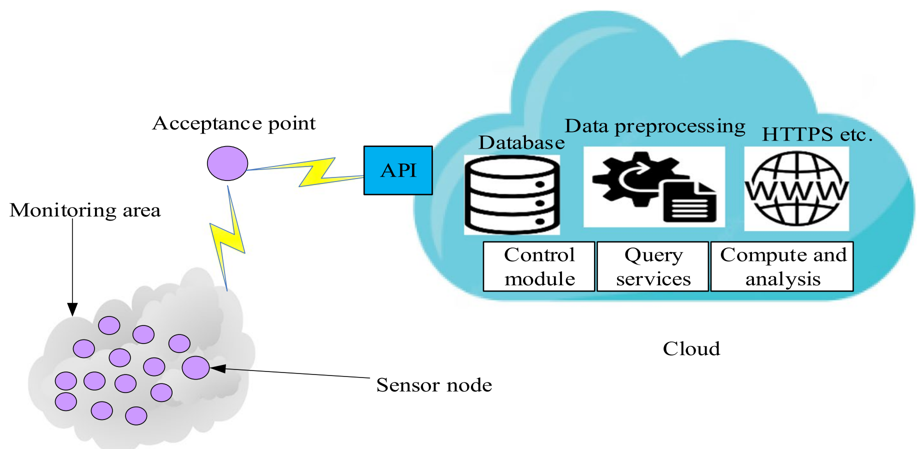


Fig. 2 Cloud computing-based WSN monitoring function

As shown in Fig. 2, the WSN utilizes various sensors to monitor the environmental conditions of the agricultural production area, such as temperature, humidity, soil moisture, and other essential parameters. The data collected from the sensors is transmitted to the cloud through the receiver, which is connected to the cloud. Once the data is uploaded to the cloud, it can be stored, processed, and analyzed using cloud computing technologies. The cloud can provide vast storage space and computing power, making it an ideal solution for processing large volumes of data. This data can then generate valuable insights into the agricultural production environment, such as identifying trends and patterns that can help improve crop yields.

Furthermore, wireless communication between nodes allows transmitting instructions and data, enabling the network to adapt to changing conditions in real-time. Communication is facilitated using various wireless protocols like Wi-Fi, ZigBee, and Bluetooth [25]. The primary objective of the security monitoring system based on wireless sensors is to obtain comprehensive information about the agricultural production environment through the cooperative perception of multiple WSNs. By utilizing cloud computing, the system can achieve real-time data analysis and decision-making capabilities, ensuring that prompt actions can be taken to address any issues that may arise in the agricultural production environment. Therefore, the security monitoring system based on wireless sensors designed in this paper collects real-time environmental information through sensors and then transmits the data to the cloud through wireless networks. The cloud is the central data storage, processing, and analysis hub, making it a crucial component of the overall agricultural production environment monitoring system. Algorithm 1 focuses on determining the service delay of a request that originates from a WSN node. This algorithm considers the coordinates of both the WSN node and the cloud node, treating them as random numbers. The processing time is also considered a random number in this algorithm. After considering the random coordinates and processing time, the algorithm sends the request from the WSN node to the cloud node using the "send a request to the cloud node" mechanism. Each individual cloud node maintains a queue to hold incoming requests within the cloud network.

The algorithm then evaluates the waiting time of the cloud node associated with the request. If the waiting time of the cloud node is less than or equal to a predefined threshold value (THRESHOLD), it signifies that the cloud node can promptly process the request. The request is processed at that specific cloud node in such a case. However, if the waiting time of the cloud node exceeds the threshold, indicating potential delays, the algorithm utilizes the "get nearest cloud node" function. This function helps identify the nearest cloud node in terms of distance or other relevant factors. Subsequently, the request is transferred to the nearest cloud node to minimize potential delays and ensure efficient processing. The service delay is then calculated by considering the summation of the process, propagation, and waiting times. These factors collectively contribute to the overall delay experienced by the request within the cloud-based system. Furthermore, the algorithm calculates the load in the cloud layer by counting all the requests in the queue. This load calculation provides insights into the current workload and helps evaluate the system's performance and capacity.

Input:	{cloud_node: A list or collection of cloud nodes, THRESHOLD: A predefined threshold value for the waiting time, process_time: A random number representing the processing time Coordinates: The coordinates of the WSN node (generated in the make_coordinates() function) c, d: Random numbers used in the algorithm}
Output:	{Delay}
Step 1:	Technique *COMPUTE DELAY (A)*
Step 2:	[Start loop] **for** each *i* in cloud_node **do**
Step 3:	[Assign random number to **a**] **a**=RAND ()
Step 4:	[Assign random number to **b**] **b**=RAND ()
Step 5:	[Coordinates making] make_coordinates () fNode(a, b) end **for**
Step 6:	[Assign random number to **c**] **c**=RAND ()
Step 7:	[Assign random number to **d**] **d**=RAND ()
Step 8:	[Calculate processing time with the help of ransom number] process_time = RAND ()
Step 9:	[Send request to WSN node] Send "**c**, **d**, service_Time, A"
Step 10:	[Check threshold] **if** cloud_node.est. waiting_Time <=THRESHOLD **then**
Step 11:	[Process A] Process (A) **else**
Step 12:	[Obtain the address of nearest WSN node] Get Nearst_Node ()
Step 13:	[Process A] Process (A) end **if**
Step 14:	[Calculate delay for A] Delay (A) =process time | comp_distance (Node(x, y), A(c, d))/PS | waiting_Time
Step 15:	[Calculate load by visiting WSN node queue] Load= visitedWSNqueue.LENGTH () end **technique**

Algorithm 1 Compute the request delay in cloud computing environmentThe comprehensive smart agricultural

production environment monitoring system based on WSN in the cloud environment is shown in Fig. 3.

As shown in Fig. 3, the overall agricultural production environment safety monitoring system includes application layer, sensing layer and cloud-based monitoring points of agricultural production environment safety monitoring system. The cloud-based monitoring of the suggested system is the basic layer of agricultural production environment monitoring, which includes multiple agricultural monitoring points, namely sensor nodes. The sensing layer uses various sensors to collect the main environmental information of crop growth in real time, mainly to achieve real-time monitoring of multiple data. While the application layer acts as a bridge between the user and sensing layer.

The agricultural production environment monitoring system is based on Wireless Sensor Networks (WSN), networks of sensors deliberately dispersed across different monitoring regions and coupled via wireless communication. On the other hand, the energy consumption of these sensors during the gathering, transmission, and processing of agricultural production environment data provides a substantial obstacle to the system's viability. To overcome this issue, incorporating WSN with a cloud environment has various advantages. First, the cloud environment reduces energy needs for sensors and increases their operational lives by enabling them to transfer computationally demanding activities to the cloud. This offloading technique uses the cloud's massive computer capacity and resources to tackle complex data processing tasks, reducing sensor energy usage. Second, the cloud environment allows for efficient data collection, storage, and processing. Rather than processing data on the sensors themselves, the cloud may aggregate data from several sensors, apply powerful algorithms and analytics, and provide valuable insights. This centralized data processing method decreases the sensors' energy strain while enabling more efficient and scalable data analysis. Third, the cloud infrastructure provides the monitoring system with scalability and flexibility. The system's flexibility to incorporate more sensors allows it to adjust to the changing demands of agricultural production situations swiftly. The cloud also offers on-demand computing resources, assuring enough processing capacity to meet shifting workloads while preserving system efficiency and speed.

Furthermore, the cloud environment improves data accessibility and stakeholder cooperation. The acquired agricultural production environment data may be

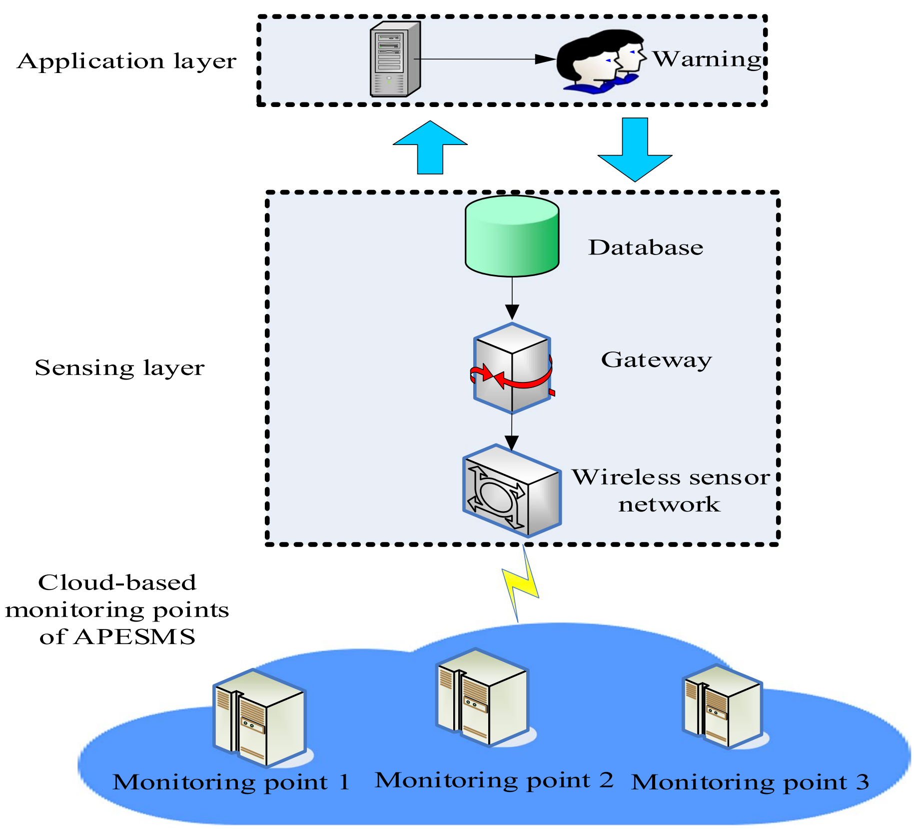


Fig. 3 Overall monitoring system of agricultural production in cloud environment

securely saved in the cloud and made available to authorized users such as farmers, researchers, and agronomists. These users may access real-time or historical data from anywhere and anytime, allowing for more informed decisions and faster actions. Cloud-based solutions promote cooperation by enabling stakeholders to exchange data, insights, and best practices. This collaborative method encourages information sharing and collaboration, resulting in better agriculture management practices and outcomes. As a result, introducing a cloud environment into the agricultural monitoring system saves costs. The cloud provides a centralized and cost-effective alternative by removing the need for individual management and maintenance of on-site servers or data centers. It eliminates upfront hardware and software expenditures, decreases maintenance efforts, and provides a pay-as-you-go approach in which users only pay for the resources and services they use, assuring cost-effectiveness for agricultural stakeholders.

Low power design of software

From the perspective of the use environment and requirements of the agricultural production environmental safety monitoring system, energy consumption has always been a big problem. To minimize the power consumption of the system, it is necessary to design the hardware reasonably and reduce the system's operating cost. As the sensor equipment has been in the field for a long time, its main task is to collect information about the agricultural production environment, dramatically impacting the performance of the entire monitoring system. As shown in Fig. 4, direct and indirect transmission can generally be used for data transmission between WSN node and cloud node [26]. In contrast, the information and communication of radio waves consume a lot of energy. Therefore, this system uses indirect transmission between nodes to reduce invalid energy consumption.

Data can be transferred directly between the WSN and cloud nodes in direct transmission mode. After receiving the data, the WSN node might send a confirmation message to the routing node. Such a data transmission method must accept data at all times, which means it must be awake at all times.

In the indirect transmission mode, the cloud node stores data and waits for the WSN node to read. Before receiving data, the WSN node must first send a data request to it, and then query according to the information in the routing table. By this method, the node can be put into sleep without data acquisition, thus greatly reducing the energy loss.

WSN based DV hop location algorithm in cloud environment

In the agricultural production environment monitoring system, the sensor monitoring nodes are typically scattered randomly, making it challenging to determine data direction and affecting agricultural production decisions. While Global Positioning System (GPS) is widely used for positioning, its large size and cost make it unsuitable for low-cost, self-organized agricultural monitoring systems. To address this, cloud computing can be incorporated to enhance the monitoring system's efficiency and accuracy. This paper selects the DV Hop location algorithm as an alternative to GPS. The DV Hop algorithm offers advantages such as minimal hardware requirements and straightforward calculations. By leveraging the power of cloud computing, the DV Hop algorithm can be further optimized and applied to the agricultural monitoring system. Figure 5 depicts a schematic diagram of the DV Hop location algorithm. Cloud computing enables the system to process and analyze data from the sensor nodes, improving the accuracy of data direction and aiding in informed decision-making for agricultural production. With the cloud's computational capabilities, the DV Hop algorithm can be efficiently executed, ensuring precise positioning and enabling a cost-effective, self-organized monitoring system for agricultural environments.

As shown in the above Figure, DV Hop location algorithm is used to locate nodes, mainly to track and locate nodes A, B, C and target nodes. Target positioning tracks target objects and events, and classifies them according to the information acquisition method monitored.

DV Hop location algorithm

This paper adopts a DV Hop location algorithm, which has strong scalability and practicality, and can be applied to location independent of nodes. In practical applications, the DV Hop positioning algorithm can improve the positioning accuracy through software settings without affecting the overall positioning effect.

The basic idea of DV Hop algorithm is to achieve node location through routing vector exchange protocol. The implementation of this algorithm is based on a network system with at least three anchors. Each anchor point in the system is combined with the position and hops of the remaining anchor points in the network. The average distance of this anchor point per hop in the network is estimated as $HopSize_i$:

$$HopSize_i = \frac{\sum_{i \neq j} \sqrt{\left(a_i - a_j\right)^2 + \left(b_i - b_j\right)^2}}{\sum_{i \neq j} h_{ij}} \tag{1}$$

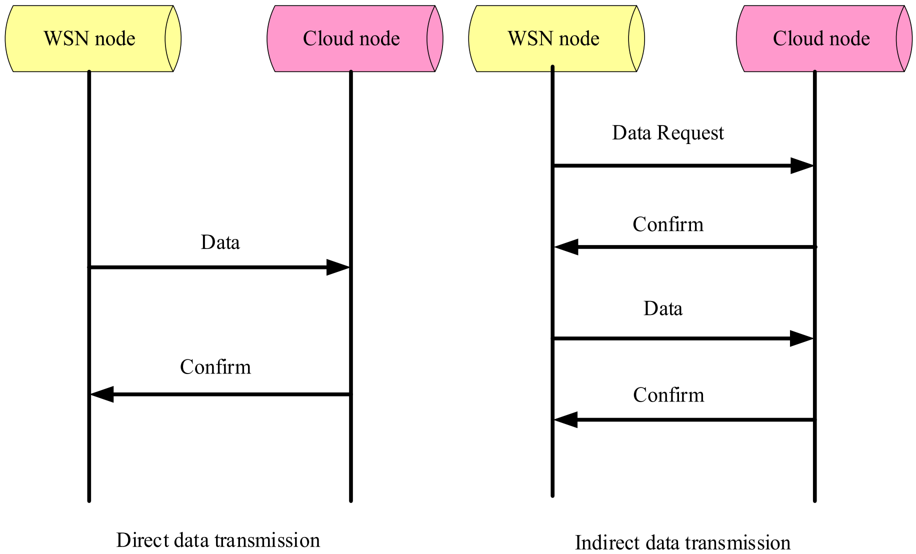


Fig. 4 Two methods of data transmission

The minimum distance between two anchor nodes is h_{ij}. To ensure that the correction value always originates from the nearest anchor node, each node only receives the correction value once, and ignores the jump information that is greater than or equal to the current correction value.

The distance estimate d_i of the node can be determined using the lowest hop value and average correction value of the first two levels:

$$d_i = k_i * HopSize \tag{2}$$

Trilateral measurement method is a measurement method that selects a series of control points on the ground to connect them into several triangles and form a variety of mesh graphics. The trilateral measurement method is used to complete the coordinate estimation of the actual position of blind nodes. If the three anchor nodes in the node network are a, b, and c respectively, and their distances from the blind node are d_a, d_b, and d_c respectively, then the following situations exist:

$$d_a = \sqrt{(a - a_a)^2 + (b - b_a)^2} \tag{3}$$

$$d_b = \sqrt{(a - a_b)^2 + (b - b_b)^2} \tag{4}$$

$$d_c = \sqrt{(a - a_c)^2 + (b - b_c)^2} \tag{5}$$

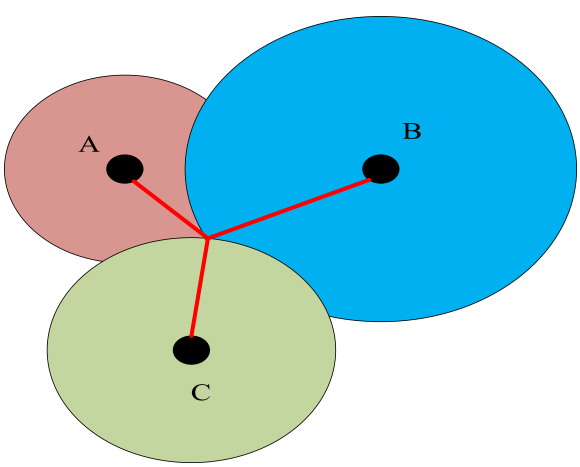


Fig. 5 Schematic diagram of DV Hop location algorithm

From the above analysis, it can be seen that DV Hop location algorithm can achieve the location of nodes. The algorithm is simple to implement, with less system deployment cost and node energy consumption, and is easy to implement for large monitoring systems.

The DV Hop location algorithm determines the average jump distance of each anchor point through the minimum jump value obtained. On this basis, the method is used to calculate each node. According to the actual situation, the jump value can be long or short, but it has the disadvantage of low positioning accuracy. Therefore, when implemented in an agricultural production environment safety monitoring system, the classic DV Hop locating method may have significant drawbacks. It may need more scalability in large-scale agricultural applications, decreasing accuracy and efficiency as sensor nodes increase [27]. Furthermore, the algorithm's dependence on hop counts for distance estimates may result in errors, limiting the system's capacity to monitor and track parameters across broad agricultural areas. Additionally, the system may need to better manage impediments or environmental variables, decreasing accuracy.

Improved DV Hop algorithm

In the DV Hop location algorithm, the hop between nodes and the average Hop distance lead to significant errors in the location process. RSSI has a signal strength indicator, which can distinguish the one-hop distance in the DV Hop location algorithm and determine the position relationship between blind spots according to the signal strength. Combined with the implementation principle of the traditional DV Hop algorithm and the causes of low positioning accuracy, RSSI is introduced into the DV Hop positioning algorithm to improve the DV Hop algorithm.

When combined with cloud computing and WSNs, the classic DV Hop algorithm and its relevance in agricultural production environment safety monitoring systems may be further strengthened. Data acquired from WSNs may be readily handled and analyzed utilizing cloud computing, enabling more efficient and effective monitoring of environmental factors. Furthermore, cloud computing enables better storage capacity, processing power, and scalability for large-scale agricultural production situations, which traditional WSNs may need help managing independently. WSNs can also benefit from the combination of DV Hop and RSSI approaches. WSNs can collect data from multiple sensors scattered throughout agricultural areas, enabling complete and accurate monitoring of environmental conditions. Incorporating RSSI in DV Hop improves location estimate accuracy in WSNs by giving exact information about the position of each sensor node. This data may be used to select the best location for sensors to obtain optimum coverage and guarantee that the system can monitor all essential metrics.

The working principle of RSSI is to determine the position of RSSI by the size of the transmitted signal, and the position of RSSI is to estimate the distance based on the attenuation characteristics of the signal. RSSI localization algorithm has small computation and simple hardware design. Its main implementation is to use the transmission strength of anchor signal and the strength that can be accepted by blind node signal to calculate the energy loss of signal. Then, through the correlation model, the loss is converted into distance.

There are many models of RSSI in WSN. Due to the influence of multipath effect and surrounding obstacles, the energy loss in the same distance is different. The power relationship between the signal transmission node and its receiving node is:

$$P_R = \frac{P_T}{r^n} \tag{6}$$

Among them, r is the distance between nodes. P_T represents the radio signal power transmitted by the transmitting anchor node. P_R represents the wireless signal energy received by the receiving blind node.

The RSSI path propagation loss model is:

$$\frac{P_L(d_0)}{P_L(d_r)} = \left(\frac{d_r}{d_0}\right)^n \tag{7}$$

In the above equation, $P_L(d_0)$ is the reference signal power received when the reference distance is set to d_0. $P_L(d_r)$ is the signal power received when the blind node is away from the transmitter d_r.

It is assumed that the RSSI value related to node communication is $RSSI_j$. When the blind node in the network obtains the broadcast packet and the received signal strength is $RSSI_j$, the hop correction value of the node can be written as:

$$hop_i = \frac{RSSI_i}{RSSI_j} \tag{8}$$

Therefore, RSSI improves the accuracy of calculating the minimum hops, and overcomes the error problem caused by the difference of hops in time, so as to reduce the average hop distance of DV Hop location algorithm and the distance error between nodes. Therefore, combining the DV Hop algorithm with RSSI and integrating it with cloud computing and WSNs provide a powerful solution for monitoring agricultural production environment safety. Integrating these techniques enables accurate, reliable, and cost-effective monitoring of environmental parameters in large-scale agricultural production environments, ensuring the safety and quality of agricultural products while minimizing the environmental impact.

Effect experiment of agricultural production environment monitoring system using WSN in cloud environment

This section evaluates the impact and effectiveness of integrating WSN technology with cloud computing in monitoring agricultural production environments. This experiment involves the deployment of a WSN consisting of sensor nodes in the agricultural field, which collect data on various parameters such as temperature, humidity, soil moisture, and crop health. The collected data is then transmitted to the cloud infrastructure for storage, processing, and analysis. The experiment assesses the system's data accuracy, real-time monitoring capability, scalability, and cost-effectiveness. By conducting this experiment, we aim to demonstrate the advantages of combining WSN and cloud computing, highlighting their potential for improving agricultural production management, optimizing resource allocation, and enhancing decision-making processes.

Test results of different positioning algorithms

This study uses MATLAB simulation software to compare the standard DV Hop method with an upgraded variant. The simulation has 120 nodes, allowing for a thorough examination of the algorithms' placement accuracy and inaccuracy. This comparison aims to validate the efficacy of the improved DV Hop algorithm, which integrates RSSI. The MATLAB simulation creates a controlled environment for testing algorithm performance and generates quantifiable measures for measuring the algorithms' ability to estimate node positions reliably. The outcomes of this study provide valuable insights into selecting the best algorithm for agricultural production environment monitoring systems in a cloud environment, thereby boosting agricultural production safety and efficiency. The positioning errors of the two algorithms are shown in Table 1.

As shown in Table 1, the errors of the DV Hop algorithm and the improved DV Hop algorithm are 21.5 m and 5.7 m respectively when the number of nodes is 20. The errors of the two algorithms are 22.3 m and 5.2 m respectively when the number of nodes is 40. The errors of the two algorithms are 22.9 m and 4.8 m respectively when the number of nodes is 60. The errors of the two algorithms are 24.1 m and 3.3 m respectively when the number of nodes is 120. It can be seen that with the increase of the number of nodes, the error of the improved DV Hop algorithm is much smaller than that of the DV Hop algorithm. The positioning accuracy of the two algorithms is shown in Fig. 8.

When the number of nodes is 20, the placement accuracy of the DV Hop algorithm and the modified DV Hop method is 66.8% and 85.4%, respectively, as shown in the above Figure. When the number of nodes is 40, the accuracy of the two methods is 64.5% and 86.7%, respectively.

Table 1 Positioning error of two algorithms (m)

Number of nodes	DV-Hop	Improved DV hop
20	21.5	5.7
40	22.3	5.2
60	22.9	4.8
80	23.2	4.1
100	23.8	3.6
120	24.1	3.3

When the number of nodes is 60, the accuracy of the two methods is 63.2% and 86.9%, respectively. When the number of nodes is 120, the accuracy of the two methods is 57.3% and 90.5%, respectively. The upgraded DV Hop algorithm has greater accuracy than the DV Hop method Fig. 6.

Due to the random distribution of nodes in the simulation run of MATLAB, some nodes have significant deviations. Therefore, in actual use, special attention should be paid to the location of nodes to improve the system's positioning accuracy. There may be some problems in the simulation implementation, such as node loss and significant positioning errors. It is mainly because the nodes are randomly distributed using MATLAB for simulation verification. To prevent losses, they should be distributed appropriately in practical applications.

Monitoring system performance test

The effect experiment of an agricultural production environment monitoring system using WSN in a Cloud Environment focuses on evaluating the reliability and performance of a WSN-based agricultural monitoring system in a cloud environment. This experiment compares two systems: System 1 represents the traditional agricultural production environment safety monitoring system, while System 2 is the proposed WSN system integrated with cloud computing. The experiments are conducted under LAN and cloud network conditions to ensure accurate results. The reliability, data receiving rate, delay, and other transmission indicators are thoroughly tested and compared between the two systems through simulations. By conducting these experiments, the study aims to demonstrate the enhanced performance and benefits of the WSN-based system deployed in a cloud environment, showcasing its potential for improving data accuracy, real-time monitoring capabilities, scalability, and cost-effectiveness in agricultural production environments.

Test of data transmission reliability

System 2 and System 1 have been tested for 60 times under local area network and cloud network. The data transmission reliability test results of the two systems under different conditions are shown in Fig. 7.

Figure 7(a) shows that the data transmission reliability of System 1 under the LAN is 76.8%, 76.9%, 75.3%, 77.7%, 75.9%, and 75.5%, respectively, when the number of tests is 10, 20, 30, 40, 50, and 60. When the test times are 10, 20, 30, 40, 50, and 60, the data transmission reliability of System 2 is 91.3%, 92.4%, 91.7%, 93.2%, 92.9%, and 93.5%, respectively. The data transfer rate of the two systems over LAN is greater than 75%. However, System 2 consistently outperforms System 1 regarding the dependability of data

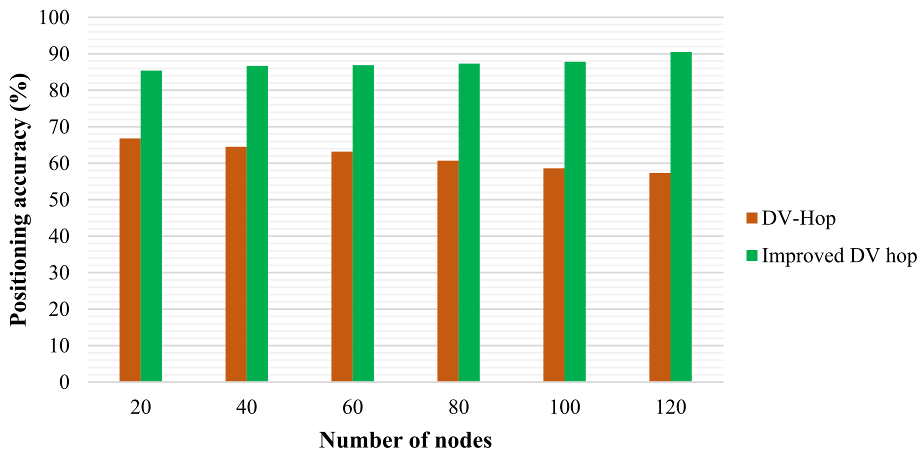


Fig. 6 Positioning accuracy of the two algorithms

transfer. Figure 7(b) shows that the data transmission reliability of System 1 in the cloud network is 75.1%, 74.3%, 74.5%, 75.2%, 72.6%, and 73.8% for test durations of 10, 20, 30, 40, 50, and 60. When the test durations are 10, 20, 30, 40, 50, and 60, the data transmission reliability of system 2 is 90%, 91.2%, 90.8%, 92.5%, 92.1%, and 91.9%, respectively. System 2 consistently outperforms System 1 regarding data transmission reliability via an external network. The research results reveal that the data transmission reliability of System 2 is always more excellent, independent of the LAN or the external network, indicating that System 2's data transmission is reasonably steady.

Data reception rate test

In order to verify the availability of System 2, this paper tests the data reception rate of the system. 200 experiments are conducted for each control command. The data reception rate of System 2 is shown in Fig. 8.

As indicated in the above figure, the device receives data 194 times when turned on, and the data reception rate is 97%. When the equipment is turned off, there are 196 data-receiving times, and the data-receiving rate is 98%. There have been 195 data-receiving requests for equipment status information, with a data-receiving rate of 97.5%. There have been 198 data-receiving requests for data information, with a data-receiving rate of 99%. The test results demonstrate that the data access rate of the system surpasses 95%, indicating that system 2 may significantly enhance data utilization and system use value.

Data delay test

When testing the data delay, 60 experiments are conducted under the LAN and the cloud network, and the data delay of the two systems under the LAN and the external network is obtained as shown in Fig 9.

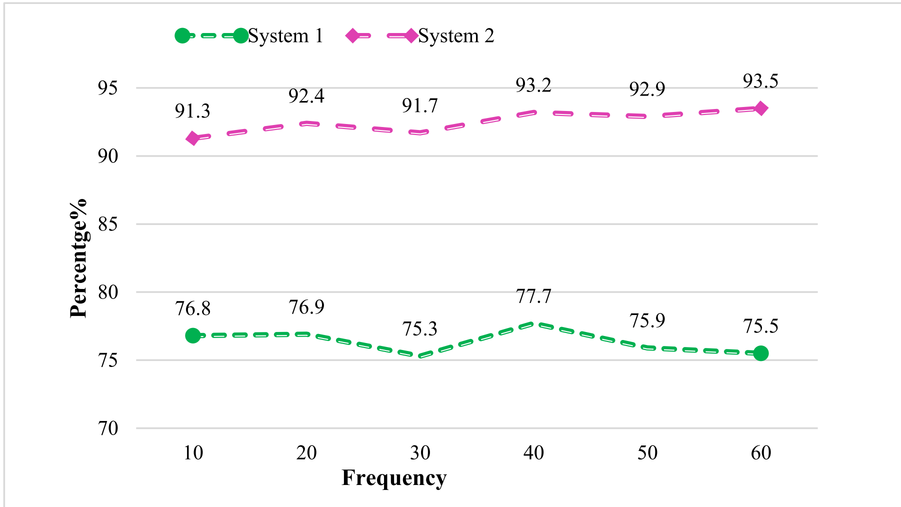
It can be concluded from Fig.9 (a) that the time delay of System 1 under LAN is 2.1 s, 2.4 s, 2.2 s, 2.5 s, 2.7 s and 2.6 s when the number of tests is 10, 20, 30, 40, 50 and 60, respectively. The time delay of system 2 is 1.3 s, 1.1 s, 1.5 s, 1.2 s, 0.8 s and 0.5 s, respectively, when the number of tests is 10, 20, 30, 40, 50 and 60. It can be concluded that the delay of System 2 is lower than that of System 1. From Fig.9 (b), it can be supposed that the delay of System 1 in the cloud network is 3.3 s and 3.5 s, respectively, when the number of tests is 10 and 60. The delay of system 2 is 1.4 s and 1.1 s when the number of tests is 10 and 60, respectively. It can be concluded that the delay of System 2 is lower than that of System 1.

Measures to promote the healthy development of agricultural production environment

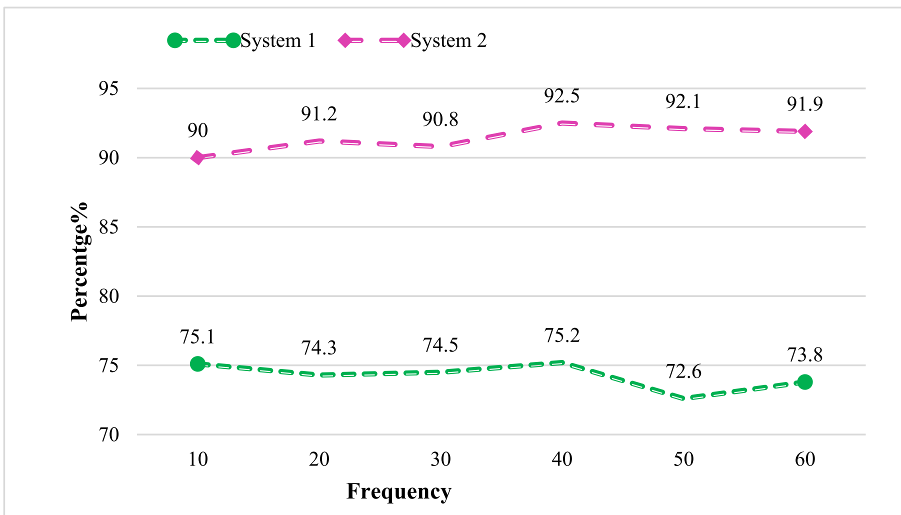
Controlling the use of chemical fertilizer to improve the utilization rate of chemical fertilizer

Through the scientific and rational use of chemical pesticides, the application of agricultural chemicals in the agricultural production environment has played a significant role in ensuring agricultural production. However, excessive or unreasonable application also causes particular pollution to the agricultural production environment, thus affecting the output and quality of agricultural products. The following methods are mainly adopted. The monitoring of pests is strengthened, and timely information is released. Chemical fertilizers are scientifically controlled and rationally used.

The safe use specifications of pesticides are strictly implemented, and pesticides are used in strict accordance with regulations to reduce the use of highly toxic and residual pesticides. The new application machinery has been vigorously promoted to improve the application method to increase fertilizer use efficiency. The use



(a) Data transmission reliability of two systems under LAN



(b) Data transmission reliability of two systems under external network

Fig. 7 Data transmission reliability of the two systems under LAN and extranet. **a** Data transmission reliability of two systems under LAN. **b** Data transmission reliability of two systems under external network

of pollution-free pesticides has been actively promoted. Relevant departments should timely release pesticide varieties with reasonable safety, strong prevention effect, strong selectivity and low dosage, recommend biological pesticides and their preparations, and increase the promotion and application of efficient, economical and green pesticides.

Establishment of a sound and effective mandatory management and supervision system

To ensure the health of the agricultural production environment, it is necessary to strictly monitor agricultural inputs such as fertilizers of agricultural products through effective environmental protection measures and inspection measures. Production operations shall be carried out in the safety management system according to the production and operation methods. A significant investment in agricultural products, such as chemical fertilizers and pesticides, greatly impacts agricultural production and management. Therefore, agricultural production should be combined with effective production management methods to minimize the adverse effect of pollution on the agricultural production environment.

Since pesticides use methods, dosage, and time are not necessarily reasonable and safe, strict control and management should be carried out on agricultural inputs and production methods, and appropriate and efficient supervision should be carried out on them. In addition,

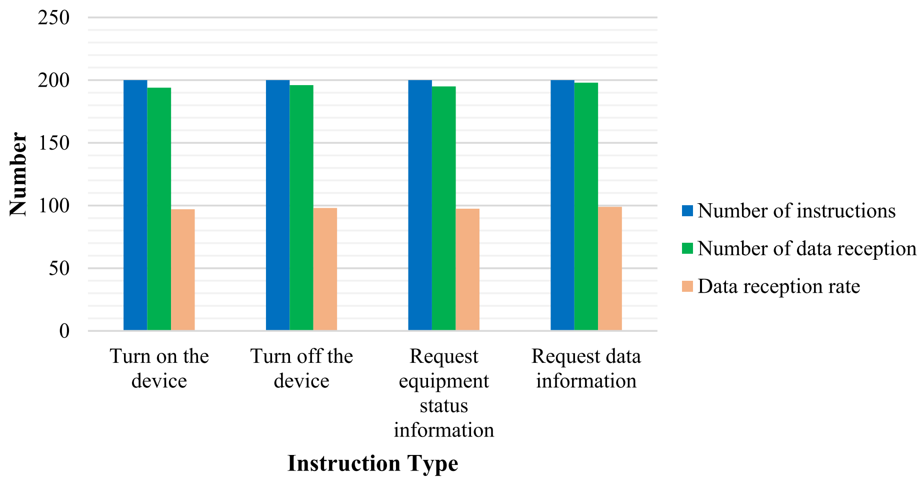


Fig. 8 Data reception rate of system 2

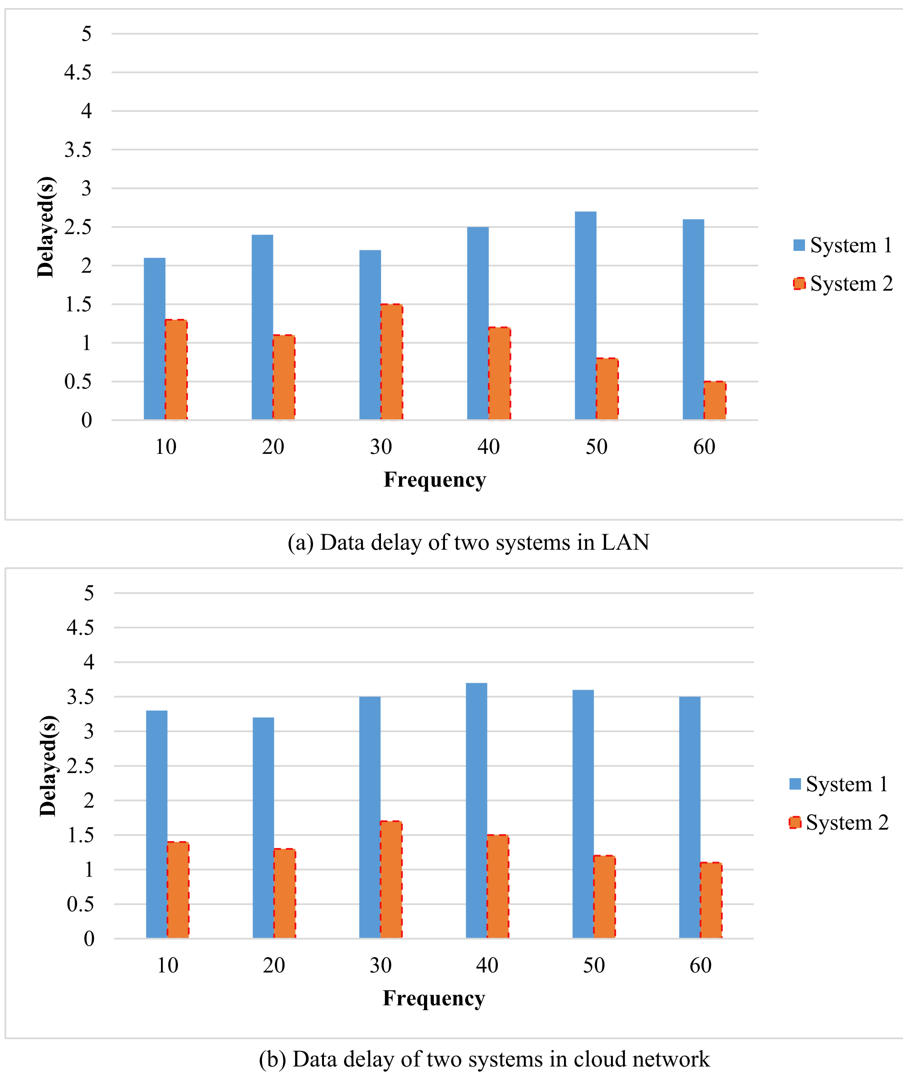


Fig. 9 Data delay of two systems under LAN and extranet. **a** Data delay of two systems in LAN. **b** Data delay of two systems in cloud network

problems should be found in time during the monitoring process, and the existing potential safety hazards should be handled on time.

Conclusions and future research directions

Environmental safety monitoring of agricultural production has always been the focus of China's agricultural work. Significantly, China's agricultural production system has entered a new stage of development. With the development of Cloud Computing, AI optimization technology, and Big Data network, people have higher requirements for intelligent safety monitoring of agricultural production environment. Therefore, this paper has successfully presented a novel Agricultural Production Environment Safety Monitoring System based on Cloud Computing, AI Optimization, and WSN in Big Data Networks. The proposed system surpasses traditional monitoring methods in terms of efficiency, accuracy, and low delay, aligning with the ongoing trend of agricultural development. The research also highlights the improved performance of the DV-Hop algorithm compared to its traditional counterpart, exhibiting reduced errors with an increasing number of nodes. Furthermore, comprehensive tests have demonstrated the system's data transmission, reception rate, and delay reliability. This research conducted a comparative analysis between two systems, namely system 1 and system 2, to assess their performance. The experimental results revealed that system 2 exhibited a remarkable data reception rate, ranging from a minimum of 97% to a maximum of 99%. Notably, these values surpassed the 95% threshold set for data reception rate, indicating the high reliability and effectiveness of system 2. These findings underscore the successful implementation and performance of system 2 in the data reception rate test, as demonstrated in this study. In the future, we plan to explore the integration of edge computing to enhance real-time monitoring capabilities and reduce reliance on cloud infrastructure in the agricultural production environment safety monitoring system.

Authors' contributions

The authors confirm contribution to the paper as follows: Conceptualization, software, visualization: Yunxiao Wei; data collection: Chao Han; analysis and interpretation of results: Zuolong Yu; draft manuscript preparation: Yunxiao Wei, Chao Han. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare no competing interests.

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References

1. Zhang J, Liu Y, Li Z, Lu Y (2023) Forecast-Assisted Service Function Chain Dynamic Deployment for SDN/NFV-Enabled Cloud Management Systems. IEEE Syst J. https://doi.org/10.1109/JSYST.2023.3263865
2. Lv Z, Xiu W (2019) Interaction of edge-cloud computing based on SDN and NFV for next generation IoT. IEEE Internet Things J 7(7):5706–5712. https://doi.org/10.1109/JIOT.2019.2942719
3. Lin Y, Song H, Ke F, Yan W, LiuCai ZF (2022) Optimal caching scheme in D2D networks with multiple robot helpers. Comput Commun 181:132–142. https://doi.org/10.1016/j.comcom.2021.09.027
4. Liu, M., Gu, Q., Yang, B., Yin, Z., Liu, S., Yin, L.,... Zheng, W. (2023). Kinematics Model Optimization Algorithm for Six Degrees of Freedom Parallel Platform. Applied Sciences, 13(5). https://doi.org/10.3390/app13053082.
5. Lv Z, Qiao L (2020) Analysis of healthcare big data. Futur Gener Comput Syst 109:103–110. https://doi.org/10.1016/j.future.2020.03.039
6. Finger R (2019) Precision farming at the nexus of agricultural production and the environment. Annual Review of Resource Economics 11(1):313–335
7. Moutinho V (2018) Efficiency in the European agricultural sector: environment and resources. Environ Sci Pollut Res 25(18):17927–17941
8. Ramankutty N (2018) Trends in global agricultural land use: implications for environmental health and food security. Annu Rev Plant Biol 69(1):789–815
9. Jinbo C (2019) Agricultural product monitoring system supported by cloud computing. Clust Comput 22(4):8929–8938
10. Akhter F (2021) An IoT-enabled portable water quality monitoring system with MWCNT/PDMS multifunctional sensor for agricultural applications. IEEE Internet Things J 9(16):14307–14316
11. Friha O (2021) Internet of things for the future of smart agriculture: A comprehensive survey of emerging technologies. IEEE/CAA Journal of Automatica Sinica 8(4):718–752
12. Arora NK (2019) Impact of climate change on agriculture production and its sustainable solutions. Environmental Sustainability 2(2):95–96
13. Adama IJ (2018) Agricultural production in rural communities: Evidence from Nigeria. Journal of Environmental Management and Tourism 9(3):428–438
14. Trukhachev VI (2018) Monitoring of efficiency of Russian agricultural enterprises functioning and reserves for their sustainable development. Montenegrin Journal of Economics 14(3):95–108
15. Lv Z, Lou R, Li J, Singh AK, Song H (2021) Big data analytics for 6G-enabled massive internet of things. IEEE Internet Things J 8(7):5350–5359. https://doi.org/10.1109/JIOT.2021.3056128
16. Lv, Z., Chen, D., Feng, H., Wei, W., & Lv, H. (2022). Artificial Intelligence in Underwater Digital Twins Sensor Networks. ACM Trans. Sen. Netw., 18(3). https://doi.org/10.1145/3519301.
17. Ashraf I (2021) 01. A review on organic farming for sustainable agricultural production. Pure and Applied Biology (PAB) 5(2):277–286
18. Basso B, Antle J (2020) Digital agriculture to design sustainable agricultural systems. Nature Sustainability 3(4):254–256
19. Ahirwar S (2019) Application of drone in agriculture. Int J Curr Microbiol App Sci 8(1):2500–2505
20. Thakur D (2019) Applicability of wireless sensor networks in precision agriculture: A review. Wireless Pers Commun 107(1):471–512
21. Einarsson R, Pitulia D, Cederberg C (2020) Subnational nutrient budgets to monitor environmental risks in EU agriculture: calculating phosphorus budgets for 243 EU28 regions using public data. Nutr Cycl Agroecosyst 117(2):199–213
22. Zhang Lu (2018) The impact of agricultural chemical inputs on environment: global evidence from informetrics analysis and visualization. International Journal of low-Carbon technologies 13(4):338–352

23. Zenggang X, Mingyang Z, Xuemin Z, Sanyuan Z, Fang X, XiaochaoXiang ZL (2022) Social Similarity Routing Algorithm based on Socially Aware Networks in the Big Data Environment. Journal of Signal Processing Systems. https://doi.org/10.1007/s11265-022-01790-3
24. Li Q, Lin H, Tan X, Du S (2020) H∞ Consensus for multiagent-based supply chain systems under switching topology and uncertain demands. IEEE Transactions on Systems, Man, and Cybernetics: Systems 50(12):4905–4918. https://doi.org/10.1109/TSMC.2018.2884510
25. Liu, D., Cao, Z., Jiang, H., Zhou, S., Xiao, Z.,... Zeng, F. (2022). Concurrent Low-Power Listening: A New Design Paradigm for Duty-Cycling Communication. ACM Trans. Sen. Netw., 19(1). https://doi.org/10.1145/3517013.
26. Yu J, Lu L, Chen Y, Zhu Y, Kong L (2021) An Indirect Eavesdropping Attack of Keystrokes on Touch Screen through Acoustic Sensing. IEEE Trans Mob Comput 20(2):337–351. https://doi.org/10.1109/TMC.2019.2947468
27. Liu G (2021) Data Collection in MI-Assisted Wireless Powered Underground Sensor Networks: Directions, Recent Advances, and Challenges. IEEE Commun Mag 59(4):132–138. https://doi.org/10.1109/MCOM.001.2000921

Publisher's Note

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