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Research Article

Energy Efficiency Analysis of Wireless Sensor Networks in Precision Agriculture Economy

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Wireless sensor network (WSN) can play an important role during precision agriculture production to promote the growth of the agricultural economy. The application of WSN in agricultural production can achieve precision agriculture. WSN has the biggest challenge of energy efficiency. This paper proposes a model to efficiently utilize the energy of sensor nodes in precision agriculture production. The proposed model provides a comprehensive analysis of the precision agriculture. The model focuses on the characteristics of WSN and expands its application in precision agriculture. In addition, this paper also puts forward some technical prospects to provide a good reference for comprehensively and effectively improving the overall development level of precision agriculture. The paper analyzes the applicability and limitations of the existing sensor networks used for agricultural production technology. The ZigBee and Lora wireless protocols are utilized to have the best power consumption and communication in short distance and long distance. Our proposed model also suggests improvement measures for the shortcomings of existing WSN in the context of energy efficiency to provide an information platform for WSN to play a better role in agricultural production.

1. Introduction

Agriculture has always been an important pillar industry in the process of China's economic construction. Because of the existence of excessive fertilization in agricultural production activities, some phenomena such as farmland pollution, environmental deterioration, and biodiversity destruction have been brought into consideration [1]. These factors seriously affect the production, growth, and economic construction of the agriculture field. To promote the sustainable development of modern agriculture, the advanced scientific production technology is required to be considered along with good management of agricultural production activities. In the process of precision agriculture, the use of WSN can play a significant role in the context of energy efficiency. Precision agriculture is a management strategy in the process of agricultural production. It uses information technology reasonably and continuously improves the output and quality of agricultural production [2]. It also reduces the degree of environmental pollution and waste of energy and resources. The resources include energy and water. It improves the accuracy and modernization of agricultural production.

In China, the development of precision agriculture is still in the exploratory stage and faces many key technical problems. It is necessary to scientifically adopt modern monitoring means and fully control the use of pesticides and fertilizers. Moreover, proper monitoring and control are also required [3, 4]. At present, precision agriculture is still in the early stage of exploration and faces many key technical problems to be solved. For instance, the use of chemical fertilizers and pesticides can greatly improve food production. It is observed that the lack of scientific monitoring for soil fertility, plant diseases, and insect pests can affect the plants badly. In addition, the lack of fast and effective perception technology and equipment can also lead to the poor food production process. Moreover, the blind use of chemical fertilizers and pesticides may not only cause a lot of waste of resources but also bring serious soil and environmental pollution. Due to the variety and high cost of applied sensors needed in precision agriculture to overcome these challenges, the product has not yet achieved market scale due to the lack of standardization research. At present, there are many restrictive factors in the use of agricultural sensors, such as diversified conditions, bad working environment, insufficient power supply, and short service life. Moreover, the agricultural production base is far away from the city due to which the public information and communication infrastructure are poor and the cost of special communication means is high. There are spectrum compatibility and interference problems as well.

WSNs are utilized for the measurement of temperature, monitoring the environment, measurement of irrigation system, and measurement of water supply in agricultural applications. WSNs support the farmers to generate high quantity crops. However, they require a battery power supply to provide energy to sensor nodes. These networks increase the quality and production of the crops which directly affect the economy. Recent studies have found that many problems in the implementation of precision agriculture will be gradually solved with the application and development of these networks. The application of wireless sensor network in agriculture is one of the most favorable methods to achieve precision agriculture, improve the yield of food crops, and reduce the burden of farmers. The use of WSN is significant for ensuring the healthy growth of crops to achieve precision agriculture [5, 6]. It can minimize the use of pesticides, effectively control weeds and pests, and achieve efficient green precision agriculture. WSN can sense and collect real-time data of various information changes in the process of agricultural production and provide timely feedback to the users. The data analysis and processing results are forwarded to users to realize the efficient management of precision agriculture.

This paper discusses the development potential of WSN in agricultural production from the communication protocol perspective. The paper focuses on the characteristics of WSN and expands its application in precision agriculture. In addition, the paper also puts forward some technical prospects to provide a good reference for comprehensively and effectively improving the overall development level of precision agriculture. The paper further analyzes the applicability and limitations of the existing sensor networks used in agricultural production technology.

The rest of this paper is organized as follows. In Section 2, the background studies in the context of our work are presented. In Section 3, our proposed design for moisture monitoring and automatic water-saving irrigation system is discussed. In Section 4, we discuss our monitoring and early warning of diseases and insect pests. In Section 5, simulation results are provided followed by concluding remarks in Section 6.

2. Background and Related Work

During the rapid deployment of WSN technology, the battery power supply with sensor nodes is mainly used as an energy supply [7, 8]. The WSN is a collection of detached and devoted sensors that observe and record the semantic state of the surroundings and transfer the recorded information to a principal site. WSN architecture and the detailed structure are shown in Figure 1. Battery-powered WSN consists of sensor nodes, processors, and radio frequency (RF) modules. The sensor node can communicate wirelessly through the communication link and forward its data to the base station or coordinator node through the gateway communication. A node is used to collect, compute, and communicate the data and information with its associate nodes in a particular network. The communication can collect information from various sensors in sensor nodes from simple (i.e., humidity, pressure, and temperature) to complex (i.e., positioning, tracking, microradar, and image) and then combine and transmit it to the wireless sensor network to realize real-time monitoring of WSN. Therefore, the sensor nodes have the function of monitoring, storing, and processing information in the whole monitoring process [9]. The communication will send the information to the WSN to implement the real-time monitoring function. WSN has a wide range of application effects to obtain sufficient and accurate environmental information in the process of precision agriculture. WSN includes three major components: base station, sensor node, and sink node [10–12].

The sensor node has the ability to communicate and compute. The connection process adopts the form of short-range wireless, which can form a multihop wireless network. The introduction of wireless sensor network into precision agriculture can fully monitor the growth data of crops, comprehensively obtain the agricultural environment information, and support the steady development of precision agriculture activities [13, 14]. WSN itself has low power consumption, simple use, and low cost. It can adapt to the agricultural production environment and has long-term stable performance. It can design some data acquisition algorithms with modern agricultural characteristics to significantly improve the speed of data acquisition and support the smooth development of precision agriculture activities. Currently, WSN is extensively utilized in monitoring the agriculture field to advance the quality of service (QoS) and enhance the production of farming. In this agriculture field, the sensors collect diverse kinds of information (e.g., CO2 level, humidity, and temperature) in instantaneous situations.

The WSN can not only realize precision agriculture and improve agricultural yield but also be used in other agricultural applications. It can be utilized for soil nutrient data to predict the health status of crops and the quality of agricultural products [15, 16]. In addition, it can also be utilized for predicting irrigation planning by observing weather conditions (such as temperature and humidity) and soil moisture. Relevant sensor nodes can be added to the existing WSN to improve the parameter agricultural monitoring system and expand the network. However, there are some problems in the application of WSN in agriculture, such as determining the best deployment scheme, measurement cycle, routing protocol, communication range, scalability, and fault tolerance [17]. The decentralized deployment of sensor nodes requires a long time of data collection, and the communication link may be weakened or

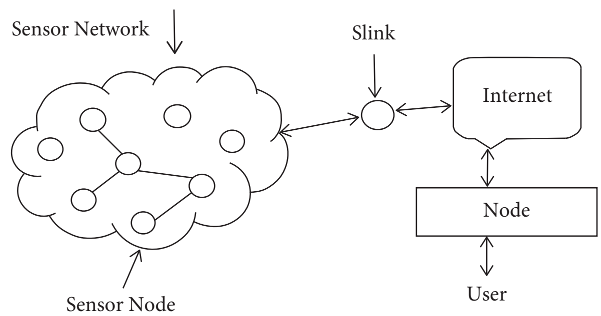

Figure 1: Schematic diagram of wireless sensor network architecture.

lost due to signal attenuation. The sensor nodes in wireless sensor networks are powered by battery, which is limited to the limited battery power, so there are some problems in WSN, such as power consumption and battery life extension. Although the application of WSN has been increasing for many years, the application of WSN is limited due to the slow development of the battery manufacturing industry [18]. UAV or UAV can be connected with the base station to establish mobile data connection service to meet the requirements of the battery power amplifier and solve the problem of the long distance between farm and base station. This connection allows sensor nodes to relay their data to the base station in the farmland area, which can buffer the limit of the wireless sensor battery.

The Internet of Things (IoT) is the revolution of the Internet, which connects all things that can be connected. The development of mobile cellular network technology plays a vital role in the field of IoT. Narrowband Internet of Things (NB IoT) is a new IoT system based on the current development of cellular network LTE function [19]. Narrowband IoT can share the LTE spectrum without interference and can use the same device to connect to LTE main network seamlessly, supporting all network facilities, such as security, tracking, policy, billing, and authentication [20]. NB IoT has very low power consumption, which can extend the battery life for 10 years. The design goal of narrowband IoT has the characteristics of low power consumption, wide coverage, many connection points, low cost, and so forth. In the near future, NB IoT technologies such as long-distance radio Lora and SIG fox will play an increasingly important role in agricultural IoT due to their advantages of low power consumption and long-distance transmission. The WSN has a wide range of applications including the agriculture production where it is extensively utilized in monitoring the agriculture field to advance the quality of production of farming. However, the battery power supply with sensor nodes is mainly used and efficient utilization of the energy is one of the big challenges during the rapid development of WSN technology.

3. Design of Moisture Monitoring and Automatic Water-Saving Irrigation System

This section provides the proposed design for moisture monitoring and water-saving irrigation system. The proposed system is designed taking into consideration the fact that Xi'an city is rainy in summer and dry in winter and has abundant sunshine that is prone to drought and flood. The average water resources per capita of the city are less than 500 cubic meters that is lower than the national average level. Based on this, a water-saving irrigation control system based on WSN is designed, and the system is mainly composed of low-power wireless sensor network nodes through ZigBee ad hoc network [21, 22]. The soil moisture information parameters to be monitored include soil water potential, soil moisture content, air temperature, relative humidity, and groundwater level. The sensor used is a four-channel temperature and humidity transmitter. Through the signal value measured by the sensor, the information parameters can be calculated by the empirical formula. A detailed description of the proposed design is provided in the upcoming subsections.

3.1. Design of Automatic Water-Saving Irrigation System for Farmland.

The agricultural irrigation system based on WSN consists of four parts that are sensor node group, receiving node, irrigation controller, and irrigation pipe network as shown in Figure 2. The sensor nodes carrying soil moisture are deployed according to the planting status and irrigation status of farmland to form an irrigation node group. Each node is responsible for monitoring the soil moisture in a small area. The irrigation area node group and the receiving node constitute a typical WSN, using ZigBee wireless data transmission technology. The sensor data are uploaded to the receiving node in the form of wireless multihop. The automatic water-saving irrigation system is to lay an irrigation pipe network on the farmland in the irrigation area and install an electric control valve on the pipe. The overall system would be more flexible if the water-saving irrigation control is flexible. The automatic water-saving irrigation can be transformed on the basis of the original irrigation pipe network. The original irrigation pipe network can be installed with an electric control valve to make better use of the original irrigation pipe network and reduce investment. In the area covered by WSN, the irrigation controller can spray irrigation in specific areas according to the sensor information. The proposed system includes a particular module that is responsible for the supervision of the entire network. The proposed Automatic Water-Saving Irrigation System is basically based on sensor-free network.

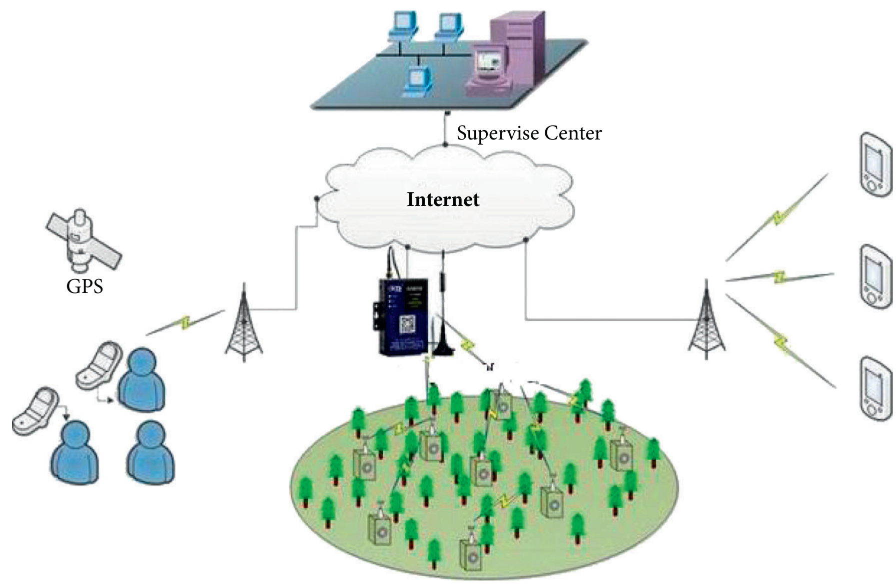

Figure 2: Automatic water-saving irrigation system based on sensor-free network.

3.2. System Function Module. The hardware structure of the sensor node realized in the proposed design is discussed in this section and shown in Figure 3. The hardware structure is mainly composed of controller module, sensor module, ZigBee protocol communication module, and solar self-powered module.

3.3. Design of Irrigation Controller. S3c2410arm9 development board of embedded system is used as the mainboard to constitute the irrigation controller. The receiving node transmits information through a serial port and processes the control information. An electric control valve is controlled by an I/O port. S3C2410 has 117 multifunction I/O ports. The system has high scalability. The WSN periodically detects the humidity (the period is 10 s) and uploads it to the irrigation controller. When the irrigation controller finds that the humidity detected by the WSN nodes in a certain area is lower than the specified value, it turns on the electric control valve of the pipe network in the area for sprinkling irrigation. When the soil humidity in the area rises to a certain value, the system will start sprinkling irrigation and close the electric control valve of the pipe network in this area to stop sprinkling.

4. Monitoring and Early Warning of Diseases and Insect Pests

The Huainan City environment is taken into consideration to issue the early warning. The warning is concerned with diseases and insects pests. The planting patterns of Huainan City are basically one rice, one wheat (water and drought mixed cropping pattern), or one bean. Wheat and rice sheath blight are the main common diseases of grain crops in Huainan City. There is an information chain of data collection to data submission and management, then data processing and forecasting, and finally the pest forecasting information release in the content of pest monitoring and early warning. The information chain is also shown as follows:

Data collection⟶data submission and management

Data submission and management⟶data processing and forecasting

Data processing and forecasting⟶pest forecasting information release

Each link of the information chain is corresponding to the technology of data acquisition, data transmission, data processing, and data application in information technology.

4.1. Associated Technologies. The technologies related to monitoring and early warning are discussed in this section. Each link of the pest monitoring and early warning information chain involves sensor technology, database technology, expert system technology, artificial neural network technology, global positioning technology (GPS), geographic information system technology (GIS), network technologies, and communication technology. Among them, the automatic counting of microinsects mainly uses computer image processing technology to solve the problems of difficult investigation and data acquisition. The automatic recording device of insect trapping is to count the number of insects through scanning grating by using the attraction of sex attractant. Pad and GPS data acquisition and recording technology are mainly used for manual investigation of conventional diseases and insect pests. It is used to record the data and GPS positioning information at the same time. The field microclimate data are also recorded at the same time that is closely related to the occurrence of diseases and various pests. The field microclimate data monitoring technology mainly uses sensor technology and GPRS network communication technology to automatically obtain real-time microclimate data. The data are relevant to diseases and various pests and transmit them to the database for standby.

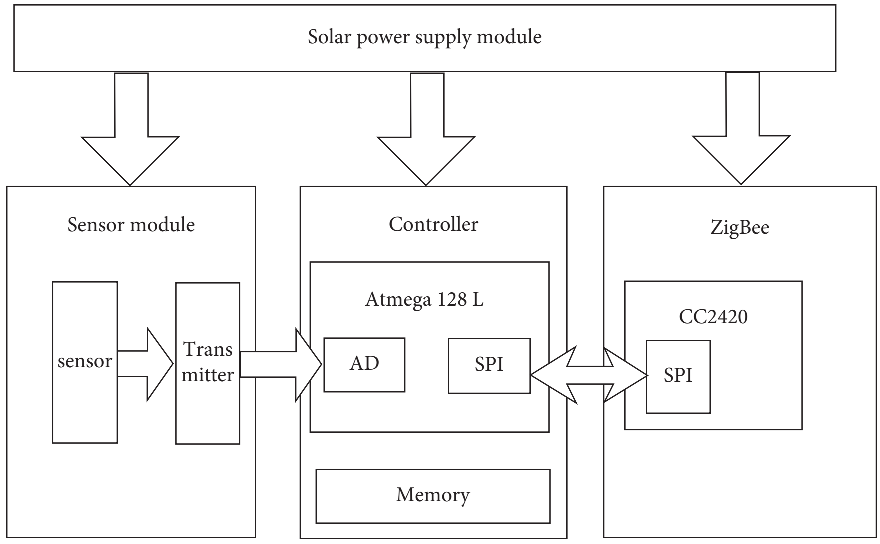

Figure 3: Hardware structure of sensor node.

4.2. Technical Assembly and Matching. The data collection technologies (the main data sources of the proposed system) are assembled with data transmission technology. It can provide real-time and reliable monitoring data of diseases and pests and microclimate for the data management system. Insect pests and environmental factors in the data management system are considered as the input of the expert system. The inference engine of the expert system is driven to forecast the diseases and insect pests, and the forecast information is released through the forecast information release system to guide the plant protection work.

5. Simulation Analysis of Precision Agriculture Effect

The simulation analysis is performed in this section for the precision agriculture effect. In order to master the growth status of animals and plants and improve the scientific management level, it is necessary to monitor the specific physiological and ecological indicators of animals and plants. In the past, the monitoring methods were relatively backward, which affected the growth control activities of animals and plants. At this stage, WSN is actively introduced in the process of precision agriculture production, which can automatically sense the state of crop growth link at a lower cost. In addition, an intelligent system is used to accurately monitor, analyze, and record the physiological and ecological parameters of animals and plants that provide a good premise for effectively improving the efficiency of monitoring work as shown in Figures 4 and 5.

The lack of water resources is an important factor for restricting the current economic growth, but there is a serious waste of agricultural water. It is necessary to strengthen the research work of water-saving irrigation. The good application of WNA (Wireless Network Agriculture) is the monitoring of water during the process of crop growth and comprehensively monitoring of the actual water and soil moisture in the irrigation area. The WNA is basically a simple WSN (Wireless Sensor Network) that is utilized for agriculture applications and production. It also formulates a scientific and effective irrigation scheme combined with the development of these crops. However, it should be noted that the application of WSN in agricultural production is not widespread, mostly in a small-scale production environment such as tea garden, orchard, and greenhouse, and further research. The development is needed in large-scale farmland production.

It is evident from Figure 4 that agricultural irrigation based on wireless sensor network has played a very good role in water saving with the increase of time. It is necessary to monitor the specific physiological and ecological indicators of animals and plants for mastering the growth status of animals and plants to improve the scientific management level. In the past, the monitoring methods were relatively backward, which affected the growth control activities of animals and plants. At this stage, WSN is actively introduced in the process of precision agriculture production, which can automatically sense the state of crop growth link at a lower cost. In addition, an intelligent system is used to accurately monitor, analyze, and record the physiological and ecological parameters of animals and plants that provide a good premise for effectively improving the efficiency of monitoring work.

Figure 5 reveals that the energy efficiency of precision agriculture based on WSN is far lower than that of traditional agriculture according to the data from January 2020 to May 2021.

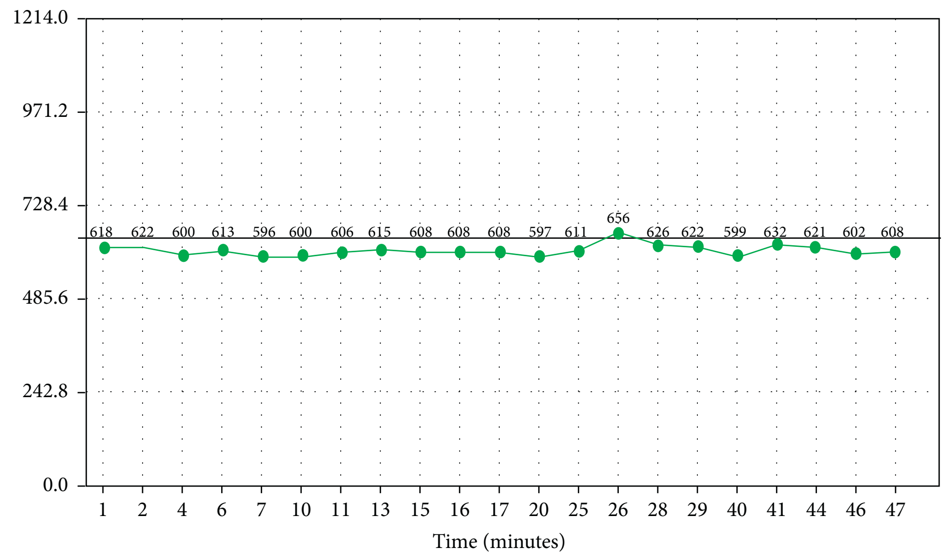

Figure 4: Change curve of agricultural irrigation water.

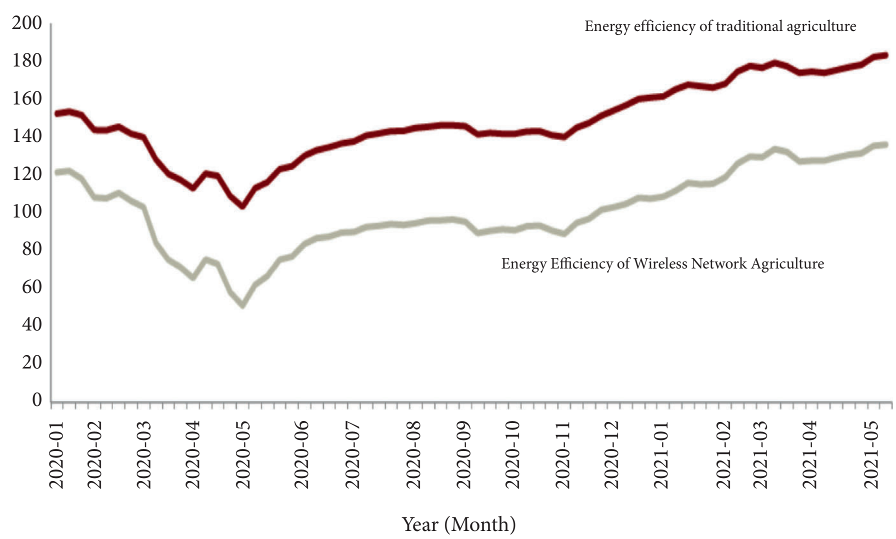

Figure 5: Energy efficiency analysis of physiological and ecological parameters.

6. Conclusion

Wireless Sensor Networks (WSNs) have the biggest challenge of energy efficiency. This paper suggests a scheme to efficiently utilize the energy of WSN in precision agriculture production. The proposed model aims to bring improvement measures for the shortcomings of existing WSN in the context of energy efficiency to provide an information platform for WSN to play a better role in agricultural production. WSN can play an important role in the growth of the agricultural economy. It is evident from the results that WSN can achieve precision agriculture by improving accuracy and efficiency and reducing the cost of wireless protocol systems. Precision agriculture can use the agricultural automation system to improve the management mode and improve the production efficiency.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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References

[1] X. Zhang, *Research and Development of Agricultural Environment Monitoring and Control Platform Based on Wireless Network*, Wuhan University of Technology, Wuhan, China, 2016.

[2] C. W. Jiexinchun, "Design and application of agricultural irrigation hydropower management system based on wireless network," *Hydropower and Energy Science*, vol. 14, no. 12, pp. 143–146, 2011.

[3] N. Jiang and C. Shrena, "Automatic obstacle avoidance system of agricultural robot based on wireless network security," *Agricultural Mechanization Research*, vol. 42, no. 2, pp. 238–242, 2020.

[4] J. Zhao, S. Sun, J. Guo et al., "Design of intelligent monitoring system for facility agricultural environment based on wireless sensor network," *China Agricultural Machinery Chemical Report*, vol. 41, no. 4, pp. 152–157, 2020.

[5] J. Yang and J. Wang, "Research on wireless sensor network protocol for precision agriculture," *Journal of Internet of Things*, vol. 4, no. 4, pp. 65–72, 2020.

[6] Y. Xie, Z. Li, Z. Wang et al., "Research on key technologies of wireless sensor network for fine agriculture," *Computer Science and Application*, vol. 10, no. 10, p. 7, 2020.

[7] S. M. Antony, S. Indu, and R. Pandey, "An efficient solar energy harvesting system for wireless sensor network nodes," *Journal of Information and Optimization Sciences*, vol. 41, no. 1, pp. 39–50, 2020.

[8] F. K. Shaikh and S. Zeadally, "Energy harvesting in wireless sensor networks: a comprehensive review," *Renewable and Sustainable Energy Reviews*, vol. 55, pp. 1041–1054, 2016.

[9] O. H. Yahya, H. Alrikabi, and I. A. Aljazaery, "Reducing the data rate in internet of things applications by using wireless sensor network," *International Journal of Online and Biomedical Engineering*, vol. 16, no. 3, pp. 107–116, 2020.

[10] E. Zhang, Z. Zhang, and J. Chang, "Development of intelligent agricultural crop environment multi parameter monitoring system based on wireless sensor network," *Journal of the Yellow River Academy of Science and Technology*, vol. 22, no. 2, pp. 84–88, 2020.

[11] Y. Liang, *Development of Remote Intelligent Control System for Facility Agriculture Based on WSN*, Chongqing Three Gorges College, Chongqing, China, 2020.

[12] F. Tian and J. He, "Design and implementation of agricultural information collection system based on ZigBee," *Journal of Suzhou Vocational University*, vol. 31, no. 1, pp. 25–29, 2020.

[13] X. Cao, "The strategy of selecting charging nodes in wireless sensor networks," *Modern Computer*, vol. 682, no. 10, pp. 31–34, 2020.

[14] M. Chen, X. Wang, and H. Zhang, "Wireless visual intelligent agricultural management system based on WSNs," *Agricultural Mechanization Research*, vol. 10, no. 7, 2021.

[15] C. Wang, D. Wang, F. Wang et al., "Multi factor authentication protocol for multi gateway wireless sensor network," *Journal of Computer*, vol. 16, no. 4, pp. 683–700, 2020.

[16] J.-J. Hao, "Application of wireless sensor network in modern agriculture in Guanzhong region," *Information and Computer*, vol. 32, no. 19, pp. 128-129, 2020.

[17] C. Huang, Z. D. Wang, F. Wang, L. Mei, and X. S. Chen, "Research and design of agricultural environment monitoring system based on STM32 + ZigBee technology," *Agriculture and Technology*, vol. 40, no. 23, pp. 62–64, 2020.

[18] L. Yang, B. Zhang, and T.-T. Chen, "Design of cluster agricultural environment information collection network based on nRF24L01," *Digital Technology and Application*, vol. 38, no. 1, pp. 134–136, 2020.

[19] Y. D. Beyene, R. Jantti, K. Ruttik, and S. Iraji, "On the performance of narrow-band Internet of Things (NB-IoT)," in *Proceedings of the 2017 IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1–6, IEEE, San Francisco, CA, USA, March 2017.

[20] S. Popli, R. Kumar Jha, and S. Jain, "A survey on energy efficient narrowband internet of things (NBIoT): architecture, application and challenges," *IEEE Access*, vol. 7, pp. 16739–16776, 2018.

[21] H. C. Wang, G. Qin, Z. Lu et al., "Design of intelligent monitoring network system for agricultural shed based on single chip microcomputer," *Wireless Internet Technology*, vol. 17, no. 5, pp. 55–57, 2020.

[22] Y. Jia, *Research on Wireless Irrigation System Based on ZigBee*, Xi'an University of Electronic Technology, Xi'an, China, 2020.