The Application Research of Ubiquitous Networking in Smart Agriculture

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Abstract. With the rapid development of information technology, Ubiquitous Networking, as an emerging network technology, has demonstrated significant application potential in various fields. Smart agriculture, as a crucial direction for agricultural development, holds great importance in improving agricultural production efficiency and product quality. This paper focuses on the application of Ubiquitous Networking in smart agriculture, analyzes existing agricultural traceability systems, identifies their problems, and proposes potential solutions for improvement using Ubiquitous Networking technology. The article provides a detailed introduction to the basic concepts of Ubiquitous Networking, its development history, and application examples in the agricultural domain. It particularly explores the roles and advantages of two key application technologies, sensor networks, and big data analytics, in agriculture. Based on this exploration, a preliminary design scheme for a Ubiquitous Networking-based agricultural production system is proposed, with detailed descriptions of its architecture, key technologies, and workflow. Finally, the paper elucidates the implementation process of the system, outlines the application prospects of Ubiquitous Networking in smart agriculture, and suggests directions and recommendations for future research.

Keywords: Ubiquitous Networking; Smart Agriculture; Agricultural Traceability; Sensor Networks; Big Data Analytics

1. Introduction

With the continuous growth of the global population, economic development, and the increasing strain on resources, traditional agriculture has found it challenging to meet the escalating demands for food safety and quality. In response to these challenges, smart agriculture has emerged. Smart agriculture harnesses modern information technology to achieve precise management and intelligent decision-making in agricultural production through real-time monitoring and data analysis of the agricultural environment. This has significantly elevated agricultural production efficiency and product quality. As the world grapples with a burgeoning population and economic activities, coupled with the growing scarcity of resources, traditional agricultural practices are increasingly inadequate to meet the rising expectations for food safety and quality. In response, smart agriculture has come to the forefront. Smart agriculture leverages modern information technology to enable real-time monitoring and data analysis of the agricultural production environment, facilitating precise management and intelligent decision-making. This, in turn, greatly enhances agricultural production efficiency and product quality. Smart agriculture, by integrating fundamental biotechnology with information technology and

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deploying intelligent equipment, infuses advanced technologies into agriculture. This infusion enhances agricultural productivity and triggers innovation in the agricultural sector[1]. Ubiquitous Networking, as a novel networking technology, connects various objects from the physical world to the network, enabling interconnection between humans and objects, as well as between objects themselves[2]. It facilitates comprehensive perception, transmission, and processing of information, providing robust technological support for the development of smart agriculture. Within the Ubiquitous Networking, numerous microcomputers collaborate, adjusting their behavior based on real-world context to deliver flexible information services[3]. Ubiquitous Networking, as a novel network technology, interconnects various objects in the physical world, achieving the interconnection of people with objects and objects with objects. It comprehensively perceives, transmits, and processes information, providing robust technical support for the development of smart agriculture. In the realm of Ubiquitous Networking, numerous microcomputers collaborate, adjusting their behavior based on the real-world context to offer flexible information services. This technology not only enables real-time monitoring of crop growth environments in agriculture but also, through the analysis of collected extensive data, provides a scientific basis for decision-making in agricultural production. This paper aims to explore the application of Ubiquitous Networking in smart agriculture, discussing how to leverage this technology to enhance agricultural productivity and product quality. It offers theoretical support and technical guidance for the modernization of agriculture. Through an analysis of existing agricultural product traceability systems, the paper proposes a design scheme for a Ubiquitous Networking-based agricultural product traceability system, providing new insights and methods for the application of Ubiquitous Networking in smart agriculture.

2. Analysis of Existing Agricultural Product Traceability Systems

The agricultural product traceability system is a management system that utilizes modern information technology to trace and record various stages of agricultural products, including production, processing, transportation, and sales. This system enables rapid feedback and precise positioning in agricultural production management. Simultaneously, it adds value to agricultural products through labeling and terminal query display functions.

2.1 Working Principles and Structure of Current Agricultural Product Traceability Systems

The agricultural product traceability system primarily functions by establishing checkpoints in various stages of agricultural product production, processing, transportation, and sales. It utilizes diverse information collection devices such as barcode scanners, RFID readers, sensors, etc., to gather relevant information about agricultural products. This information is then transmitted over the network to a central database for storage and management. Consumers can access detailed information about agricultural products, including place of production, production date, production batch, inspection and quarantine results, transportation routes, etc., by inputting the unique identification code through the internet or other query terminals. This enables comprehensive tracking and traceability of agricultural products. We analyzed the above cases and constructed the flow chart, for an example see **Figure 1**, which explains the structure of agricultural product traceability system:

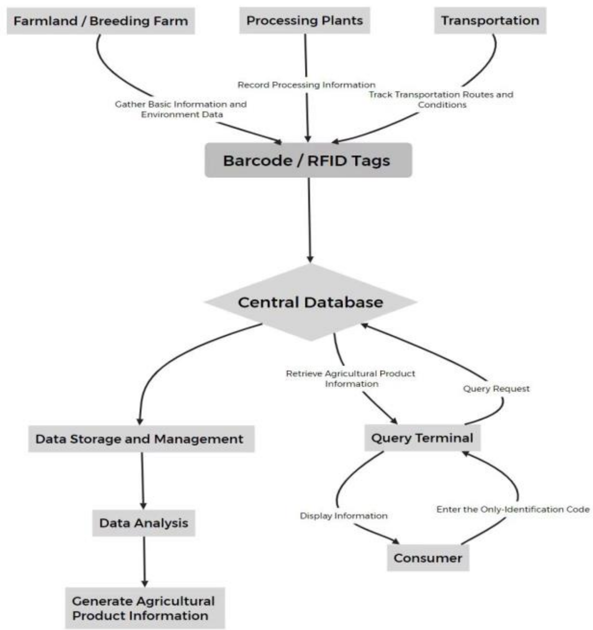

Figure 1. Farm Product Traceability System Architecture

The structure of an agricultural product traceability system typically comprises four main components: information collection layer, network transmission layer, data processing layer, and application service layer.

Information Collection Layer: This layer is primarily responsible for gathering relevant information about agricultural products throughout various stages such as production, processing, transportation, and sales. Commonly used information collection devices include barcode scanners, RFID readers, sensors, cameras, etc. Network Transmission Layer: This layer is mainly responsible for transmitting the data collected by the information collection layer over the network to the data processing layer. Commonly used network transmission technologies include wireless networks, wired networks, mobile communication networks, etc. Data Processing Layer: This layer is primarily responsible for storing, managing, and analyzing the data received from the network transmission layer. Commonly used data processing technologies include database management systems, big data analytics, cloud computing, etc. Application Service Layer: This layer is mainly responsible for providing services to users such as querying, verification, and analysis. Users can input the unique identification code of agricultural products through the internet or other query terminals to retrieve detailed information about the products.

Through the collaborative work of these four layers, the agricultural product traceability system can achieve comprehensive tracking and recording of the entire process of agricultural products, ensuring the quality and safety of the products.

2.2Advantages and shortcomings of the current system

The advantages of the existing agricultural product traceability system are primarily reflected in 1) The safety of agricultural products has been enhanced. According to the "China Digital Rural Development Report (2022)," in 2021, China's smart agriculture construction experienced rapid development, with the informatization rate of agricultural production reaching 25.4%. The rural internet penetration rate reached 58.8%. The efficiency of digital governance in rural areas continued to improve. The construction of agricultural informatization is conducive to the comprehensive monitoring of the entire process of agricultural products. Once issues are detected, they can be traced back to the source quickly, and timely measures can be taken[4]; 2) Increased consumer trust in agricultural products, as consumers can directly access detailed information, making purchases with confidence; 3) Improved market competitiveness for agricultural products, as the traceability system serves as a guarantee, making it easier for products to gain consumer recognition.

However, the existing agricultural product traceability system also has some shortcomings: 1) The phenomenon of data silos is severe. According to the "Digital Government Construction: Data Sharing and Digital Governance," during the implementation of integrated government services, various levels of government have access to massive public data, but issues such as data silos and closed loops persist. The limited sharing of public data is primarily due to the close association between public data and data security. Public data with fine granularity often involves various types of people's privacy[5]. It is challenging to achieve data sharing and interoperability among traceability systems in different regions and enterprises.; 2) Insufficient precision in monitoring the production stages of agricultural products, as many critical data depend on manual entry, leading to potential errors; 3) The real-time and accuracy aspects of the system need improvement, as issues with the traceability system could potentially disrupt the normal operation of the entire agricultural product supply chain.

To address these issues, improvements to the existing agricultural product traceability system can be achieved through the utilization of Ubiquitous Networking Technology. Ubiquitous Networking Technology enables real-time monitoring of the agricultural production environment by installing various sensors in the fields to collect data on soil, climate, etc. The data is then transmitted wireless to a database, ensuring real-time and accurate information. Furthermore, Ubiquitous Networking Technology facilitates data sharing and interoperability among different traceability systems, breaking down data silos and establishing a unified, open agricultural product traceability platform, providing robust assurance for the safe production and distribution of agricultural products.

3. Ubiquitous Networking Technology

3.1 Overview of Ubiquitous Networking

Ubiquitous Networking is a novel network concept aimed at achieving the omnipresence of network services, enabling people to conveniently access the network and use various services anytime, anywhere. Its core concepts include "ubiquitous" connectivity, intelligent services, and user-friendly interactions. Ubiquitous Networking integrate various network technologies such as traditional internet, mobile communication networks, and sensor networks, achieving comprehensive perception and intelligent control of the physical world.

The concept of Ubiquitous Networking was initially proposed by Mark Weiser in 1991, originally termed as "Ubiquitous Computing." With the rapid development of wireless communication, sensor, and internet technologies, Ubiquitous Networking have transitioned from theory to practical implementation, finding widespread applications across various domains.

Here are some examples of ubiquitous applications:

1) Smart Cities: By deploying numerous sensors and cameras in cities, real-time monitoring and management of city traffic, environment, public safety, etc., are achieved, enhancing city management efficiency and residents' quality of life.

2) Smart Homes: Utilizing Ubiquitous Networking Technology, various household appliances are connected to the network, allowing users to remotely control home devices through smartphones or other terminals, achieving home automation.

3) Remote Healthcare: By connecting medical devices to the network, remote monitoring of patients' health conditions is realized, with data transmitted to hospitals. Doctors can remotely diagnose and treat patients based on this data.

These application examples demonstrate that Ubiquitous Networking Technology has permeated into various aspects of society, gradually changing people's lifestyles and work methods. In the future, with continuous technological advancements and the expanding scope of applications, Ubiquitous Networking Technology will play an even more crucial role.

3.2 Key Application Technologies

(1) Sensor Networks

Sensor networks are systems composed of numerous distributed sensor nodes that collaborate to perform real-time environmental monitoring and data collection. Each sensor node typically consists of a sensor, a microprocessor, a wireless communication module, and a power source. Sensors are responsible for perceiving physical or chemical parameters in the surrounding environment, such as temperature, humidity, light intensity, etc., and converting the sensed information into electrical signals. The microprocessor conducts preliminary processing on these signals and transmits the data through the wireless communication module to other nodes or aggregation nodes in the network. The power source supplies energy for the node's operation, commonly using batteries or solar panels.

In some complex or large-scale sensor networks, dedicated routing nodes may be deployed to assist in data forwarding. These routing nodes typically possess stronger processing capabilities and a larger communication range than regular sensor nodes, enabling more efficient resource utilization and performance balancing[6]. Aggregation nodes or base stations serve as central nodes in the sensor network, responsible for collecting data from the entire network and transmitting it to remote servers or data centers for further processing and analysis. Aggregation nodes typically have robust processing capabilities, ample storage space, and may be connected to wired networks.

Sensor networks commonly adopt specially designed network protocol stacks to accommodate their resource-constrained and energy-sensitive characteristics. The protocol stack typically includes the physical layer, data link layer, network layer, transport layer, and application layer. Additionally, to ensure the stable operation of the network, a management and maintenance module is needed to handle network configuration, monitoring, and maintenance. We analyzed the above cases and constructed the **Figure 2**, which describes the structure of the sensor network:

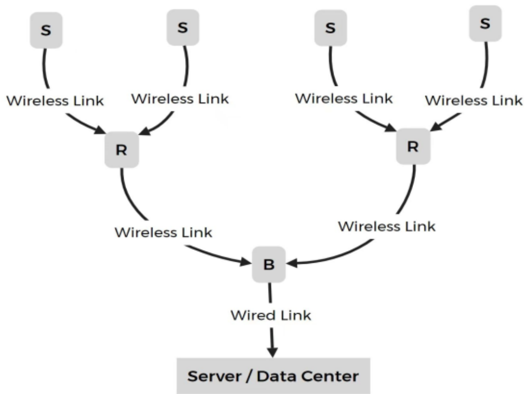

Figure 2. Sensors Network Structure

"S" represents sensor nodes deployed in the monitoring area, responsible for collecting environmental data. "R" represents routing nodes, tasked with receiving data from sensor nodes and forwarding it to other nodes or aggregation nodes. "B" represents aggregation nodes, responsible for collecting data from the entire network and transmitting it to a remote server or data center. "Server/Data Center" denotes the remote server or data center where the data is ultimately sent. "Wireless Link" represents wireless communication connections, and "Wired Link" represents wired connections.

Through its unique structure and operating mechanism, a sensor network can achieve real-time monitoring of environmental parameters over extensive areas, providing robust data support for various applications. In the field of agriculture, sensor networks find wide applications, providing a technical foundation for precision agriculture and smart farming through real-time monitoring of agricultural environments.

(2) Application and Integration of Big Data Technology in Ubiquitous Networking

In Ubiquitous Networking, big data technology and Ubiquitous Networking are closely intertwined, collectively building a robust digital ecosystem. Firstly, Ubiquitous Networking generate massive real-time data by connecting various devices and sensors, and big data technology provides efficient storage, processing, and analytical capabilities for this data. This correlation enables Ubiquitous Networking to achieve comprehensive perception, better understanding the environment, device status, and user behavior. In this correlation, big data technology plays a crucial role by deeply analyzing Ubiquitous Networking data, uncovering potential information and trends. For example, in smart cities, the perception layer collects various data through a sensor network, and big data technology can analyze this data to provide intelligent decision support for city planning and traffic management. This correlation makes cities smarter, enhancing the efficiency and quality of urban management.

In the field of smart agriculture, the association between big data technology and Ubiquitous Networking has brought revolutionary changes to agricultural production. Agricultural sensor networks, through monitoring various aspects of data such as soil and weather, achieve comprehensive perception of the agricultural environment. Big data technology then analyzes this data, providing precise agricultural decision support for farmers. For instance, based on real-time monitoring of soil moisture and weather conditions, big data technology can intelligently adjust irrigation strategies, achieving precision irrigation and improving water resource efficiency. This correlation not only optimizes agricultural production processes but also promotes the improvement of crop quality.

The association between big data technology and the Internet of Things (IoT) in the Ubiquitous Networking era shows tremendous potential. By efficiently processing and analyzing data, big data technology provides more intelligent and efficient solutions for various industries. In smart agriculture, this association makes agricultural production more scientific and sustainable, opening up new possibilities for food security and sustainable agricultural development.

4. AgriNetSense - Smart Agriculture Ubiquitous Networking Solution Design

4.1 Analysis of Existing Ubiquitous Networking Instance Systems

In today's digital era, Ubiquitous Networking Technology offers new possibilities for achieving smart agriculture. Taking agriculture as an example, many countries and enterprises have deployed advanced Ubiquitous Network instance systems, utilizing technologies such as sensor networks and big data analytics to achieve real-time monitoring of farmland, crops, and equipment. These systems not only provide precise agricultural decision support for farmers but also lay the foundation for the sustainable development of agricultural production. In this context, this paper will delve into the analysis of several typical Ubiquitous Networking instance systems, revealing their architectures, functionalities, and application values.

IBM's Smart City Solution:

IBM's smart city solution typically includes the perception layer, network layer, platform layer, and application layer. The perception layer consists of various sensors, cameras, and monitoring devices responsible for collecting various information in the city. The network layer is responsible for transmitting the data collected from the perception layer to the central processing platform. The platform layer is the core of the system, responsible for data storage, processing, and analysis. The application layer provides various services and applications such as traffic management, energy management, public safety. We analyzed IBM's Smarter Building Management'white paper and constructed the flow chart as **Figure 3**, which describes the architecture of IBM's smart city solution

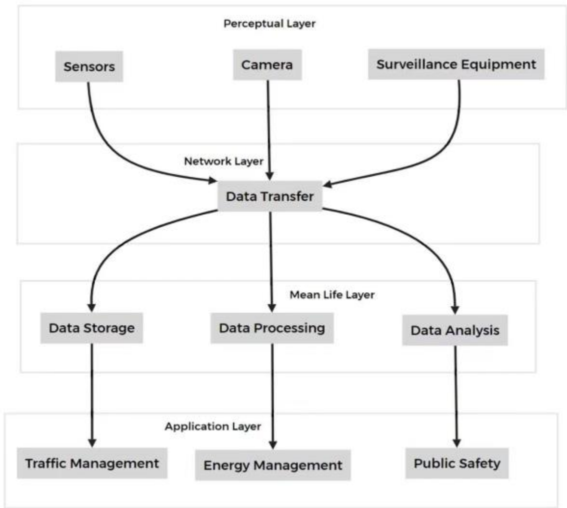

Figure 3. IBM Smart City Solution Architecture
Source: International Business Machines Corporation Smarter Building Management 'white paper.

IBM's Smart City Solution aims to enhance the efficiency and effectiveness of city management, as well as improve residents' quality of life through the utilization of big data and analytics technologies. It enables real-time monitoring and management of various aspects such as city traffic, energy, water, and public safety, providing intelligent decision support.

Cisco's Smart Grid Solution:

Cisco's Smart Grid Solution mainly consists of the perception layer, network layer, and application layer. The perception layer includes smart meters and other sensing devices used to collect energy usage data. The network layer is responsible for transmitting the collected data to the data center, and the application layer provides data analysis and management services to help users optimize energy usage.

Functionality: This solution aims to improve energy efficiency and achieve intelligent management of the power grid. Through real-time monitoring and analysis of energy usage data, it assists users in making more rational use of energy, reducing energy consumption, and minimizing environmental pollution. We analyzed the above cases and constructed the **Figure 4** as follow, which describes the architecture of the Cisco Intelligent networking solution:

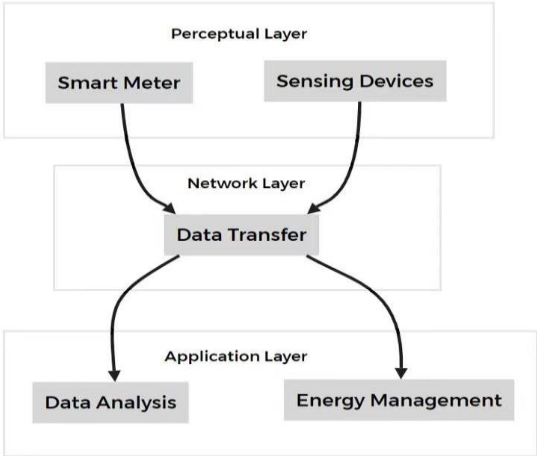

Figure 4. Cisco's Smart Network Solution Architecture

Source: "Cisco Networking Solution Overview." Cisco, 2021, www.cisco.com

South Korea's U-City Project:

The U-City Project is a comprehensive smart city initiative encompassing various aspects such as traffic management, environmental monitoring, and public safety. Its architecture includes the perception layer, network layer, platform layer, and application layer. The perception layer consists of various sensors and monitoring devices responsible for collecting relevant data on city operations. The network layer handles data transmission, the platform layer conducts data processing and analysis, and the application layer provides various smart city services.

The U-City Project aims to enhance urban management and residents' quality of life by constructing an intelligent, networked urban environment. Through real-time monitoring and management of traffic, environment, public safety, etc., it achieves efficient utilization of urban resources and rapid response to urban issues.

4.2 AgriNetSense Smart Agriculture Ubiquitous Network Solution

Based on the theoretical foundation of Ubiquitous Networking and big data, as well as insights from relevant past cases, the design of this system aims to achieve a comprehensive enhancement in the field of smart agriculture. Ubiquitous Networking Technology, by deeply integrating the physical and digital worlds, facilitates real-time sensing and intelligent control throughout the agricultural production process. Big data technology provides support for the storage, processing, and analysis of massive data, thereby making agricultural decision-making more scientific and precise.

Taking examples such as U-City and IBM's smart city, similar systems have achieved significant success in other domains. Learning from these cases reveals that effective integration of

Ubiquitous Networking and big data can significantly improve production efficiency, optimize resource utilization, enhance product quality, and achieve the goals of sustainable agriculture.

Building upon this theoretical foundation and insights from past cases, the system design aims to construct a highly intelligent and automated agricultural production system. By fully leveraging the sensing and control capabilities of Ubiquitous Networking Technology, it can real-time monitor various factors such as soil conditions, weather, and crop status, providing farmers with scientific decision support. The application of big data technology, through in-depth analysis of this data, offers more precise guidance for agricultural production, such as optimizing irrigation strategies, rational fertilization, and timely pest and disease warnings.

(1) System Architecture

a. Perception Layer

As the first layer of the system, various sensors and intelligent devices will be deployed. This includes sensors monitoring agricultural field conditions such as soil moisture, temperature, and light, as well as smart devices actively collecting agricultural data, such as smart farming tools and cameras. This layer will achieve comprehensive perception across various stages of agricultural production. The introduction of edge computing nodes enables real-time data processing and initial analysis, alleviating the burden on the central processing platform.

b. Network Layer

An efficient and stable wireless network will be established to ensure timely transmission of data collected by the Perception Layer to the central data platform. The immense potential of Ubiquitous Cloud Technology lies in achieving instant, cross-device transfer of various rich data types, covering various aspects of human experience. However, concerns about its security and privacy arise. Additionally, due to physical obstacles in agricultural settings, IoT device communication signals may weaken upon reaching transceivers[7,8]. Therefore, the most reliable and robust network technology should be employed for data transmission in agricultural environments. Adopting 5G technology will construct a high-speed, low-latency communication network, ensuring rapid transmission of large-scale data. The introduction of blockchain technology ensures secure data transmission and storage, preventing data tampering and unauthorized access.

c. Platform Layer

This layer plays a central role in the system, responsible for storing, managing, and processing massive agricultural data. Big data technology will be applied to data analysis to extract valuable information, such as crop growth trends and optimal irrigation timing. Combining edge computing and cloud computing enables efficient processing of large-scale data and training of deep learning models.

d. Application Layer

Introducing Augmented Reality (AR) and Virtual Reality (VR) technologies provides farmers with an intuitive display of agricultural information and an operational interface. Using blockchain technology to construct smart contracts automates the execution of intelligent agricultural decisions. Smart contracts minimize information silos between enterprises, eliminate the need for central authorities and intermediaries, and enhance the integrity, reliability, and security of transaction record[9]. We analyzed the above cases and constructed the **Figure 5**, which explains the architecture of the AgriNetSense smart agriculture:

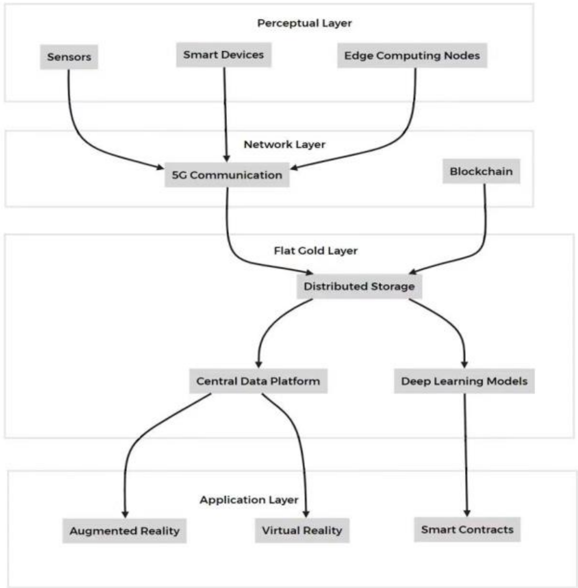

Figure 5. AgriNetSense Smart Agriculture System Architecture

(2) Key Technologies

a. Internet of Things (IoT) and 5G Communication

Utilize IoT technology to connect various sensors and devices, creating an extensive agricultural IoT network. 5G communication technology provides high-bandwidth, low-latency communication support, ensuring real-time data transmission.

b. Artificial Intelligence (AI) and Edge Computing

The application of deep learning algorithms for real-time analysis of data at the perceptual layer enables intelligent judgments on crop growth status, early detection and prevention of fires, disease identification, and more. Visual neural systems such as YOLOv5 can be employed for artificial intelligence-based image recognition. YOLOv5-7.0 is a high-performance image detection model based on the NVIDIA Ada Lovelace architecture, capable of achieving fast, accurate, and real-time object detection. In this experiment, YOLOv5-7.0 was used for firework recognition, and all experiments were conducted on the NVIDIA GeForce RTX 4070 Ti. Each training session utilized single-card training with default parameters from the source code, an epoch setting of 310, and a batch size of 17. The final training set consisted of 4,362 images, the validation set included 925 images, and the test set comprised 1,263 images. Collect agricultural firefighting materials and input them into our own YOLOV5 trained model to generate the following image examples, as shown in **Figure 6**, which describes firework recognition in the results:

Figure 6. An example of firework recognition in the training results

Introducing edge computing technology, transferring a portion of computational tasks to the perceptual layer, enhances response speed and reduces data transmission costs. Ubiquitous computing is a novel information and communication technology that utilizes a large number of collaboratively operating small nodes with computing and/or communication capabilities[10].

c. Blockchain Technology

Ensure the immutability of data through blockchain technology, achieving end-to-end data traceability. Use smart contracts to automate the execution of agricultural decisions, enhancing the system's autonomy and level of intelligence.

(3) Workflow

a. Data Collection and Transmission

Sensor networks collect real-time data from various farm sources and transmit it to the central platform through a 5G communication network.

b. Real-time Analysis and Preliminary Processing

Edge computing nodes perform initial processing on real-time data, identifying anomalies and filtering key information. Deep learning algorithms are utilized for real-time analysis of multimodal data, such as images and sounds.

c. Data Storage and Management

Blockchain technology ensures secure data transmission and storage, constructing a decentralized data management system. A distributed storage system enables efficient storage and retrieval of large-scale data.

d. Intelligent Decision-Making and Execution

The application layer executes automated agricultural decisions through smart contracts, such as intelligent irrigation and precision fertilization. Blockchain-based data integrity ensures the traceability of decisions.

(4) Implementation of the System

To realize the smart agricultural production system based on the Ubiquitous Networking, a series of advanced technologies has been adopted. Firstly, the selection and deployment of sensors and smart devices, including temperature sensors, humidity sensors, and cameras. The primary goal of these sensors is to determine the physical properties and environmental conditions of the soil and the applications of sensors include control and monitoring, safety, alarms, diagnosis, and analysis, making innovative agriculture more efficient and worry-free[11].

To ensure efficient transmission of sensor data, a 5G communication network has been established. The use of 5G technology effectively reduces data transfer latency, enhancing the system's responsiveness to real-time data.

For data security, blockchain technology has been introduced. By configuring a blockchain network, a decentralized data management system has been established, ensuring the immutability and security of data, providing a reliable data foundation for the entire system. To achieve real-time data processing, edge computing nodes are deployed within the farm. These nodes are responsible for the initial processing and analysis of real-time data, reducing the burden on the central platform and improving the system's response speed.

To address the storage and management challenges of large-scale data, a distributed storage system has been established. Multiple storage nodes have been configured, enhancing the system's stability and reliability to ensure efficient storage and retrieval of vast amounts of data. Deep learning technology is applied to train agricultural data, and the models obtained are analyzed in real-time at edge computing nodes for tasks such as identifying crop growth status and detecting diseases. Additionally, comparisons with other parameters, such as soil humidity and temperature, enable the control of irrigation quantity and duration in farmland[12]. The introduction of smart contracts allows the system to achieve automated decision-making. Smart contracts, written on the blockchain network, define the logic and conditions of agricultural decisions, enabling various decisions to be automatically executed through contracts, thus improving efficiency and accuracy in decision-making.

The final section involves the development of user-friendly interfaces, including mobile applications and web interfaces. The use of internet technology and intelligent object communication patterns in smart agriculture presents potential advantages. Therefore, a location-based context-aware web service framework can be designed, leveraging existing pervasive environment-related foundational technologies. This enables farmers to interact with surrounding automated systems and access various services anytime, anywhere[13]. It provides an intuitive and convenient user experience, allowing farmers to monitor farm status and execute decisions with ease. We analyzed the above cases and constructed the **Figure 7**, which explains the architecture of the overall implementation of AgriNetSense intelligent farming system:

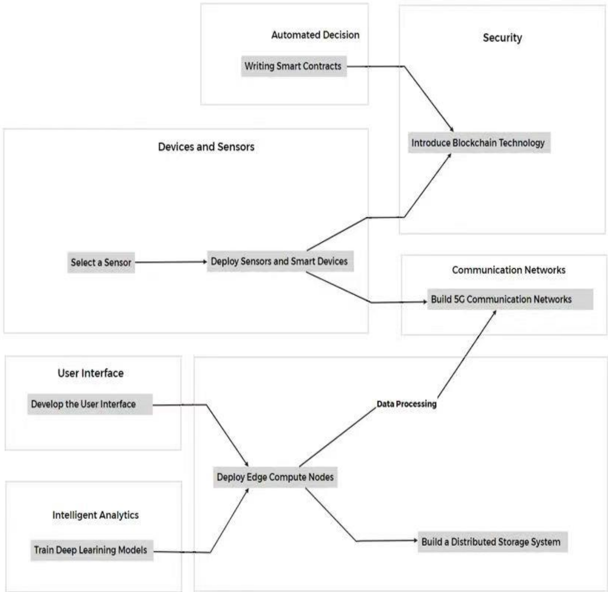

Figure 7. Overall Implementation of AgriNetSense Smart Agriculture System

By implementing these technological details and steps, a successful Ubiquitous Networking based smart agricultural production system has been established, providing comprehensive and intelligent support for agricultural production.

5. Summary and Future Prospects

This paper comprehensively explores the current state and future prospects of the application of Ubiquitous Networking Technology in smart agriculture, based on an analysis of the advantages and disadvantages of the agricultural product traceability system and a review of key technologies in the Ubiquitous Networking. Building upon this, the paper proposes the design of the AgriNetSense system for agricultural production based on the Ubiquitous Networking, discussing the key technologies and steps for system implementation. The aim is to contribute to the national agricultural production industry, enhancing agricultural production efficiency, optimizing agricultural decision-making, and strengthening product safety and credibility.

Future research will focus on enhancing security and privacy protection, optimizing intelligent decision-making, adapting to regional differences, assessing social impacts, and promoting international cooperation. In-depth exploration of these directions can better drive the application of Ubiquitous Networking technology in the field of smart agriculture, offering more possibilities for agricultural modernization.

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