Research on ecosystem detection based on wireless communication network

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Abstract. Ecosystem monitoring is of great significance in environmental protection and sustainable development. Wireless communication networks provide a broad application prospect for ecosystem monitoring, but there is a lack of further research on the strengths and weaknesses of the existing research results and specific application scenarios, as well as on the reliability of data processing. This paper aims to explore the theoretical basis of the reliability of wireless communication networks in ecosystem monitoring. Firstly, the current status, characteristics and challenges of wireless communication networks in ecosystem monitoring are reviewed, the key elements in ecosystem monitoring and the requirements for data integrity and accuracy are analyzed in detail, and the reliability problems of signal interference, node failure and data loss in data transmission are discussed. Secondly, methods and strategies to improve the reliability of ecosystem monitoring based on wireless communication networks are explored. By reviewing and analyzing the existing research results, the advantages and disadvantages of different methods as well as the applicable scenarios are elaborated. Finally, the paper proposes directions and challenges for future research. The exploration of emerging technologies is emphasized. At the same time, issues that need to be addressed, network security, energy efficiency and cost feasibility are pointed out. The significance of this paper in academic and industry practice can further deepen the exploration of the theoretical basis of reliability and combine it with practical application scenarios for verification and optimization.

Keywords: wireless communication network, ecological monitoring, smart city, data processing and acquisition, reliability of ecological monitoring system

1. Introduction

In today's digital era, wireless communication networks have become an integral part of people's lives and work. As an ecosystem, wireless communication networks cover a wide range of technology areas, including wireless sensor networks and data transmission. Studying the ecosystem of wireless communication networks is important for optimizing network performance, improving user experience, driving technological innovation, and formulating related policies.

Meanwhile, the formulation of policies and regulations also, involves issues such as wireless spectrum management, network neutrality, privacy protection, and cybersecurity. With the development of the times, the advancement of each generation of mobile communication technology brings new challenges and opportunities, such as the introduction of 5G technology and the emergence of emerging technology trends. Therefore, an in-depth study of the ecosystem of wireless communication networks, an understanding of the interrelationships of the different components therein, and a close focus on technology, policy, and zeitgeist trends will help to optimize network performance, improve user experience, and prepare for future developments.

Wireless communication technologies are widely used in various industries. The first is the coal mining industry. He Yong and Xu Yuantao (He et al., 2023) conducted a study on the application and research of 5G communication technology in intelligent coal mines in 2023, to achieve high-precision positioning and remote control of equipment for monitoring information collection by advancing the intelligent process of coal mines, and to better meet the real-time demand of coal mine production through 5G communication technology. However, from the current situation, the 5G wireless communication system architecture is still not perfect, and there are still some deficiencies in the form of equipment and deployment methods, so the 5G communication technology for the coal industry needs to be continuously improved. At the same time, Yang Jianyu explored the application and practice of wireless communication system in mine rescue. (Yang. ,2023) When mine accidents occur, especially gas explosion, water penetration and other large-scale accidents will lead to serious damage to the power supply system and communication system at the scene. In order to be able to accurately grasp the location of trapped people and the damage of the tunnel at the scene, the mine rescue wireless multimedia communication system is applied to the actual production through video and audio signals according to the demand of emergency rescue. The result proves that the wireless communication system can guide the emergency rescue personnel to rescue the scene, so as to improve the rescue efficiency and provide support for the commanders to formulate the rescue plan. Moreover, the system video and audio signals can be transmitted stably and the video signal is clear, and the system can meet the emergency rescue demand of 8h.

A similar rescue application is the application of wireless communication technology in the automatic fire alarm system of subway, which was experimentally investigated by Wu Hui and Liang Jintao et al.6 in 2023 (Wu et al., 2023). This wireless communication system uses FPGA as the core control chip and ZigBee technology as the wireless communication protocol. Each wireless node is equipped with sensors such as aerosol sensor and carbon dioxide sensor, as well as wireless communication function module and alarm module. The validation test shows that for the 10 wireless nodes involved in the test, the aerosol sensor accurately monitors the occurrence of fire and is able to alarm the fire in the form of video and sound through the display module and the alarm module, and the wireless communication module also sends the fire monitoring information to the upper computer without any problem.

Wireless communication system also has great contribution in urban transportation7. With the rapid development of rail transportation engineering, the traditional communication technology has been difficult to meet the actual needs of its development, so it has also increased the application of 5G technology, which has been very widely used in the field of rail transportation due to its multiple advantages such as low latency, high bandwidth and high speed rate (Yang, 2022). At the same time, Liu Xiaozhou also conducted a discussion on the application of 5G mobile communication technology in urban rail transit vehicle-land wireless communication system in 2022.(Liu, 2022) Under the significant features of 5G mobile communication technology, the development of the rail transit vehicle-land wireless communication system tends to be more safe and convenient, and it can provide more high-quality services, which greatly meets a variety of needs.

Indoor positioning and teleconferencing are also profoundly affected by wireless communication systems. For example, the application of ultrasonic ranging technology in indoor robot localization system studied by Tianyi Wang (Wang, 2023). As well as the study of convergent communication technology in the design of current high-level conference and exhibition projects, Shen Yuxiang and Tian Jianqiang et al. (Shen et al., 2023) found that the design and application of 5G communication system and dedicated wireless communication system in the World Meeting Room project will bring many benefits such as promoting the development of the conference and exhibition economy, innovating the management of the conference and exhibition and improving the efficiency of the conference and exhibition services, and so on.

In recent years, the application of wireless communication in ecological monitoring is also increasing. In fact, wireless communication technology has been applied to ecological monitoring since 10 years ago. As countries and social organizations pay more and more attention to the protection of ecological environment, the application of advanced wireless communication technology in ecosystem monitoring is an inevitable trend of development.

2. Fundamentals of Wireless Communications

The application of wireless communication networks in ecosystem monitoring is receiving extensive attention and research. It provides powerful tools and technical support for real-time ecosystem monitoring and data collection. The following section will address the current status, characteristics and challenges of the application, as well as the transmission medium, network topology and node arrangement.

2.1. Logic diagram

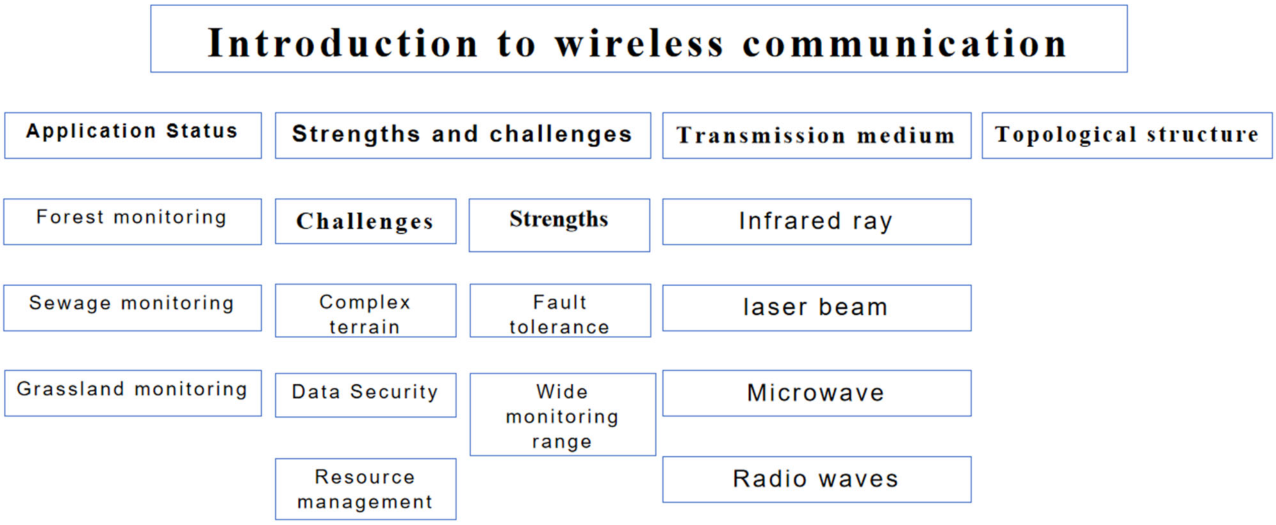

Figure 1. Logic diagram

The introduction of wireless communication in this paper as the figure 1 is divided into four aspects: application status, advantages and challenges, transmission media, topology. Understanding the framework of wireless communication is conducive to further research and development.

2.2. Application Status

Currently, the application of wireless communication networks in ecosystem monitoring has made some important progress in practice. Many studies have used wireless sensor networks (WSNs) for monitoring different ecological environments such as forests, lakes, and oceans. These studies have utilized sensor nodes to monitor environmental parameters such as temperature, humidity, light intensity, water quality, etc. in real time in order to assess the health of the ecosystems and the trends of changes. Branko Kerkez, Steven D. Glaser et al. (Kerkez et al., 2012) deployed WSNs in forests 1 kilometer headwater catchment in the southern Sierra Nevada Mountains of California. The network integrated readings from over 300 sensors to provide spatially representative measurements of snow depth, solar radiation, relative humidity, soil moisture, and substrate potential. The ability of this densely instrumented watershed to capture catchment-level snow depth and soil moisture distributions was investigated by comparing it to three integrated gridded surveys and 1-day detailed LiDAR snow data. Xiaodong Wang, Wei Xie (Wang et al., 2022) et al. established a grassland environmental monitoring system based on ZigBee wireless sensor network. The system consists of a grassland wireless monitoring network and a remote PC to realize real-time and remote monitoring of environmental information such as air temperature and humidity, light intensity, rainfall and other environmental information affecting the growth of grassland forage. Among them, the ZigBee wireless sensor network subsystem is deployed in the grassland area, which mainly realizes the real-time collection, processing and wireless transmission function of grassland data. The remote management software subsystem is mainly used for receiving, storing and displaying data, and maintains communication with gateway nodes to support real-time monitoring of grassland data by remote browsers. Erik van Rooijen, Michael Dietze (Van Rooijen et al., 2023), et al. explored the capability of smart sensors actually developed for the agricultural sector to measure soil moisture and temperature as well as the movement of the banks of the northern rivers in different geographic, climatic and landscape environments in real time, where the soil movement and its timing can be easily determined from the measurements, so that in many cases the cause of the onset of movement can be inferred.

2.3. Characteristics

Wireless communication networks have several significant features in ecosystem monitoring. First, it enables large-scale and high-density node deployment covering a wide monitoring area. This allows for a wider monitoring range and more comprehensive data.

Secondly, wireless communication network can provide real-time data transmission and processing capabilities, so that the monitoring data can be fed back and analyzed in a timely manner, so that it is easy for monitors to make appropriate decisions. In addition, the wireless communication network has the ability of self-organization, automatic adjustment to adapt to the complex and dynamic ecological environment.

2.4. Challenges

However, wireless communication networks also face some challenges in ecosystem monitoring. First, ecological environments usually have complex geographic and topographic features, such as mountains, lakes, and forests, which can affect the propagation and reception of wireless signals. Second, energy management is an important issue, as sensor nodes are usually unattended, and a balance needs to be struck between optimizing energy consumption and extending node lifetime. In addition, security and privacy protection of data transmission and processing are also concerns, especially in ecological monitoring applications involving sensitive information.

2.5. Transmission medium

In ecosystem monitoring with wireless communication networks, the choice of transmission medium is crucial. Wireless communication technologies such as Wi-Fi, Bluetooth, and ZigBee can be used for data transmission between nodes. In addition, satellite communication can also be used for data transmission across larger areas, which is particularly suitable for monitoring remote areas or marine ecosystems.

2.6. Network Topology and Node Arrangement

Network topology and node arrangement have an important impact on ecosystem monitoring in wireless communication networks. Reasonable choice of network topology, such as star, tree or mesh, can meet the needs of different ecosystem monitoring. The node arrangement needs to be optimized according to the actual monitoring objectives and environmental characteristics to achieve high-precision monitoring of key parameters.

Overall, wireless communication networks have great potential and advantages in ecosystem monitoring. By making full use of its features and technological advantages, solving challenges and making continuous improvements, we can achieve more accurate, efficient and comprehensive ecological environment monitoring and provide scientific support for environmental protection and sustainable development.

3. Key elements in ecosystem monitoring:

The data acquisition, transmission and processing aspects of ecosystem monitoring are critical to obtaining accurate and reliable data to support environmental protection and sustainable development.

3.1. Data Acquisition

In the data acquisition chain, ensuring the accuracy and stability of sensors is key. Drift or malfunctioning of sensors may lead to degradation of data quality (He et al., 2010), so calibration and alignment need to be carried out regularly to eliminate any errors and ensure consistency. In addition, the collected data should be consistent and comparable for effective comparison and analysis. Therefore, standardized data collection methods and quality control procedures are essential to ensure data integrity.

3.2. Data Transmission

The data transmission chain also faces reliability challenges, which include problems such as signal interference, node failure and data loss. Signal interference may be caused by electromagnetic wave interference, multipath propagation, and signal attenuation, leading to data loss or corruption in data transmission (Song, 2014).To cope with this problem, technical means such as signal enhancement, error detection and error correction coding can be used to improve the reliability and integrity of data transmission. In addition, monitoring systems usually consist of multiple nodes, and if one of them fails, it may lead to the interruption of the entire data transmission chain. To minimize this risk, redundancy mechanisms and backup strategies can be employed to ensure that data transmission continues even in the event of node failure (Li, 2007).

3.3. Data Processing

During the data processing session, it is crucial to ensure the completeness and accuracy of the data. During data processing, quality control and calibration should be performed to exclude any outliers and erroneous data. At the same time, data processing algorithms need to be highly accurate and robust in order to correctly process the different types and sizes of data collected (Jiang, 2010). This involves processes such as data cleansing, analysis, and modeling to extract useful information and insights and provide a scientific basis for decision making. In addition, proper data storage and backup strategies are necessary to ensure long-term data accessibility and integrity to prevent data loss or corruption (Ni, 2017).

Taken together, the data collection, transmission and processing aspects of ecosystem monitoring must address the challenges of reliability and integrity. By adopting appropriate technical measures, quality control procedures and redundancy mechanisms, we can ensure that accurate, reliable and complete data are available to provide scientific support for environmental protection and sustainable development. This will contribute to a better understanding of the state of ecosystems, the prediction of environmental changes and the assessment of the impacts of human activities on ecosystems, leading to effective conservation and management measures.

4. Methods and strategies to improve the reliability of ecosystem monitoring

4.1. Ecological Assessment and Intelligent Monitoring System in China

To further improve the reliability of ecosystem monitoring based on wireless communication networks, we can draw on a number of success stories. A typical case is the Ecological Assessment and Intelligent Monitoring System of Mangrove Wetlands in Southeast Coast of China published in the Journal of Hainan Tropical Oceanography College. The study established a mangrove monitoring system in the mangrove wetland at the tip of Lingshan Island, Guangzhou City, based on information technology such as the Internet of Things and big data, and utilizing on-site surveys, regular automatic monitoring, video surveillance and remote sensing monitoring. Through data collection and processing, they formed a mangrove ecological database and established an ecological assessment system for mangrove wetlands along the southeast coast of China. By analyzing the key elements as the figure 2 shown, through hierarchical analysis, they designed an intelligent mangrove ecological assessment model and successfully assessed the health of the mangrove wetland at the tip of Lingshan Island. This case demonstrates the application of information technology in ecosystem monitoring, which enables accurate ecological assessment and intelligent decision support through data collection, transmission and processing.

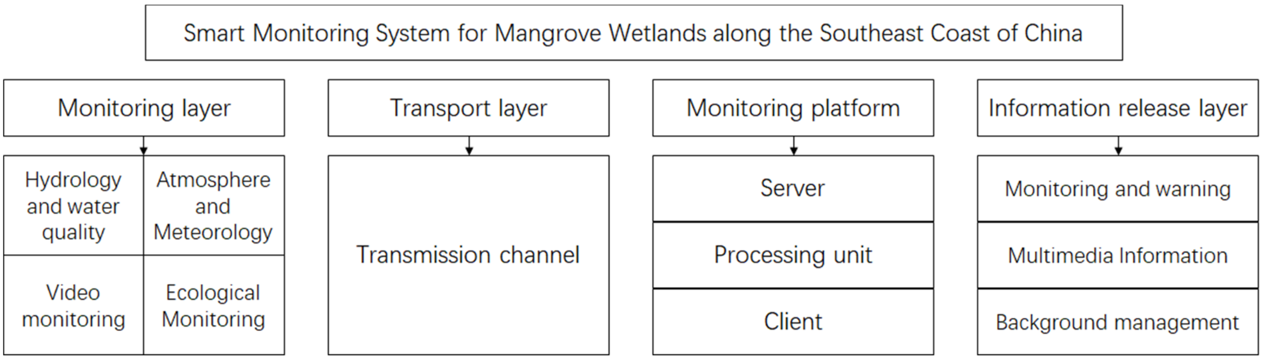

Figure 2. Ecological Assessment and Intelligent Monitoring System

4.2. Chongqing Guangyang Island: Creating a New Model of "Intelligent Eco"

Ecosystem Wisdom Application as the figure 3 shown: A Case Study of Guangyang Island, Chongqing. Another success story comes from "Chongqing Guangyang Island: Creating a New Model of "Intelligent Ecology"", published by China Construction Information Technology. At the very beginning of its planning, Guangyang Island established the construction theme of "intelligent ecology" to lead the green development demonstration of the Yangtze River Economic Belt, and put forward the innovative theory of "intelligent ecology". Through the application of information technology, Guangyang Island has successfully created an internationally leading ecological wisdom integration development model. They have realized comprehensive monitoring, real-time response and intelligent management of the ecological environment through intelligent systems and data processing algorithms, providing scientific support and decision-making basis for green development. This case highlights the key role of information technology in ecosystem monitoring and management.

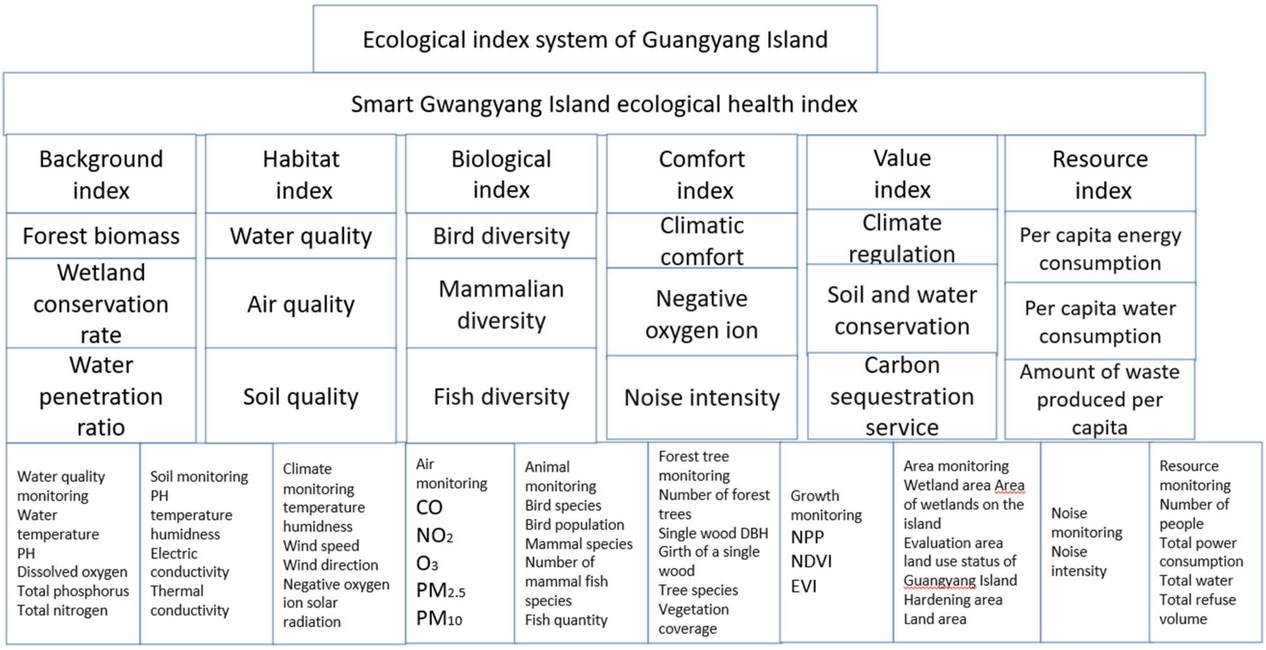

Figure 3. Chongqing Guangyang Island: Creating a New Model of "Intelligent Eco"

4.3. Discussion

Based on the successful experience of these cases, we can further explore and optimize the related methods and strategies, including optimizing the network topology, improving the signal transmission quality and designing efficient data processing algorithms. By introducing adaptive network configuration and dynamic routing algorithms, we can adjust the layout and connectivity of network nodes according to the real-time network status and demand, in order to improve the self-healing capability of the network and the continuity and integrity of data transmission. At the same time, we can study new channel scheduling and power control strategies, adopt smart antenna technology and multi-antenna system to improve signal coverage and anti-interference ability in order to improve signal transmission quality and reliability. In addition, we can develop efficient data processing algorithms to extract more useful information, detect abnormal data and automate the data processing process by utilizing techniques such as machine learning, data mining and artificial intelligence. At the same time, data quality control and calibration measures have been strengthened, and a sound data storage and backup mechanism has been established to ensure that the quality of the data collected is reliable. In summary, by drawing on the experience of successful cases and by further exploring and optimizing relevant methods and strategies, we can continuously improve the reliability of ecosystem monitoring based on wireless communication networks. This will provide more accurate and credible data support for environmental protection and sustainable development, and help decision makers to formulate effective conservation strategies and management measures for more sustainable ecosystem management and environmental governance.

5. Conclusion

To improve the reliability of ecosystem monitoring based on wireless communication networks, future research should explore and optimize the application of emerging technologies.

1 Internet of Things (IoT) technology can realize the intelligence and automation of sensor networks to provide more comprehensive monitoring coverage and real-time responsiveness through real-time collection of environmental data and remote monitoring.

2 Artificial intelligence can be applied to data processing and analysis to improve data integrity and accuracy through efficient and accurate information extraction and decision support.

3 Big data analytics, on the other hand, can identify potential correlation patterns and trends, providing deeper insights and predictive capabilities for ecosystem monitoring. The exploration and application of these emerging technologies will provide more comprehensive, efficient and reliable solutions for ecosystem monitoring.

However, despite the many opportunities presented by emerging technologies, a number of challenges remain.

1 Network security. In the process of data collection, transmission and processing, network security and privacy protection need to be fully attended to and safeguarded. Ensuring the confidentiality and integrity of data, as well as establishing robust security mechanisms and protective measures are crucial.

2 Energy efficiency. With the increase in the number of monitoring nodes and the demand for data processing, how to design and develop energy-efficient communication and computing solutions to reduce energy consumption and improve system sustainability is a key issue. In addition, cost feasibility is also a factor to be considered.

In practical applications, cost-effective technologies and solutions need to be explored to ensure the feasibility and sustainability of ecosystem monitoring.

In summary, future research should be devoted to further exploring and optimizing the application of emerging technologies in improving the reliability of ecosystem monitoring based on wireless communication networks. By fully utilizing technologies such as the Internet of Things, artificial intelligence, and big data analysis, the efficiency and accuracy of data collection, transmission, and processing can be improved, thereby enhancing the reliability of ecosystem monitoring. However, issues that need to be addressed include cybersecurity, energy efficiency, and cost feasibility. Through continuous research and innovation, we can overcome these challenges and promote the development and practice in the field of ecosystem monitoring to provide more accurate and credible data support for environmental protection and sustainable development. This will provide a scientific basis for decision makers to formulate effective conservation strategies and management measures, and promote more sustainable ecosystem management and environmental governance.

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