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Research Article

Assessing the Complexity of Intelligent Parks' Internet of Things Big Data System

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Today, intelligence in all walks of life is developing at an unexpectedly fast speed. The complexity of the Internet of Things (IoT) big data system of intelligent parks is analyzed to unify the information transmission of various industries, such as smart transportation, smart library, and smart medicine, thereby diminishing information islands. The traditional IoT systems are analyzed; on this basis, a relay node is added to the transmission path of the data information, and an intelligent park IoT big data system is constructed based on relay cooperation with a total of three hops. Finally, the IoT big data system is simulated and tested to verify its complexity. Results of energy efficiency analysis suggest that when the power dividing factor is 0.5, 0.1, and 0.9, the energy efficiency of the IoT big data system first increases and then decreases as α_0 increases, where the maximum value appears when α_0 is about 7 J. Results of outage probability analysis demonstrate that the system's simulation result is basically the same as that of the theoretical result. Under the same environment, the more hop paths the system has, the more the number of relays is; moreover, the larger the fading index m, the better the system performance, and the lower the outage possibility. Results of transmission accuracy analysis reveal that the IoT big data system can provide a result that is the closest to the actual result when the successful data transmission probability is 100%, and the parameter λ values are between 0.01 and 0.05; in the meantime, the delay of successful data transmission is reduced gradually. In summary, the wireless relay cooperation transmission technology can reduce the outage probability and data transmission delay probability of the IoT big data system in the intelligent park by adding the multihop path, thereby improving the system performance. The above results can provide an experimental basis for exploring the complexity of IoT systems in intelligent parks.

1. Introduction

Technologies such as the Internet of Things (IoT), cloud computing, big data, and mobile IoT have gradually been employed in various industries as science and technology advance forward. The economic level of the entire human society has been greatly improved. While comprehensively promoting the integration and innovation of a new generation of information and communication technology and urban development, the IoT composed of massive sensors is continuously collecting variously structured and unstructured data day and night. The amount of data in various industries, including surveillance video data, geographic information, traffic data, population data, and security and environmental monitoring data, is undergoing explosive growth. Under the trend of intelligent development in various industries, the phenomenon of "information islands" gets increasingly prominent, protruding the importance of parks [1, 2]. Therefore, how to interconnect and share information in such parks has become the research focus of scholars and experts worldwide.

An intelligent park is the vital link of smart city development; its architecture and development models are the epitomai of a smart city [3]. Compared with cities, intelligent parks often have smaller spatial granularity and more specific functions and development goals. Thus, it is easier for them to implement smart city designs and constructions, playing a demonstrative and leading role in smart city construction [4]. Like smart cities, the management and service methods of intelligent parks should be based on the demands of people and meet the needs of the public, society, and government as much as possible. Intelligent parks are the outcomes of the in-depth development of the "Internet plus Technology," which will have a huge and far-reaching impact on the planning and management of the parks, public services, production methods, people's livelihood, and market operations [5].

Today, when the Fifth-Generation (5G) communication technology is about to become popular, the situation where "everyone is connected" and "everything is connected" has been formed. Moreover, IoT has become the core symbol of smart cities and intelligent parks in the "Internet +" era as it gradually penetrates various industries. According to statistics, in 2020, the total number of IoT connections worldwide approached 30 billion, and the market size reached 1.7 trillion US dollars; meanwhile, nearly 55% of IoT achievements were concentrated in business fields, such as smart manufacturing, smart home, smart cities, and intelligent parks [6, 7]. Only adopting IoT cannot contribute to intelligent park construction. Instead, this process also requires big data analysis and cloud computing technologies. The big data analysis technology uses its various data to serve the parks and provides big data platforms and tools for enterprises in the parks [8, 9]. Cloud computing can gather massive amounts of data on the cloud servers, analyze and sort out the parks' data, and utilize these data for optimizing the parks' management and operation. Cloud computing manifests as a data center in constructing intelligent parks, which is the core of the information system of smart cities and intelligent parks [10]. Therefore, it is vital to collect and process data and information while constructing intelligent parks.

In summary, the research purposes are to further develop the intelligent parks and increase the degree of information transmission and sharing. Innovatively, the wireless relay cooperation transmission technology is added to the traditional IoT systems, and an IoT big data system for intelligent parks is constructed based on relay cooperation. Besides, the complexity of the system's performance is verified through simulation, which can provide a reference basis for the development of intelligent parks in the future.

2. Related work

2.1. The Application Trend of IoT in Intelligent Parks. Today, as communication technology advances at an unexpectedly fast speed, IoT technology has been gradually accepted in all walks of life. Scholars worldwide have done a lot of works on IoT technology. Rathore et al. proposed an IoT-based big data analysis next-generation super park planning system. They proposed a complete system, including various intelligent systems based on IoT, such as smart homes, Internet of Vehicles, weather and water systems, smart parking lots, and monitoring objects, for data generation. The final simulation results confirmed that the proposed super park planning system could provide higher efficiency and scalability [11]. Bresciani et al. modeled the data of multiple IoT smart city project alliances and found that an enterprise's development was closely connected to the rapid development of urbanization. They also emphasized that knowledge management capabilities indirectly improved the flexibility of alliances through the information and communication technology capabilities of enterprises. They recommended that managers of multinational enterprises design knowledge management tools and develop new information and communication technology skills [12]. Qian et al. applied IoT technology to promote the construction of infrastructure in intelligent parks so that the economy could grow sustainably and people's livelihood could be significantly improved [13]. Watson et al. analyzed and estimated the big data-driven decision-making process in the knowledge-based city economy by comprehensively analyzing the existing achievements and basis of IoT intelligent parks. Consequently, they found that despite the fact that IoT had made a great contribution to intelligent parks, the development needs of intelligent parks could not be met yet [14].

2.2. The Application Status of Cloud Computing in Intelligent Parks. Cloud computing acts as the data center in smart cities and intelligent parks, which is the core of their information systems. Hence, many scholars have researched cloud computing technology. Mazza et al. introduced a mobile cloud computing model to describe the data flow and operations that occurred in smart cities and intelligent parks. In the meantime, they proposed a unified offloading mechanism in which communication and computing resources were jointly managed, allowing load balancing between different entities in the environment and delegating communication and computing tasks simultaneously, thereby satisfying the application requirements of smart cities and parks [15]. Hossain et al. discovered that although traditional cloud computing methods could provide the largest computing and storage facilities to support data processing, the latency was high. Thus, they introduced edge computing into the construction of smart cities and intelligent parks. Finally, they found that processing raw IoT data on edge devices was effective in terms of latency and provided context awareness for smart city decision-makers in a seamless manner [16]. Giannakoulias researched the data security issues in the cloud computing environment and introduced some of the most important security threats in cloud computing, as well as key recommendations on how to deal with these threats, namely, security standards and certifications, service provider auditing, security API, transport layer protection, identity verification and encryption key management, and cloud service agreement [17]. Javadzadeh and Rahmani believed that the technology used to implement smart cities was usually based on cloud computing; however, this technology was accompanied by unreliable delays, lack of mobility support, and location awareness. To further develop another path, they applied fog computing to smart cities and parks to explore their research trends and development directions [18].

2.3. The Application Status of Big Data in Intelligent Parks. The rise of big data provides powerful and efficient solutions for IoT and various fields; moreover, its applications are very broad. People's lives are undergoing tremendous changes under the influence of communication, network, and computer technology. After reviewing the development trend of industrial communication and IoT, Wollschlaeger et al. applied the 5G telecommunication network to IoT, which greatly improved the efficiency and data processing rate of the IoT systems [19]. Gai et al. proposed a dynamic privacy protection model under the premise that data transmission had great security risks. They also developed an Android application to evaluate the effectiveness of the model and, finally, protected the security of data privacy [20]. Zhang et al. put forward a new network paradigm called CIoT, including the generation of big data perception, efficient computing, and storage at the edge of CIoT, which could be further integrated into deep learning and data analysis to improve the operating efficiency of the system [21]. With the rapid advancement of big data technology, Wang et al. (2021) established a data management system to link international academic research and city-level management policies. Furthermore, they increased the number of uses based on the practicality of the collected data to enhance smart cities and the development efficiency of the parks [22].

In summary, although various new technologies such as cloud computing, IoT, big data, and artificial intelligence are widely accepted in various industries, they do not have information interoperability, resulting in information islands. Therefore, adding a wireless relay cooperation transmission system to the traditional IoT system can provide a basis for the information transmission of intelligent parks, which is of great value to the development of the economy and society.

3. Big Data System of IoT in Smart Park

3.1. Status Quo of Intelligent Park Construction. Regarding the actual situation at the current stage, the construction of smart cities and intelligent parks worldwide is in the exploratory and experimental stage. The development of smart cities is a solid foundation for the construction of intelligent parks, and the construction and development of smart cities drive the construction of intelligent parks. According to statistics, there are more than 100 smart cities worldwide, most of which are located in Asia and Europe [23]. In China, the construction of parks shows obvious clustering characteristics, and the current development pattern presents a pattern of "the eastern coastal cluster, the central riverside linkage, and the western characteristic development." According to statistics, as of the end of 2019, more than 15,000 parks of various types have been built across the country, and GDP accounts for about 30% of the overall economy. Industrial parks have become an important force in promoting high-quality economic development in China [24]. The development trend of the intelligent park in China is shown in Figure 1 [22].

3.1.1. Problems of Intelligent Park Construction. In the era of intelligence, as various new technologies emerge, such as cloud computing, IoT, big data, and artificial intelligence, the construction of smart cities and intelligent parks in various regions and departments in China has been actively developed. The initial construction of intelligent parks is separated; the different information system standards, incompatibility, blocked access, and information islands have become a major bottleneck for the intelligent development of the park. As a result, the integration and sharing of data have become the current focus. Big data plays an indispensable role in the construction of various industries and even smart cities. The amount of data in various industries is growing explosively. A powerful data vector engine is required to accelerate the "smart" development process of the industry and even the city in various aspects, including government decision-making and services, the lifestyle of people, the cities' industrial layout and planning, and the cities' operation and management methods. In the meantime, the safety of intelligent park also needs to be taken seriously. Highly intelligent interconnection means that personal privacy, data security, and other issues are facing major tests. Only when the fundamental safety of the entire intelligent park system is guaranteed can it exert its actual effectiveness.

3.1.2. Demand Analysis of Intelligent Park Construction. While applying information technology such as cloud computing, IoT, decision analysis, and optimization, intelligent parks highly integrate existing Internet technology, sensor technology, intelligent information processing, and other information technologies. Besides, the parks adopt perceptual, interconnected, and intelligent means to centralize various highly dispersed infrastructures and resources in them for unified configuration and regulation so that the use efficiency of various resources and equipment can be improved [26].

Regarding the demand for intelligent park construction, first, under the guidance of the "people-orientation" service concept, intelligent park is the demand for intelligent humanized services and IoT. The informatization, digitization, and visualization of the intelligent park can be achieved through intelligent processing of people's needs on the environment, public safety, government affairs, and people's livelihood. The second is the demand for security services. Safety and stability are the most basic guarantees for a park's environmental protection, high efficiency and convenience, and intelligent and humanized development. The third is the demand for information services. The informatization services to the park's needs are the premise to meet the basic requirements of park operation and management and enterprises' informatization, which are also the need for the development of environmental protection, facilitation and humanization, and integration of the park construction.

3.2. IoT and Wireless Communication Technologies in Intelligent Park Construction. As the "Internet of everything" has penetrated various industries, IoT has become a symbol of

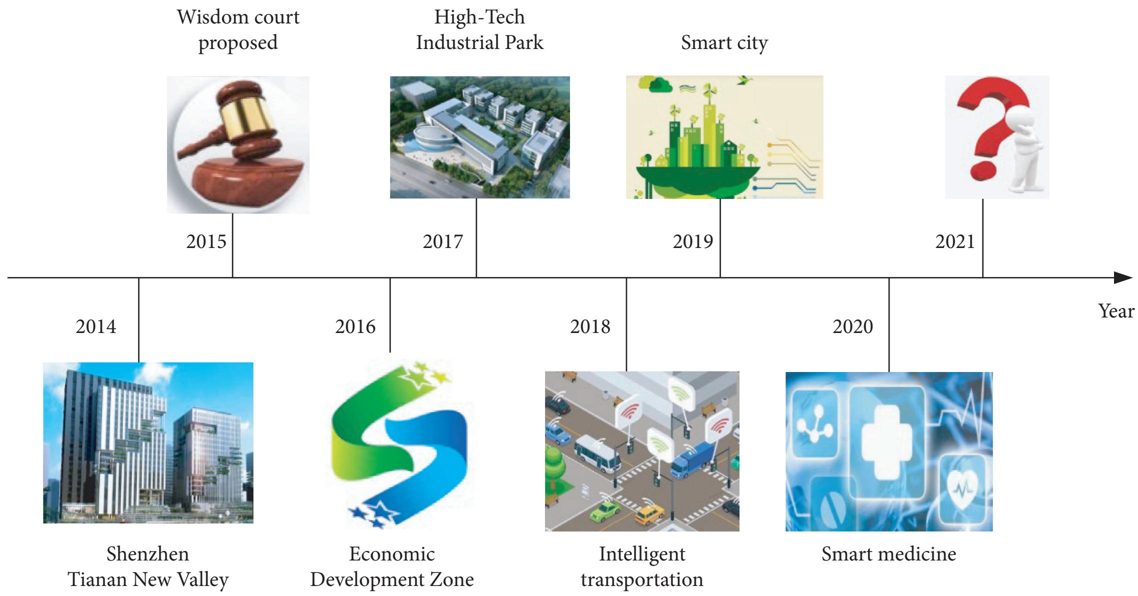

Figure 1: A schematic diagram of the development trend of intelligent parks in China.

smart cities and intelligent parks in the "Internet +" era. IoT equips various sensor devices such as Radio Frequency Identification (RFID) tags, sensors, and QR codes to various real objects, connects these objects to the wireless network through interfaces, and runs the originally set program to achieve remote control or direct communication between things. Finally, people and things and things and things can communicate and interconnect so that the city and park environment can achieve self-perception, laying a solid foundation for the collection, mining, and analysis of urban big data, as well as auxiliary decision-making [27]. When IoT is applied to intelligent parks, it is still based on the original three-layer architecture, as shown in Figure 2.

During intelligent park construction and management, a large amount of data must be collected; however, the collection area of these data is scattered, the geographical environment is complicated, and sometimes the geographical scope is relatively wide. The common wiring network used to construct and manage the intelligent parks will cause great restrictions. Therefore, it is of great significance to adopt wireless sensor networks to construct and manage intelligent parks.

The energy collected by the IoT sensing device from the radiofrequency energy source can be expressed as E, and the unit is Jps, as shown in the following equation:

$$E = \eta G P. \tag{1}$$

In (1), P refers to the transmit power allocated by the radiofrequency energy source to the sensing device, G refers to the channel fading between the radiofrequency energy source and the wireless sensing device, and $\eta \in (0, 1)$ refers to the energy conversion efficiency of sensor equipment. Assuming that the energy E collected by the sensing device is used for information transmission, the achievable transmission rate of the IoT sensing device can be expressed as the following equation:

$$R = \log_2\left(1 + \frac{G' E}{I + N_0}\right) = \log_2\left(1 + \frac{\eta G' G E}{I + N_0}\right). \tag{2}$$

In (2), G' represents the signal fading between the sensing device and the IoT information gateway, I represents the power of cochannel interference signals, and N_o represents Additive White Gaussian Noise (AWGN) [14]. In a narrow sense, the channel state of a specific sensing device is defined as the following equation:

$$\theta \triangleq \frac{G' G}{I + N_0}. \tag{3}$$

In addition to the channel state, the energy conversion efficiency η of different sensing devices in actual IoT scenarios may also be different. Based on this statement, the data transmission rate achieved by the sensing device with the channel state θ can be expressed as

$$R(\theta, P) = \log_2 (1 + \eta \theta P). \tag{4}$$

In (4), $R(\theta, P)$ refers to the achievable transmission rate. The utility of a sensing device with a channel state of θ is defined as the difference between its achievable transmission rate and the cost it pays to operators deploying radiofrequency energy sources. The equation is as follows:

$$U\left(\theta, P, \prod\right) = R(\theta, P) - \prod. \tag{5}$$

In (5), Π denotes the cost that the sensor device needs to pay to the operator that deploys the radiofrequency energy source, which is connected to the transmit power P provided by the radiofrequency energy source.

Wireless communication technology is the foundation and core of the IoT applications in intelligent parks, whether for the collection of basic equipment data or the transmission of data information. In wireless communication, the

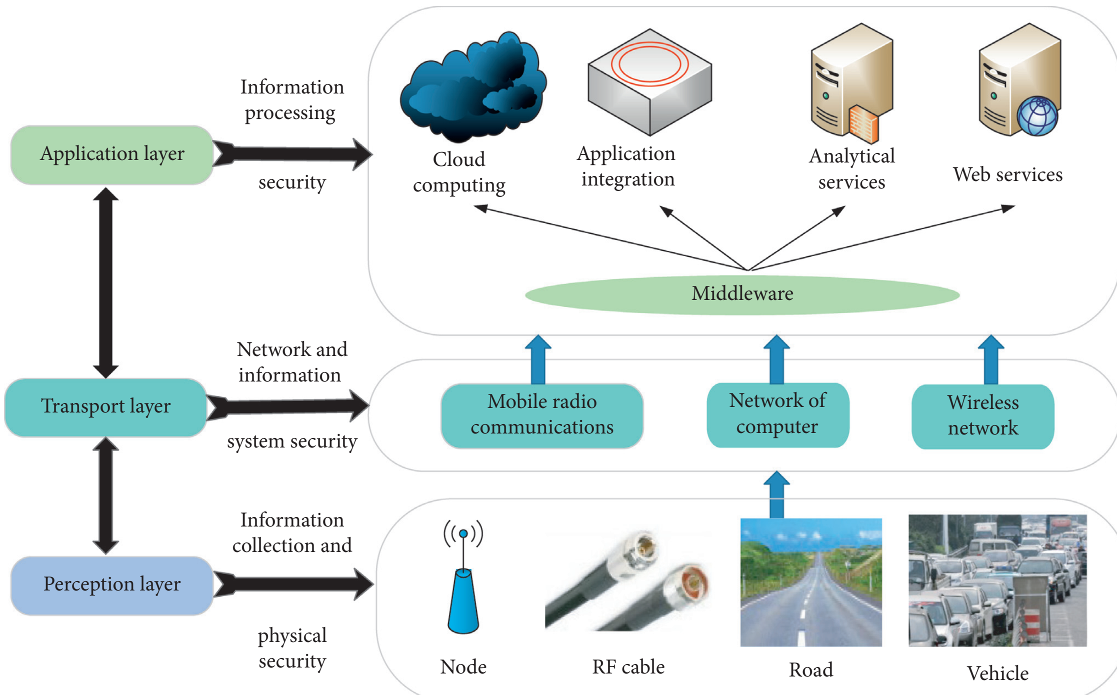

Figure 2: A schematic diagram of the architecture framework of the IoT system in the construction of intelligent parks.

received signal of the wireless channel can be considered as a superposition of a large number of independent scattered components. Hence, the central limit theorem is adopted, and the scattered component of the received signal is assumed to obey a Gaussian distribution. The commonly used wireless channel fading models in wireless networks include Rayleigh fading, Rice fading, and Nakagami fading [28]. The amplitude X_{pq} of the Rayleigh fading channel obeys the Rayleigh distribution, and its Probability Distribution Function (PDF) is

$$f_{X_{pq}}(x) = \frac{x}{\sigma^2} e^{(x^2/2\sigma^2)}, \quad x \geq 0. \tag{6}$$

In (6), σ^2 represents the variance of the wireless channel X_{pq}; namely, $E\{X_{pq}^2\} = 2\sigma^2$, where $E\{\cdot\}$ represents the expectation and X_{pq}^2 represents the chi-square random variable (χ^2). The amplitude X_{pq} of the Rice fading channel obeys the Rice distribution, and its probability density function is

$$f_{X_{pq}}(x) = \frac{(1+K)}{\sigma^2} e^{-K((1+K)x^2/2\sigma^2)} I_0\left(2x\sqrt{\frac{K(1+K)}{2\sigma^2}}\right), \quad x \geq 0. \tag{7}$$

In (7), K refers to the Rice factor, $K = 0$ indicates that the Ricean fading [29] channel is transformed into the Rayleigh channel, $K = \infty$ means that the scattering component of the channel is zero and the received signal only contains the LOS component, and I_0 refers to the zero-order modified first Bessel function [30], which is defined as follows:

$$I_0(x) = \frac{1}{2\pi}\int_0^{2\pi} e^{-x\cos\theta} d\theta. \tag{8}$$

The Nakagami fading distribution is more suitable for the actual transmission conditions of the communication channel, where $\Omega = E\{X_{pq}^2\}$ is the average power of the channel envelope amplitude, and m is the fading index of the function. Thus, the Nakagami fading distribution can be expressed as

$$\begin{aligned} f_{X_{pq}}(x) &= \frac{2}{K(m)}\left(\frac{m}{\Omega}\right)^m x^{2m-1} e^{-(mx^2/\Omega)}, \\ m &= \frac{\Omega}{E\left[\left(X_{pq}^2 - \Omega\right)^2\right]}. \end{aligned} \tag{9}$$

The value of m determines the Nakagami fading distribution. When $m = 0.5$, the distribution is a unilateral distribution. When $m = 1$, the distribution can be converted to a Rayleigh distribution. When $m = \infty$, the channel has no fading trend.

The wireless channel transmission of the IoT system can be divided into single-hop and multihop data transmissions. If there are two or more relay cooperative communication systems in the relay cooperation path, the system is called a multihop relay cooperation system. The relay network is more flexible and changeable and can independently form a cooperative communication network according to actual needs. A typical multihop relay cooperation network is shown in Figure 3 [31].

3.3. Intelligent Park IoT Big Data System Based on Relay Cooperation. With the rapid development and construction of intelligent parks, the IoT big data system contains multiple types of destination nodes to meet the complex di-

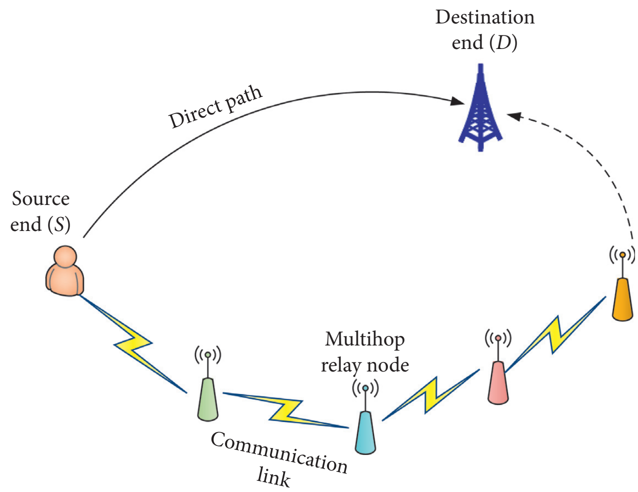

Figure 3: The relay cooperation network of an IoT system.

versity of various fields, such as collecting energy and receiving information. Due to the large-scale coverage of IoT and the small size of communication equipment, the relay node has no power to charge. Instead, it obtains energy from the source node through the wireless channel while using the previous node to receive the required information. Therefore, in this system, the first hop transmission refers to the process in which the first relay node R1 collects energy and receives information from the source node. The second hop transmission refers to the process where the information is transmitted from the first relay node R1 to the energy collecting node and, finally, to the second relay node R2. In this process, the first relay node R1 uses the transmission energy from the source node to send the signal to the second relay node R2 through the precoding design algorithm for information and energy transmission. In the meantime, the receiving energy node collects energy to meet its own energy needs. The third hop transmission means that the second relay node R2 uses the collected energy to send the information to the information-receiving node after splitting the information and energy; finally, the data collection and transmission tasks of the intelligent park IoT big data system are completed. The information transmission model of intelligent park IoT big data system based on relay cooperation is displayed in Figure 4.

In this information transmission model, the signal received by the relay node R1 for the first hop of the IoT transmission is described in the following equation:

$$y_{R_1} = \sqrt{P_s} hx + n_1. \tag{10}$$

In (10), P_s refers to the transmit power of the source node in the IoT network. The transmit power of the relay node is the energy obtained by the source node's signal transmission. The signal transmission of the relay node R1 for the second hop completely depends on the signal of the first hop source node to obtain energy. After R1 receives the signal from the source node, the relay node splits the power to collect energy:

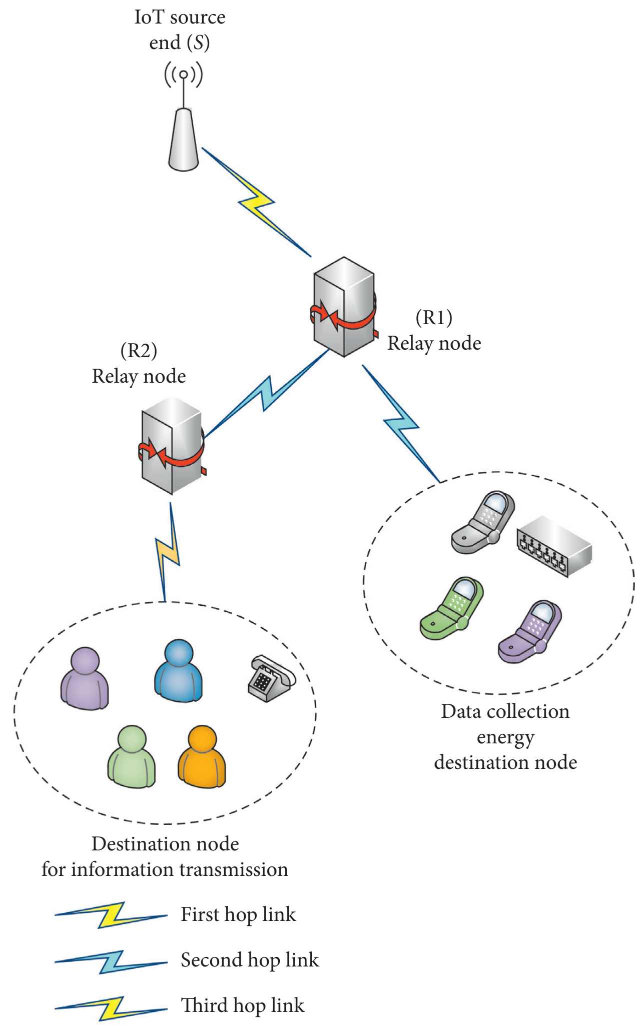

Figure 4: A flowchart of the information transmission model of the intelligent park IoT big data system based on relay cooperation.

$$y_{R_{1,E}} = \sqrt{1-\rho}\, y_{R_1}. \tag{11}$$

In (11), $\rho \in (0, 1)$ represents the power dividing factor. Here, the system performance is analyzed when ρ takes 0.5, 0.1, and 0.9, respectively. Therefore, the energy after the relay node R1 splits the signal from the received signal is $\sqrt{1-\rho}\, y_{R_1}$, and the received power is

$$P_{E1} = (1-\rho)\left(P_s \|h\|^2 + \sigma_1^2\right). \tag{12}$$

Then, $\sqrt{\rho}\, y_{R_1}$ after power splitting is the wireless signal received by the relay node R1, as shown in (13):

$$y_{R1,I} = \sqrt{\rho}\, y_{R1} + z_1, \tag{13}$$

$$z_1 \sim \mathrm{CN}\left(0, \sigma_z^2\right). \tag{14}$$

In (14), the expression of z_1 obeys the conversion noise from radio frequency to baseband with a mean value of zero variance σ_z^2. Then the signal power received by the relay node R1 is

$$P_{I_1} = \rho\left(P_s\|h\|^2 + \sigma_1^2\right) + \sigma_{z_1}^2. \quad (15)$$

On the second-hop link, the energy received by the destination node for energy collection is

$$\left\|y_E\right\|^2 = \sigma_E^2 + \|K\|^2(1-\rho)\left(P_s\|h\|^2 + \sigma_1^2\right). \quad (16)$$

In (16), k~CN(0, 1) denotes the wireless channel from the relay node R1 to the energy collecting node, σ_E^2 represents the noise variance at the energy collecting node, and the signal received by the relay node R2 is

$$y_{R_2} = g \cdot \tilde{y}_{R1} + n_2. \quad (17)$$

In (17), g~CN (0, 1) refers to the wireless channel from the relay node R1 to the relay node R2, and n_2 refers to the Gaussian white noise at the relay node R2. Continuously, the shunt method is adopted for the relay node R2, and the collected energy and signal are, respectively,

$$\begin{aligned} y_{R_{2,E}} &= \sqrt{1-\theta}\, y_{R2}, \\ y_{R_{2,I}} &= \sqrt{\theta}\, y_{R_2} + z_2. \end{aligned} \quad (18)$$

Then the signal sent by the relay node R2 is as follows:

$$\tilde{y}_{R2} = \sqrt{\frac{\left\|y_{R_{2,E}}\right\|_F^2}{\left\|y_{R_{2,I}}\right\|_F^2}}\, y_{R2}. \quad (19)$$

On the third-hop link, the signal received by the destination node is

$$y_D = f \cdot \tilde{y}_{R2} + n_3. \quad (20)$$

In (20), f~CN(0, 1) refers to the wireless channel from the relay node R2 to the destination node of the collected signal, and n_3 is the Gaussian white noise at the destination node of the collected signal, whose equation is

$$n_3 \sim \mathrm{CN}\left(0, \sigma_3^2\right). \quad (21)$$

In this IoT big data analysis system, P_s is a cubic term, so that the calculation can be very difficult. Thus, the high Signal-to-Noise Ratio (SNR) approximation method is used to solve this problem. In the case of high SNR, the noise variance σ_z^2 (usually 1) can be ignored. The high SNR approximation method is adopted, and the power of the relay node R2 adopts an even distribution strategy. Hence, the equation of the SNR can be simplified as follows:

$$\begin{aligned} &\mathrm{SNR}'_D = P_S, \\ &\frac{\|f\|^2\|g\|^2(1-\rho)\|h\|^2}{\|f\|^2\|g\|^2(1-\rho)\sigma_1^2 + \rho\left(\|f\|^2\sigma_2^2 + \sigma_3^2\right)} = \Psi P_S. \end{aligned} \quad (22)$$

According to (16) and (22), the energy collected by the energy collection node to meet its required energy α_0 is regarded as a constraint, and the problem can be expressed as the following equation:

$$\begin{aligned} &\min \quad \frac{aP_S + b}{\log_2\left(1+\mathrm{SNR}'_D\right)}, \\ &\text{s.t.} \quad \sigma_E^2 + \|k\|^2(1-\rho)\left\|P_S\|h\|^2 + \sigma_1^2\right\| \geq \alpha_0. \end{aligned} \quad (23)$$

In (23), $\alpha_0 > 0$ refers to the preset threshold, which defines the minimum energy collected at the energy collection destination node of the IoT network; $a > 0$ and $b > 0$ are parameters in a power consumption model that considers power conversion efficiency and hardware circuit power consumption costs. This equation is converted to be solved using the Lagrangian multiplier method:

$$\begin{aligned} &\min \quad \frac{aP_S + b}{\log_2\left(1+\mathrm{SNR}'_D\right)}, \\ &\text{s.t.} \quad P_S \geq \frac{\alpha_0 - \sigma_E^2}{\|h\|^2\left(\|k\|^2(1-\rho)\right)} - \frac{\sigma_1^2}{\|h\|^2} \triangleq \varphi. \end{aligned} \quad (24)$$

Then it is expressed with the Lagrangian function:

$$\tilde{\phi} = \frac{aP_S + b}{\log_2\left(1+\mathrm{SNR}'_D\right)} + \lambda\left\{\frac{1}{\log_2\left(1+\Psi P_S\right)} - \frac{1}{\log_2(1+\Psi\varphi)}\right\}. \quad (25)$$

In (25), λ refers to the Lagrangian multiplier. The progressively optimal transmit power of the source node can be obtained by taking the first derivative of P_s and setting it to 0, as shown in the following equation:

$$P_S = \left(\frac{\ln 2}{W\{2\ln 2(1/\ln 2\ \Psi\varphi + b\Psi - a)\}}\right)\frac{1}{\Psi}. \quad (26)$$

In (26), $W\{\}$ is the Lambertian function [32]. Therefore, when the multihop IoT system receives energy and sends information, it is constrained by the minimum energy collected by the energy collection node, and the optimal transmission power of the source can be calculated. The transmission power of all relay nodes comes from the source.

3.4. Simulation Analysis. The performance of the constructed system is evaluated through simulation experiments. The simulation tool is Matlab, and the number of cycles is 10000. The energy collection node and the information-receiving node both receive energy and information through wireless transmission. Assume that the values of parameter a in the power consumption model ($p_{\text{total}} = ap_t + b$) are 5 and 10, respectively, and the values of b are 10, 100, and 300. The variances of all noises are set as $\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_E^2 = \sigma_{z_1}^2 = \sigma_{z_2}^2 = 1$. The channel obeys the Nakagami fading distribution; hence, the value of the parameter m can take multiple different values. In this simulation experiment, m takes 1, 2, and 3, respectively. The system performance is evaluated and analyzed from system energy harvesting, system interruption probability, and data transmission delay. The simulation environment setups are summarized in Table 1.

Table 1: Simulation environment setups.

Configuration		Version
Software	Operating system	Linux 64-bit
	Python version	Python 3.6.1
	Simulation platform	Matlab
	Development platform	PyCharm
Hardware	CPU	Intel Core i7-7700@4.2 GHz 8 cores
	Internal memory	Kingston DDR4 2400 MHz 16G
	GPU	Nvidia GeForce 1060 8G

4. Results and Discussion

4.1. Energy Efficiency of Intelligent Park's IoT Big Data System. The energy efficiency at the energy collection node is analyzed under different power dividing factors ($\rho = 0.5$, 0.1, and 0.9) to have an overall understanding of the intelligent park IoT big data system based on relay cooperation. The results are presented in Figures 5–7.

As shown in Figures 5–7, when the power dividing factor is 0.5, 0.1, and 0.9, the energy efficiency of the entire IoT system changes with respect to the minimum energy α_0 collected at the energy collecting node. The energy efficiency results show a trend of first increasing and then decreasing with the increase in α_0. According to Figure 5, when the values of a and b are different, the basic energy efficiency shows a trend of first increasing and then decreasing. Figure 6 suggests that when the power dividing factor is very small, the energy efficiency decreases further compared with that when $\rho = 0.5$. The reason is that the system has a strong ability to collect energy when the power dividing factor is very small; however, the efficiency of information collection is low. As shown in Figure 7, when the power dividing factor is large, the system information transmission capacity is enhanced. However, the energy collection capacity and the system energy efficiency are reduced. Furthermore, if the power shunt factor takes different values, the energy efficiency will decrease with the increase in the value of b when parameter a is a fixed value. Similarly, when parameter b is a fixed value, the energy efficiency value also shows a downward trend as the value of a increases. Therefore, a suitable power dividing factor is very important to the energy efficiency of the IoT system.

4.2. Outage Probability of Intelligent Park's IoT Big Data System. The outage probability of the IoT big data system is analyzed in terms of the simulation and theoretical result comparison, the presence and absence of the multihop path, the presence and absence of a direct path, and the different numbers of multihop path relays. The results are displayed in Figures 8–11.

As shown in Figure 8, the comparative analysis of the outage probability between the simulation result and the theoretical result suggests that the two are basically the same. Meanwhile, the outage probability gradually decreases as the SNR decreases with the increases in the value of parameter

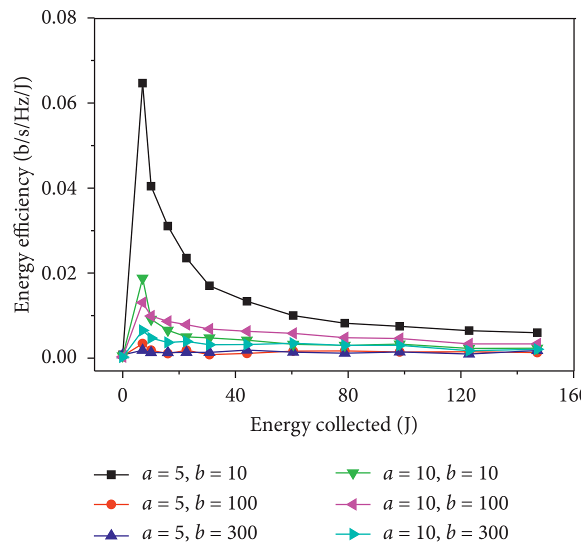

Figure 5: The IoT energy efficiency results achieved by the proposed scheme when $\rho = 0.5$.

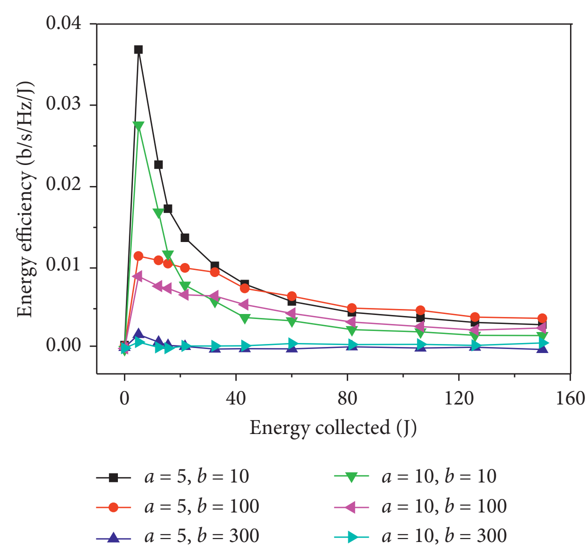

Figure 6: The IoT energy efficiency results achieved by the proposed scheme when $\rho = 0.1$.

m. These results mean that, under the same environment, when the value of m is more considerable, the system performance is better, and the outage possibility is lower.

Furthermore, the outage probability of the IoT big data system is analyzed, as shown in Figures 9–11. As shown in Figure 9, the comparative analysis of the outage probability given the presence or absence of the multihop path suggests that, despite the value of m, the outage probability can be significantly reduced when the multihop path exists; as the value of m increases, the outage probability decreases. The reason is that the formation of virtual antennas when multihop paths exist results in collaboration, which improves system performance. Figure 10 shows the outage probability results under the presence or absence of a direct path. Regardless of the value of m, the outage probability can

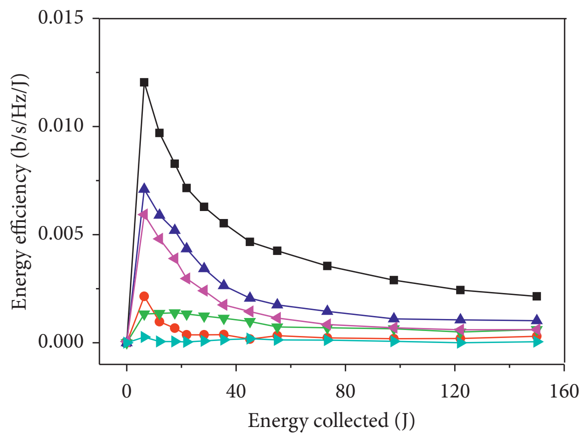

FIGURE 7: The IoT energy efficiency results achieved by the proposed scheme when $\rho = 0.9$.

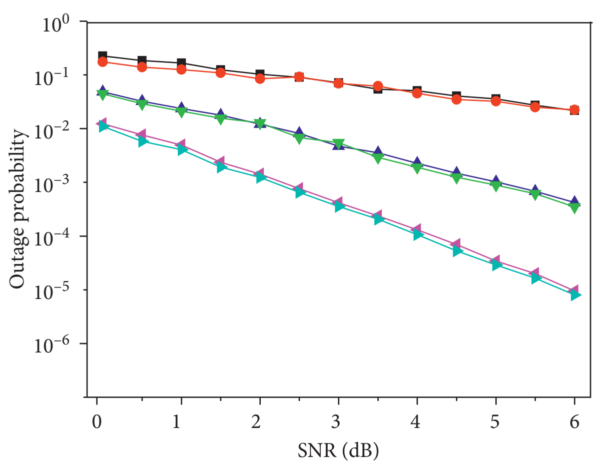

FIGURE 8: Comparison of simulation and theoretical outage probability results.

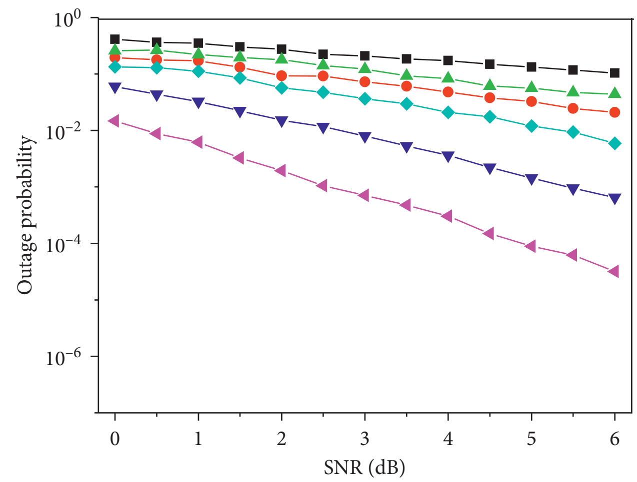

FIGURE 9: Comparison of outage probability results under the presence/absence of a multihop path of the system.

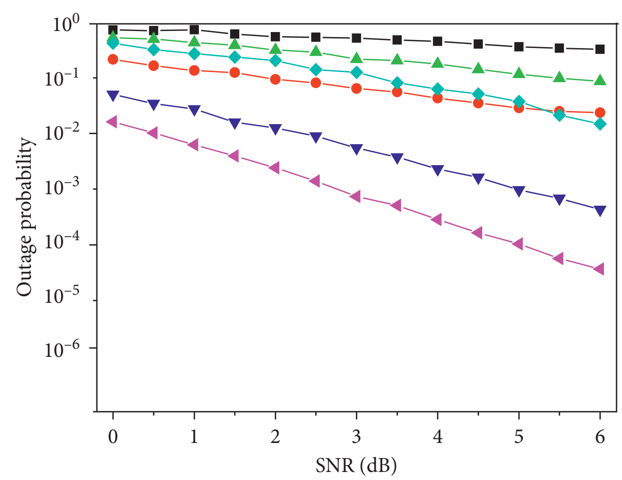

FIGURE 10: Comparison of outage probability results under the presence/absence of a direct path of the system.

be significantly reduced when the direct path exists; as the value of m increases, the outage probability decreases more obviously. The reason is that, in the direct path, the signal is sent directly from the source node to the terminal node, which can reduce loss and increase system performance. Figure 11 displays the comparative analysis of outage probability when the number of relays in the multihop path is different. When the number of system relays is different, the system outage probability is different. When the parameter m is fixed, the more the number of relays, the smaller the system outage probability, and the better the system performance.

4.3. Transmission Accuracy of Intelligent Park's IoT Big Data System. The data transmission performance of the IoT big data system is analyzed. Under different successful transmission probabilities p, when λ is 0.05 and 0.001, the data propagation delay is shown in Figures 12 and 13. Furthermore, the correlation between different λ values and the actual propagation delay are analyzed when the successful transmission probability p is 100% and 80%, as displayed in Figures 14 and 15.

As shown in Figures 12 and 13, when $\lambda = 0.05$ and $\lambda = 0.001$, the data information propagation delay decreases with the increase of the probability of successful transmission. The delay time is the shortest when the probability of successful

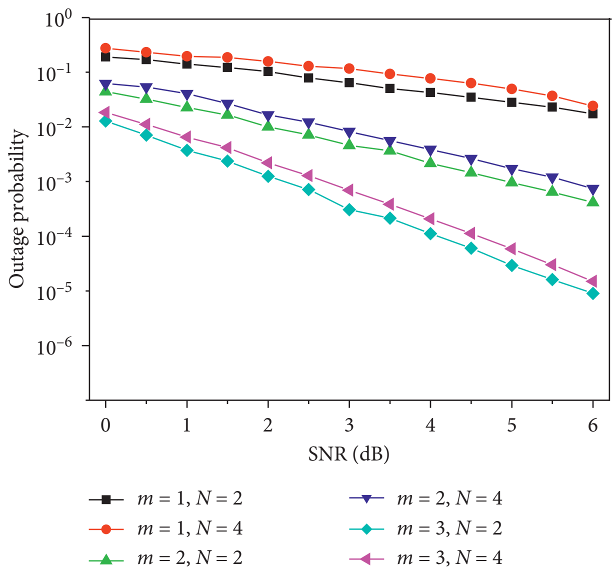

FIGURE 11: Comparison of outage probability results given different number of multihop path relays.

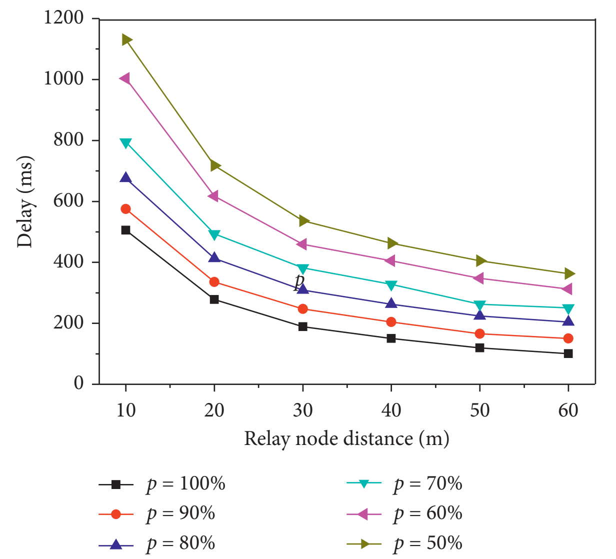

FIGURE 13: The transmission delay results under different successful transmission probability p when $\lambda = 0.001$.

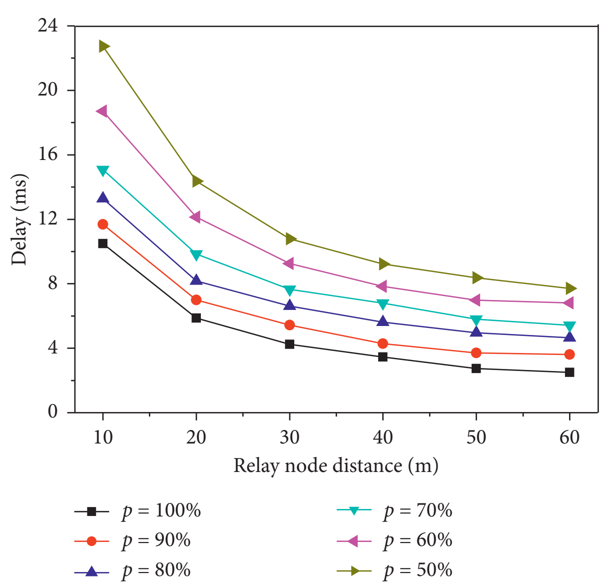

FIGURE 12: The transmission delay results under different successful transmission probability p when $\lambda = 0.05$.

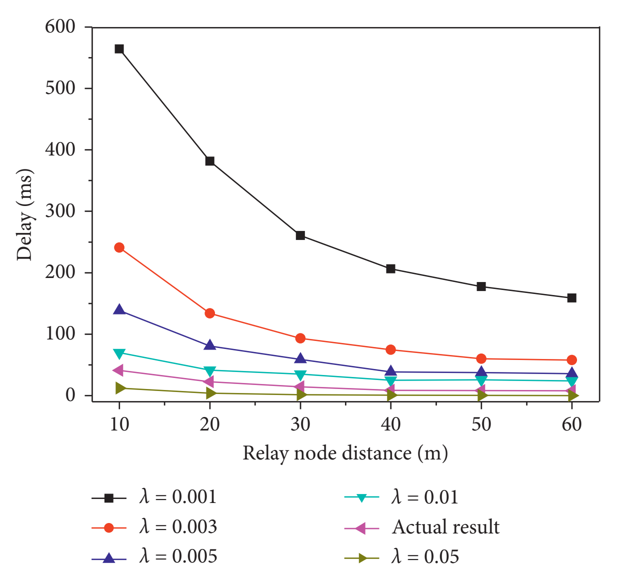

FIGURE 14: The experimentally measured transmission delay results when $p = 100\%$.

transmission is 100%. Therefore, the higher the successful transmission probability, the shorter the transmission delay, and the value of λ will not affect this correlation.

According to Figures 14 and 15, when the probability of successful transmission is 100% and 80%, different values of λ have different influences on the transmission delay time. As the distance of the relay signal collection node increases, the delay of the same λ value is continuously reduced. When the delays between different λ values are compared, the delay time decreases as the λ value increases, and the maximum delay time is about 570 ms and 670 ms when $\lambda = 0.001$. The delay time approaches 0 when $\lambda = 0.05$. When the λ value is between 0.01 and 0.05, the result is the same as the actual delayed transmission result. Therefore, analysis of the influence of different λ values on the transmission delay time reveals that the theoretical results when the λ value is 0.01 to 0.05 are most similar to the actual transmission results.

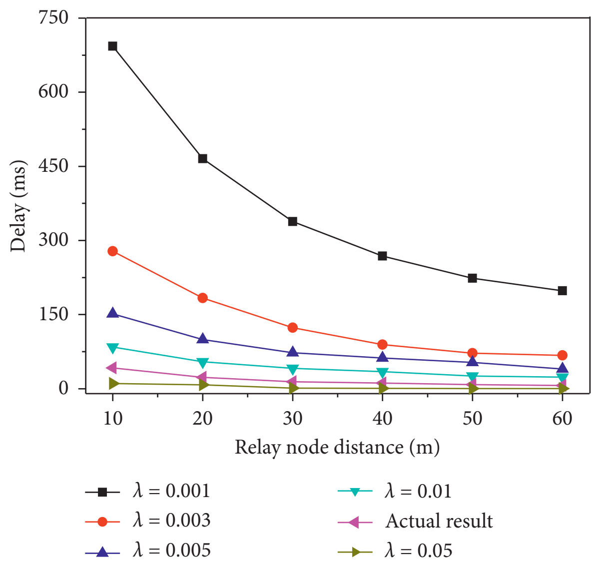

Figure 15: The experimentally measured transmission delay results when $p = 80\%$.

5. Conclusion

As the 5G networks develop rapidly, the architecture and performance of the IoT systems are improving continually. Intelligent parks are also continually developing towards functional composite industrial parks with community value association and circle-level resource sharing. Here, an IoT big data system is constructed for intelligent parks based on wireless relay cooperation transmission technology, where the wireless sensor networks serve as the information collector and transmitter. The simulation experiment evaluates the complexity of the system and proves that the constructed IoT big data system can employ methods such as multihop paths to reduce the outage probability of the system and lessen the delay time of successful data transmission, thereby improving the overall performance. The results can provide an experimental basis for the development of IoT big data systems in intelligent parks.

However, there are several shortcomings. First, the constructed system has only been simulated and not applied in a real-life setting. In practice, there are often differences from theoretical values, such as video image transmission and recognition effects. Second, the research emphasis is on improving the system performance; nevertheless, the constructed system has not been compared with traditional methods and systems to exhibit its universal applicability. Therefore, the IoT system will be improved in the following research, and more intelligent science and technology, such as relay cooperation and deep learning, will be utilized to build a more optimized system, whose performance, advantages, and disadvantages will be investigated through comparisons with traditional methods, in an effort to provide a reference for social and economic development.

Data Availability

The IOT data used to support the findings of this study have not been made available because of the privacy of this research.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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References

[1] A. Androniceanu, "The social sustainability of smart cities: urban technological innovation, big data management, and the cognitive internet of things," *Geopolitics, History, and International Relations*, vol. 11, no. 1, pp. 110–115, 2019.

[2] G. Sun, C. Li, and L. Deng, "An adaptive regeneration framework based on search space adjustment for differential evolution," *Neural Computing and Applications*, vol. 4, pp. 1–17, 2021.

[3] Y. Mehmood, F. Ahmad, I. Yaqoob, A. Adnane, M. Imran, and S. Guizani, "Internet-of-things-based smart cities: recent advances and challenges," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 16–24, 2017.

[4] R. Tuyls and A. Pera, "Innovative data-driven smart urban ecosystems: environmental sustainability, governance networks, and the cognitive internet of things," *Geopolitics, History, and International Relations*, vol. 11, no. 1, pp. 116–121, 2019.

[5] K. Löfgren and C. W. R. Webster, "The value of big data in government: the case of 'smart cities'," *Big Data & Society*, vol. 7, no. 1, 2020.

[6] F. Yin, X. Xue, C. Zhang et al., "Multifidelity genetic transfer: an efficient framework for production optimization," *SPE Journal*, vol. 1, pp. 1–22, 2021.

[7] B. Silva, M. Khan, C. Jung et al., "Urban planning and smart city decision management empowered by real-time data processing using big data analytics," *Sensors*, vol. 18, no. 9, p. 2994, 2018.

[8] E. Park, A. Del Pobil, and S. Kwon, "The role of Internet of Things (IoT) in smart cities: technology roadmap-oriented approaches," *Sustainability*, vol. 10, no. 5, p. 1388, 2018.

[9] D. Grimaldi and V. Fernandez, "Performance of an internet of things project in the public sector: the case of nice smart city," *The Journal of High Technology Management Research*, vol. 30, no. 1, pp. 27–39, 2018.

[10] W. Serrano, "Digital systems in smart city and infrastructure: digital as a service," *Smart Cities*, vol. 1, no. 1, pp. 134–153, 2018.

[11] M. M. Rathore, A. Paul, A. Ahmad, and G. Jeon, "IoT-based big data: from smart city towards next generation super city planning," *International Journal on Semantic Web and Information Systems*, vol. 13, no. 1, pp. 28–47, 2017.

[12] S. Bresciani, A. Ferraris, and M. Del Giudice, "The management of organizational ambidexterity through alliances in a new context of analysis: Internet of Things (IoT) smart city projects," *Technological Forecasting and Social Change*, vol. 136, pp. 331–338, 2018.

[13] Y. Qian, D. Wu, W. Bao, and P. Lorenz, "The internet of things for smart cities: technologies and applications," *IEEE Network*, vol. 33, no. 2, pp. 4-5, 2019.

[14] A. Watson, Z. Musova, V. Machova, and Z. Rowland, "Internet of things-enabled smart cities: big data-driven decision-making processes in the knowledge-based urban economy," *Geopolitics, History and International Relations*, vol. 12, no. 1, pp. 94–100, 2020.

[15] D. Mazza, D. Tarchi, and G. E. Corazza, "A unified urban mobile cloud computing offloading mechanism for smart cities," *IEEE Communications Magazine*, vol. 55, no. 3, pp. 30–37, 2017.

[16] S. K. A. Hossain, M. A. Rahman, and M. A. Hossain, "Edge computing framework for enabling situation awareness in IoT based smart city," *Journal of Parallel and Distributed Computing*, vol. 122, pp. 226–237, 2018.

[17] A. Giannakoulias, "Cloud computing security: protecting cloud-based smart city applications," *Journal of Smart Cities*, vol. 2, no. 1, pp. 41–52, 2019.

[18] G. Javadzadeh and A. M. Rahmani, "Fog computing applications in smart cities: a systematic survey," *Wireless Networks*, vol. 26, no. 2, pp. 1433–1457, 2020.

[19] M. Wollschlaeger, T. Sauter, and J. Jasperneite, "The future of industrial communication: automation networks in the era of the internet of things and industry 4.0," *IEEE Industrial Electronics Magazine*, vol. 11, no. 1, pp. 17–27, 2017.

[20] K. Gai, K.-K. R. Choo, M. Qiu, and L. Zhu, "Privacy-preserving content-oriented wireless communication in internet-of-things," *IEEE Internet of Things Journal*, vol. 5, no. 4, pp. 3059–3067, 2018.

[21] Y. Zhang, X. Ma, J. Zhang, M. S. Hossain, G. Muhammad, and S. U. Amin, "Edge intelligence in the cognitive internet of things: improving sensitivity and interactivity," *IEEE Network*, vol. 33, no. 3, pp. 58–64, 2019.

[22] A. Wang, A. Zhang, E. H. Chan, W. Shi, X. Zhou, and Z. Liu, "A review of human mobility research based on big data and its implication for smart city development," *ISPRS International Journal of Geo-Information*, vol. 10, no. 1, 2021.

[23] T. Zaree and A. R. Honarvar, "Improvement of air pollution prediction in a smart city and its correlation with weather conditions using metrological big data," *Turkish Journal of Electrical Engineering & Computer Sciences*, vol. 26, no. 3, pp. 1302–1313, 2018.

[24] S. Shadroo and A. M. Rahmani, "Systematic survey of big data and data mining in internet of things," *Computer Networks*, vol. 139, pp. 19–47, 2018.

[25] W. Villegas-Ch, X. Palacios-Pacheco, and S. Luján-Mora, "Application of a smart city model to a traditional university campus with a big data architecture: a sustainable smart campus," *Sustainability*, vol. 11, no. 10, Article ID 2857, 2018.

[26] X. Ma, K. Zhang, L. Zhang et al., "Data-driven niching differential evolution with adaptive parameters control for history matching and uncertainty quantification," *SPE Journal*, vol. 26, pp. 1–18, 2021.

[27] M. Babar, F. Arif, M. A. Jan, Z. Tan, and F. Khan, "Urban data management system: towards big data analytics for internet of things based smart urban environment using customized Hadoop," *Future Generation Computer Systems*, vol. 96, pp. 398–409, 2019.

[28] H. Bangui, M. Ge, and B. Buhnova, "A research roadmap of big data clustering algorithms for future internet of things," *International Journal of Organizational and Collective Intelligence*, vol. 9, no. 2, pp. 16–30, 2019.

[29] S. Hodgkins, "Big data-driven decision-making processes for environmentally sustainable urban development: the design, planning, and operation of smart city infrastructure," *Geopolitics, History, and International Relations*, vol. 12, no. 1, pp. 87–93, 2020.

[30] N. A. Zhuravleva, J. Wright, L. Michalkova et al., "Sustainable urban planning and Internet of Things enabled big data analytics: designing, implementing, and operating smart management systems," *Geopolitics, History and International Relations*, vol. 12, no. 1, pp. 59–65, 2020.

[31] S. Bennett, P. Durana, and V. Konecny, "Urban internet of things systems and interconnected sensor networks in sustainable smart city governance," *Geopolitics, History, and International Relations*, vol. 12, no. 2, pp. 51–57, 2020.

[32] V. Bhatnagar, K. Thirunavukkarasu, A. S. Singh et al., "An analysis of IoT and big data for smart city development," *Journal of Critical Reviews*, vol. 7, no. 5, pp. 1440–1443, 2020.