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THE FUTURE OF URBAN RAIL: INTEGRATING IOT AND 5G FOR INTELLIGENT VEHICLE MAINTENANCE AND OPERATIONS

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Abstract: Urban rail transit, as an important part of a city, mainly includes a series of rail related transportation systems such as subway systems, light rail systems, and trams. It has the advantages of energy conservation, land saving, large traffic volume, and almost pollution-free, and is the backbone of urban public transportation. However, there are many problems in the operation and maintenance of urban rail transit vehicles, which require a series of means to assist in their management. Therefore, this article would design an intelligent operation and maintenance system to assist in the management of urban rail transit vehicles. After a series of research and design in this article, the experimental product was finally applied to a parking lot in a certain city for testing. Compared with another parking lot, the difference in traffic flow before the experiment was not significant, with only about 270 times. After the experimental subjects were loaded with the new system, the average traffic flow reached 305.4 vehicles, while the control group only had 272.7 vehicles. Such a significant increase in traffic flow undoubtedly reflects the practicality of the new system.

Keywords: IoT-5G, Urban Rail Transit, Intelligent Vehicle Operation and Maintenance System, 5G Data Encoding Algorithm

1. Introduction

Vehicle operation and maintenance refers to the operation, maintenance, and repair of vehicles. As the most important means of transportation in today's society, vehicles are closely related to everyone's lives. Therefore, vehicle operation and maintenance in the context of urban rail transit are equally important. This article attempts to establish an intelligent operation and maintenance system for urban rail transit vehicles from the perspective of the Internet of Things, using 5G as a technical tool.

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The fifth generation network technology, as an emerging product of the current Internet era, would inevitably receive attention. Chettri Lalit once pointed out in his research that 5G can play an important role in the Internet of Things [1]. The powerful functionality of 5G is beyond doubt. Dolgui Alexandre believed that 5G technology can achieve end-to-end real-time connectivity at a highly refined level, and achieve relevant end-to-end visibility through the Internet of Things [2]. 5G has been applied in many aspects, and Xiao M L's research attempted to amplify the video power of 5G base stations [3]. Siriwardhana Yushan believed that 5G technology can be applied to mobile augmented reality applications [4]. The power Internet of Things is also an industry that requires 5G. Tao J S proposed that the power Internet of Things must be combined with 5G, bringing many advantages to the power Internet of Things [5]. Mao S Q also introduced 5G in his research to address the growing computing needs of the power Internet of Things [6]. Through the research of the above scholars, it is evident that 5G has rich diversity.

The logistics, manpower delivery, and other aspects of urban transportation are inseparable from transportation, and urban rail transit, as an important part of urban transportation, has always been highly concerned. Bešinović Nikola once pointed out pointedly that key infrastructure such as transportation and power networks are crucial for the operation of society and the economy [7]. In order to address these issues, Abduljabbar Rusul proposed that the operation and maintenance of urban rail transit require the use of artificial intelligence algorithms [8]. Liu Y also believed that with the explosive development of smart cities, green energy management systems have received research and industry attention [9]. Among many ideas, the Internet of Things has attracted people's attention. Zhu F H believed that intelligent transportation systems driven by the Internet of Things have enormous potential and capabilities, which can make transportation systems efficient, safe, intelligent, reliable, and sustainable [10]. Wijethilaka Shalitha discussed the possibility of combining the Internet of Things with many emerging technologies, such as blockchain and artificial intelligence [11]. Based on the above research, highly compatible IoT technologies are highly likely to provide assistance for vehicle operation and maintenance.

2. Basic Urban Rail Transit Intelligent Operation and Maintenance System

In order to meet the actual operation and maintenance needs of urban rail transit vehicles, Deng B proposed an intelligent operation and maintenance system architecture for urban rail transit, consisting of a hardware system of intelligent detection equipment and facilities and a software system of maintenance and guarantee management mode [12]. Under this framework, the operation and maintenance of urban rail transit are subdivided into multiple aspects, or specialties, mainly reflected in vehicles, power supply, and communication. Under this clear division of labor, the efficiency of management and operation of intelligent operation and maintenance systems can be fully released. Guo J W further proposed the establishment of an intelligent operation and maintenance system for urban rail transit vehicles based on full element and full process data fusion [13]. The system has very powerful functions, including intelligent scene management, vehicle maintenance management, vehicle health management, trackside intelligent detection, and intelligent control center for classification and work. It can be said that the versatility of this system effectively solves the problem of vehicle operation and maintenance.

Based on the new generation of information technology applications, this system can achieve many intelligent application functions, such as condition monitoring, condition evaluation, and proposing maintenance methods for vehicle professional equipment. The system itself also has the function of fault analysis. In this multifunctional environment, the maintenance and support costs of the system can be reduced, as well as the risk of malfunctions, ultimately improving the service life of the equipment.

Figure 1. Design of intelligent operation and maintenance system for urban rail transit vehicles

As shown in Figure 1, the operation of this intelligent operation and maintenance system for urban rail transit vehicles based on the entire process and all elements mainly relies on various technical means including the Internet of Things, big data, and artificial intelligence. It would break through the technology of integrating diverse and heterogeneous data of urban rail transit vehicles, and combine the data fusion of the entire process and all data to ultimately output it to the intelligent operation and maintenance platform, making it digital, networked, and intelligent, and implement a new mode of urban rail transit operation and maintenance services.

The above is the overall framework of the system, which is further divided into business architecture, technical architecture, and functional architecture. The business architecture mainly consists of operation monitoring, fault detection, and vehicle scheduling, while the technical architecture is divided into monitoring center, decision-making center, dispatch center, and support center. The functional architecture is mainly responsible for supporting the business architecture. As shown in Figure 2, it is a schematic diagram of the system architecture division of labor.

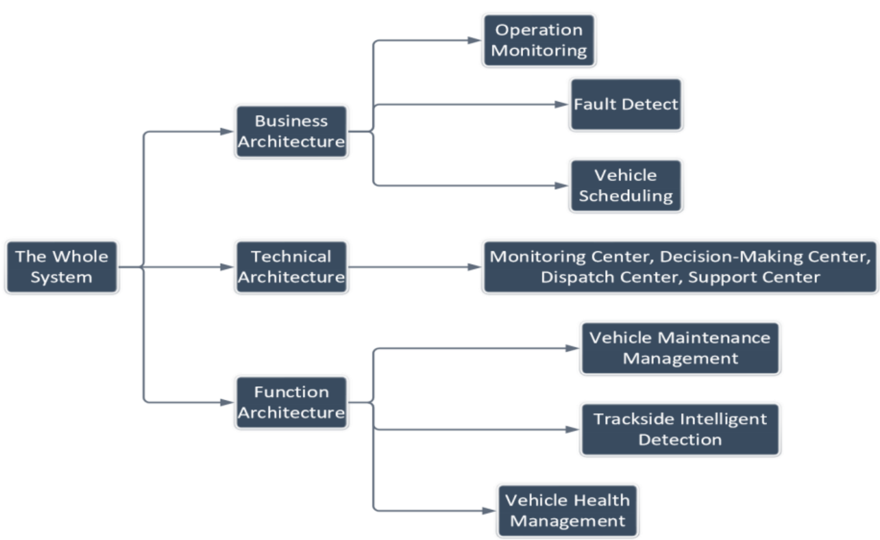

Figure 2. Architecture division of intelligent operation and maintenance system for urban rail transit vehicles

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3. IoT Applications Based on 5G Networks

In today's society, 5G networks are gradually becoming popular and have strong applicability. However, Wang W believed that there are some weak links in the compatibility between 5G and current IoT services, which still cannot meet the existing communication services [14]. In his research, in order to design a 5G with strong compatibility, he proposed a series of internet technologies, among which SDN (Software Defined Network) integrates multiple network communication technologies to achieve integrated control of all network terminal devices. Lu ZP also held the same opinion, believing that SDN promotes network innovation and simplifies network management [15]. In addition to SDN, there is also NFV (network functions virtualization). In his research, Gong F believed that NFV can inject new impetus into the development of communication network technology [16]. The last key technology, NB IoT (Narrow Band Internet of Things or Cellular Internet of Things), has also been recognized by other researchers. Ma HY proposed that the total scale of global cellular Internet of Things connections exceeds 2 billion, which has been widely applied [17]. With the supplementation of the above technologies, 5G can be compatible with and used by the Internet of Things. The following shows the differences in the communication performance of the Internet of Things with the support of 5G and 4G respectively.

Table 1. Comparison of the Effects of 4G and 5G on Communication Performance

Terminal Type	4G Edge IoT Agency	5G integrated communication gateway
Downlink Rate (Mbps)	44.5	893.1
Uplink Rata (Mbps)	7.8	94.6
Network Delay (ms)	37.2	18.3

According to Table 1, 4G has a downlink rate of only 44.5Mbps, which is much lower than 5G's 893.1Mbps. Similarly, the downlink rate is only 7.8Mbps, which is much better than 5G's 94.6Mbps. In terms of latency, 5G's 18.3ms is lower than 37.2ms, indicating that 5G is much stronger than 4G in these communication performance indicators.

3.1 A blockchain-based Logistics System

After the improvement of 5G network, the universality and compatibility of IoT technology have made it reusable in other places. Ai X Y established a logistics system based on 5G IoT and blockchain in its research [18]. This system encrypts logistics information in response to recent issues such as drug and food safety, fully leveraging the role of 5G.

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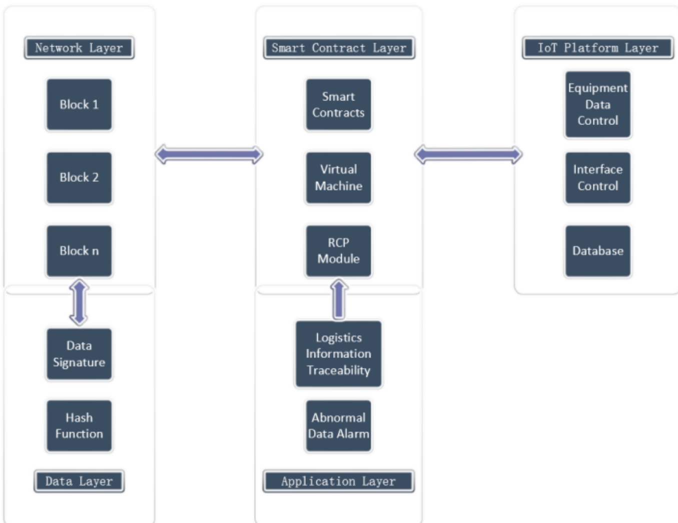

Figure 3. Logistics system framework based on blockchain and 5G Internet of Things

As shown in Figure 3, the framework can be divided into network layer, smart contract layer, IoT platform layer, data layer, and application layer as a whole. First of all, people can see that the data layer and the network layer are closely connected. The data layer contains data signatures and hash function, mainly involving block data, while the network layer connected to it is mainly responsible for the main logic of the blockchain. Next is the smart contract layer, which mainly relies on the RCP (remote file copy) module to interact with virtual machines. Then there is the IoT platform layer, which retrieves IoT data information and control instructions based on the database. Finally, there is the application layer, which interacts with the smart contract layer and the IoT platform layer for information exchange.

3.2 *Application of 5G Internet of Things Technology in Distribution Networks*

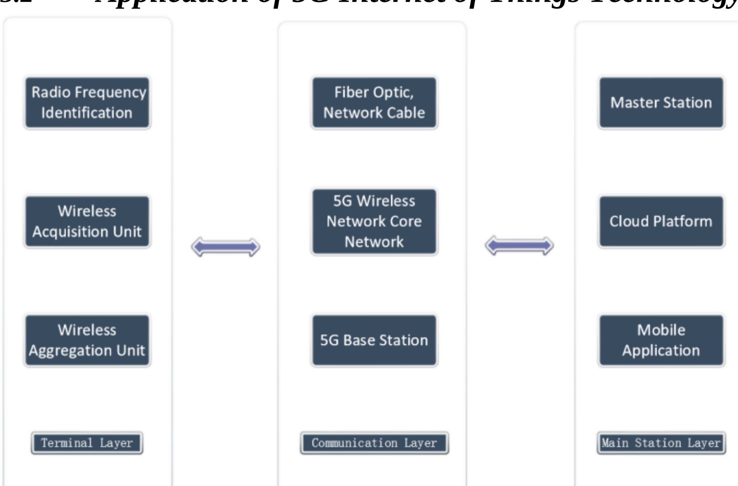

Figure 4. Network extension graph based on 5G

As an important link in ensuring electricity consumption in modern society, it is necessary to ensure its efficiency and safety in power transmission. Therefore, supervision and management of the distribution network are also essential. The wireless network selection system with 5G base stations can also be seen as a combination of 5G Internet of Things technology.

As shown in Figure 4, the wireless network routing system consists of three major systems, namely the terminal layer, communication layer, and main station layer. The terminal layer is mainly composed of wireless radio frequency identification, wireless acquisition units, and wireless aggregation units, while the communication layer is composed of a 5G wireless network core network and a base station, which are interconnected by optical fibers and network cables. Finally, there is the main station layer, which basically receives signals from the main station, uploads them to the cloud platform, and finally delivers them to mobile applications.

4. Comprehensive Calculation during 5G Application

With the rapid development of wireless communication technology, the use of 5G has become increasingly widespread. In order to allocate resources reasonably, Chen F T proposed the NOMA (Non orthogonal Multiple Access) algorithm [19]. Similarly, Xiang X Y proposed a 5G data encoding algorithm to address the interference of traditional power IoT terminal tasks [20]. Firstly, the indicator vector of user a is set to η:

$$\eta=\{\eta_{a1},\ \eta_{a2},\ \ldots\ldots\eta_{an}\} \qquad (1)$$

The channel state information matrix is set to A; the channel precoding matrix is set to B; the beamforming signal flag is b; the user’s noise is c, C is the number of terminals in the power IoT; α is the number of users, and the signal received by user a is set to y_a:

$$y_a = \sum_{n\in C}\eta_{an}A_{an}B_{an}b_a + \sum_{a=1}^{\alpha}\sum_{n=1}^{C}A_{an}B_{an}b_a + c \qquad (2)$$

Assuming that during the calculation process, the user uses a frequency band with a bandwidth of D, and sets E as the bandwidth channel state and F as the encoding and processing coefficients, then:

$$F=\frac{\sum_{a=1}^{\alpha}\sum_{n=1}^{C}\eta_{an}A_{an}B_{an}b_{an}}{D} \qquad (3)$$

After each parameter is determined, the channel capacity G should be calculated as:

$$G(AB,\ ) = D\cdot\lg\left(\frac{1+\sum^{C}\eta_{an}\left|E B_{an}\right|^{2}}{1+\sum_{a=1}^{2}\sum_{n=1}^{C}\eta^{n}\left|F F_{an}\right|^{2}}\right) \qquad (4)$$

This algorithm can determine the channel capacity of the power Internet of Things terminal task access, and can establish a secure communication channel. The security authentication method for task access of power IoT terminals based on 5G data algorithm has good anti-interference performance and solves many problems that exist compared to traditional methods. Through this method, the bit error rate is lower, the overall anti-interference

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performance is better, and the practicality is stronger, which can provide a basis for the safe and stable operation of the power Internet of Things[21].

5. Comparative Experimental Design Based on 5G and Ordinary Vehicle Operation and Maintenance Systems

After the design of the intelligent operation and maintenance system for urban rail transit vehicles based on IoT-5G technology is completed, this article also needs to conduct experimental analysis of the actual effect of this system. Therefore, this article selects two large parking lots in deep bustling areas of a certain city, and sets the vehicle operation and maintenance system in the parking lot as the research carrier. One of them is selected to load the vehicle operation and maintenance system designed in this article, and is set as parking lot 1. The other remains the same and uses a traditional system, set as Parking Lot 2. Then, a certain ten days after using the new system for a period of time and a certain ten days before loading are selected as a comparison to calculate the changes in traffic flow in the two parking lots [22].

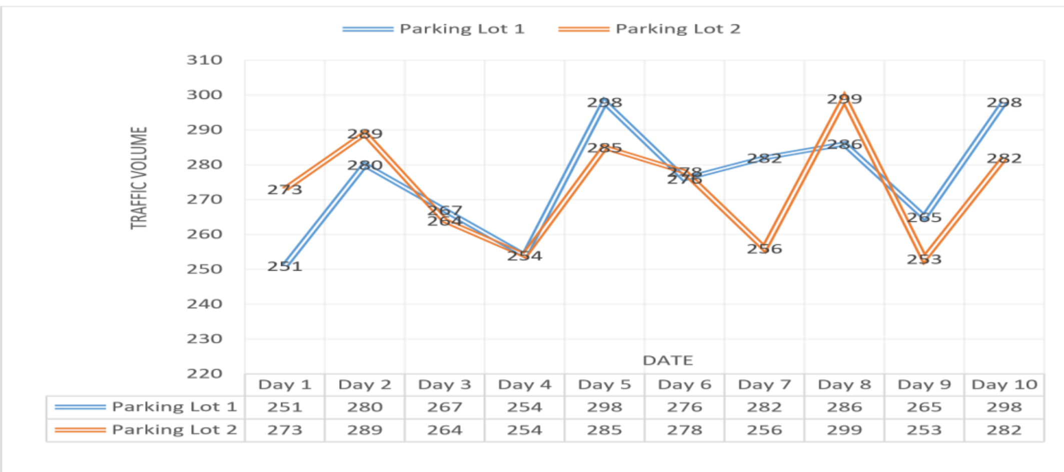

Figure 5. Comparison of traffic flow in two parking lots before loading the new system

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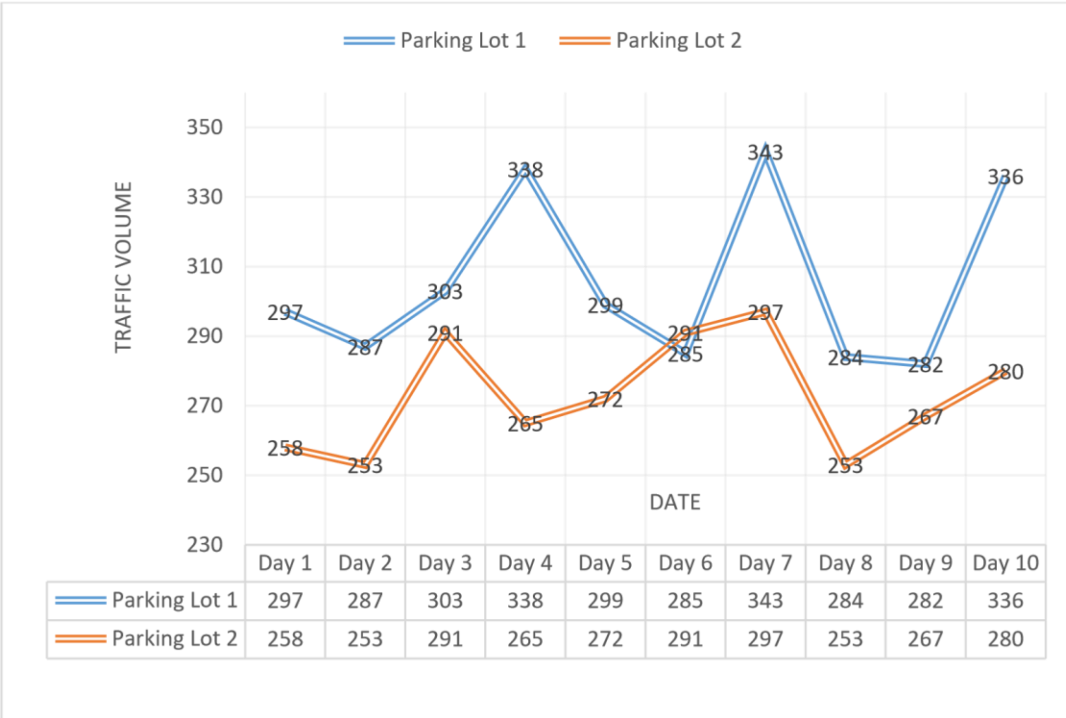

Figure 6. Comparison of traffic flow between two parking lots after loading the new system in parking lot 1 From Figure 5, it can be seen that the traffic flow of the two parking lots before loading the new system is actually similar. Within the ten days selected for the experiment, the average traffic flow of parking lot 1 was 275.7 vehicles, and the average traffic flow of parking lot 2 was 273.3 vehicles. From Figure 6, it can be seen that with the assistance of the new system, the average traffic flow of Parking Lot 1 is 305.4 vehicles. In the same ten days, the traffic flow of Parking Lot 2 has not changed significantly compared to before, only 272.7 vehicles. This indicates that the new system can help with the vehicle operation and maintenance system in the parking lot, allowing for more efficient vehicle operation and maintenance work, with a greater vehicle throughput. At the same time, it can also attract more car owners to come and park with the help of efficient work.

6. Conclusions

After a series of introductions, system construction, and formula calculations, the idea of this article is basically clear. It is to first demonstrate the process of vehicle operation and maintenance through the basic vehicle intelligent operation and maintenance system, and integrate the operational logic of an intelligent operation and maintenance system. By combining 5G with the Internet of Things, people can discover the powerful tool of IoT-5G, because the Internet of Things is actually based on the Internet, allowing any terminal that can be accessed through the network to connect, commonly known as the Internet of Things. This approach is fully in line with vehicle operation and maintenance and urban rail transit management. Then, this article uses the 5G data encoding algorithm as a mathematical tool to establish the underlying logical foundation for the combination of IoT-5G and vehicle operation and maintenance. Finally, by comparing the new system designed in this article with traditional vehicle operation and maintenance systems, it was found that the assistance of the new system for vehicle operation and maintenance work is much greater than that of traditional systems, which is consistent with the research conclusion of this article. However, the design process of this article is not perfect, and the research days in the experimental section are too few, so the experimental results may not be accurate. In summary, as an important component of urban transportation, urban rail transit and its vehicle operation and maintenance are closely related to urban development. Therefore, it would inevitably receive more resources for development and research with high attention. The ideas designed in this article have certain significance, but it is clear that this work would not stop here, and its development prospects are worth looking forward to.

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