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Application of Wireless Communication Technology in Tunnel Communication

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Abstract: Tunnel wireless communication refers to the erection of invisible bridges in the winding underground corridor, allowing the radio waves of information to shuttle between the thick rock walls. Nowadays, with the rapid development of transportation, more and more subways, railways and highway tunnels have been built, but there are still some problems in communication in the tunnel that have not been solved. For this reason, many companies and research teams around the world are trying to apply communication technology on the ground to tunnel communication. At present, some of these ideas and attempts have developed into adoptable and mature technologies. So, tunnel wireless communication is not only a demonstration of technology, but also a guardian of safety and efficiency. This paper mainly uses literature analysis to study the basic principles of communication technology and its application in follow-up communication. This article finds that the communication technology currently applied in tunnel communication is Multiple-Input Multiple-Output (MIMO) technology, General Packet Radio Service (GPRS) technology, Synchronous Digital Hierarchy (SDH) technology, collaborative relay technology, Zig Bee technology and WiMAX technology.

Keywords: Wireless communication, Tunnel communication, MIMO, Collaborative relay technology

1. Introduction

In this stage, the purpose of tunnel wireless communication technology is to ensure efficient and stable communication in the tunnel environment, to ensure the safe operation of vehicles and trains, and to receive information in time in case of emergency. The main system involves on-board electronic equipment. Among them, the public network wireless system mainly involves telecommunications operators to provide telephone mobile communication and intelligent terminal web browsing and other services. However, at present, the construction of the public network wireless system is difficult to meet the actual requirements of communication within the channel. Therefore, this article mainly introduces the overview and case analysis of MIMO technology, GPRS technology, SDH technology, collaborative relay technology, Zig Bee technology and WiMAX technology to build ideas to solve some practical problems. These technologies jointly ensure the stability and efficiency of tunnel communication, and provide support to improving tunnel safety, promoting intelligent management, supporting emergency rescue and promoting underground space

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development. It is an important part of modern social infrastructure construction and scientific and technological development.

2. Application of wireless communication technology in tunnel communication

This study will summarize communication technology in combination with the current research results and then analyze tunnel communication technology.

2.1. Application of MIMO technology

Vehicle-to-Vehicle communication has recently attracted great attention regarding new traffic telematic applications, which can improve safety and flexibility on roads[1]. There are two main implementation methods of MIMO technology: Spatial disclosure technology and Spatial reuse technology. Spatial disclosure technology is used to improve the reliability of signal transmission, which reduces the symbol error rate caused by channel decay and noise by sending the same data on multiple antins. See the encoding methods of space-time grid code and space-time packet code interlux. Spatial reuse technology is used to improve the data capacity of the system, which increases the channel capacity of the system by sending independent data streams on multiple atrines at the same time. The realization of spatial reuse technology requires that the number of transmitting and receiving antennas needs to be greater than or equal to the channel capacity of the data stream system.

The channel capacity of the MIMO system can be calculated according to the following formula:

$$C = \min(N, M) \bullet B \bullet \log_2(1 + SNR) \tag{1}$$

Among them, B is the signal bandwidth, SNR is the signal-to-noise ratio of the receiver, and min(N,M) is the minimum value of the transmitting of receiving antennas M.

From past to now, the technical application of MIMO in tunnels has made remarkable progress. Arshad et al proposed a ray tracing method to simulate the propagation of signals in a acurved tunnel environment, and further explored the impact of the layout of tunnel base situations on signal coverage. And in 2014, Forooshani et al introduced a multi-mode wave-guide model to predict the phenomenon of signal angular dispersion in tunnel environments, and proved that the wave-guide model can be used to model the signal transmission in far-field regions of tunnels [2]. In summary, the MIMO system can make full use of space resources, and the parallel transmission channel of the resume space greatly improves the channel capacity of the communication system and can be well applied to tunnel communication.

2.2. Application of GPRS technology

GPRS (General Packet Radio Service) is the abbreviation of General Packet Wireless Service. It is a transition technology from the second-generation communication technology GSM (Global System for Mobile Communications) wireless packet switching technology of the global mobile communication system to the third-generation mobile communication technology 3G [3]. GPRS technology is the data transmission by switching packets through the grouping switching function entity in the GSM digital mobile communication network.

GPRS provides technical support for wireless Internet. Users can avoid disconnection and stay online all the time by accessing the Internet through GPRS mobile phones. And the GPRS billing method is based on traffic billing. If users do not transmit data, they will not be charged even if they are online, which can greatly reduce communication costs [4].

Figure 1 is a GPRS wireless communication diagram. The basic principle of GPRS technology is to establish a dedicated channel on the mobile network to transmit data and information from the

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source address to the destination address, so as to achieve high-speed and long-distance data transmission. GPRS technology mainly uses the wireless communication between the base station and mobile device of the GSM network, and realizes the high-speed and long-distance data transmission of GPRS technology through the wireless communication between the base station and the mobile device in the GSM network.

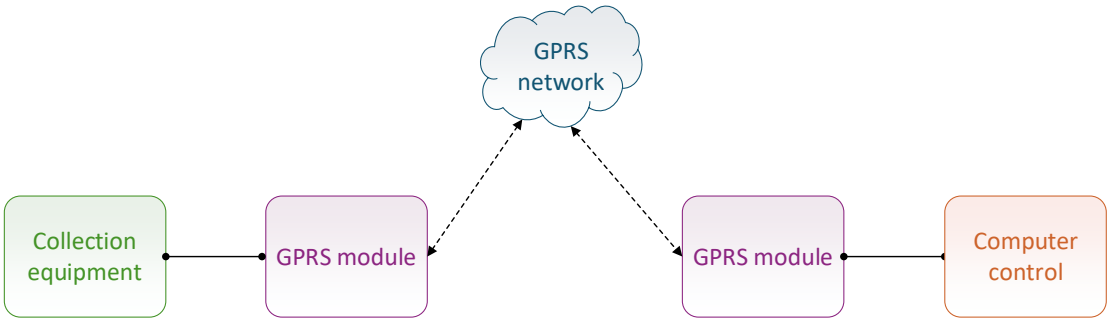

Figure 1: Schematic diagram of GPRS wireless communication

2.3. Application of SDH technology

Synchronous Digital System (SDH) is a digital transmission technology used in telecommunications networks, which solves problems such as interfaces, reuse method, operation and maintenance, and network management interfaces of quasi-synchronous digital systems (PDH). PDH has the advantages of a unified interface standard, synchronous reuse, efficient maintenance and compatibility.

2.3.1. The main features of SDH

Unified interface standard: SDH adopts a unified network node interface (NNI) to standardize the physical interface performance and solve the problem that standards in different regions in PDH are difficult to communicate internationally.

Synchronous multiplexing: SDH adopts synchronous multiplexing technology to realize signal synchronization and phase calibration through pointer processing, and supports direct interpolation switching, reducing network complexity.

Efficient maintenance and network management ability: SDH arranges sufficient bits in the frame structure for the communication of overhead management information, which enhances network management ability and supports self-healing network formation.

Besides, SDH technology has many advantages in application:

2.3.2. Great opening performance

The comprehensive network management system of SDH transmission network can be connected to the network management system of SDH equipment manufactures, manage IP groups, and SDH unified management and maintenance of network equipment. When networking with other manufactures' network management systems, it can also provide relevant interfaces for other network management systems. Therefore, the SDH transmission network comprehensive network management system is an open and compatible network management system, which can not only realize the interconnection of other manufacturers' equipment, but also provide corresponding service interfaces when interconnecting with other manufacturers' equipment.

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2.3.3. Rich management methods

Manual is generally used in the traditional SDH transmission network management model, this model not only has a great workload, but also low work efficiency. For this reason, when building a comprehensive network management system for SDH transmission network, it is necessary to further improve and optimize the management mode to improve management efficiency. In addition, with the help of advanced software technology and network technology, we should also improve the work quality of the SDH transmission network and further improve the management efficiency of the SDH transmission network.

2.3.4. Convenient means of maintenance

The application of the comprehensive network management system makes the maintenance of the SDH transmission network more convenient, reduces the investment of labor costs, and improves maintenance efficiency. Because in the process of network maintenance, the comprehensive network management system can quickly identify specific problems and give corresponding handling methods to reduce the maintenance cycle and ensure the stable operation of the entire network. And the integrated management platform can monitor the working status of the entire network and monitor, configure and manage network in real time. So the comprehensive network management system can be well applied to tunnel communication maintenance [5].

However, there are disadvantages of point-to-multipoint, point-to-point and poor image transmission of SDH technology. Therefore, it can be combined with IP technology to make up for it. Based on this factor, IPoverSDH has become the best choice. The SDH network unit is one of the important components of the SDH transmission network. And it is a comprehensive information network that can realize synchronous information transmission in satellite, optical fiber or functions, and operate through unified network management [6]. This is conducive to the dynamic management and maintenance of the underground network and improves the efficiency of network utilization.

2.4. Application of collaborative relay technology

The basic principle of collaborative relay technology is in traditional communication systems, each site can only send and receive signals independently. In a collaborative relay system, multiple sites can collaborate with each other to send and receive signals together, and this system was the first proposed by Meulen, which includes the source node S and the relay node [7].

The three node channel model of R and the target node D is shown in Figure 2. With the deepening of collaborative relay technology research, collaborative models for different application scenarios are becoming more and more abundant, mainly in the following forms [8]:

From the number of R, the collaborative relay network model is promoted from a single R to a multi-R. The mode contains a single S, a single D and multiple R. Multiple R forms constitute the relay set R, which can form a virtual antenna array and forward the information of S to D(Figure3).

From the number of S, the collaborative relay network model is promoted from a single S to multiple S; multiple S forms the emission set of S and cooperates to transmit signals to the common D.

From the number of D, the collaborative relay network model is promoted from a single D to multiple D. Multiple D from the receiving set D and collaboratively receive signals from a single S.

Based on the above models, they can be combined into more complex network models, such as multiple S, multiple R and multiple D in the network at the same time. In addition, there is also a multi-hop collaborative relay network, and the information emitted by S needs to go through multiple R to reach D>

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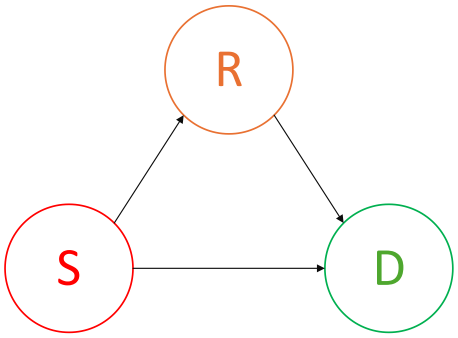

Figure 2: Three node channel model

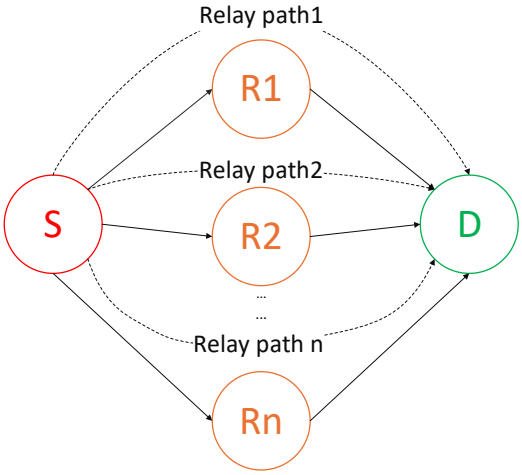

Figure 3: Relay path diagram

In addition, Zhao H and SU W propose two Collaborative multicast schemes, called Distributed Cooperative Multicast(D-CM) and Genie-Aided Co Operative Multicast (GA-CM), which only obtain a fixed second-order set gain [9]. Therefore, when there are more than two multicast transmissions proposed by Yang Long can achieve better performance than the D-CM scheme and GA-CM scheme.

On the other hand, both the D-CM scheme and the GA-CM scheme require all successfully decoded users or relays to forward multicast packets, but in the user collaborative multicast transmission, only the best users are selected to forward multicast packets. Therefore, the transmission power overhead of the user collaborative multicast transmission is smaller, and compared with the multicast scheme based on relay collaboration, the user collaborative multicast transmission scheme is more suitable for large-scale wireless multicast systems, especially in tunnel communication.

Besides, the parameter is easy to estimate and does not require a distance or location estimation structure GPS, etc. And Zhou, through a large number of experiments, shows that multi-relay transmission can not only expand the coverage of the network, but also save the total power of the system compared with the one-way single-relay collaborative network [10].

Therefore, collaborative relay systems can use the signal processing capacity and transmission capacity of multiple stations to improve communication performance.

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2.5. Application of Zig Bee technology

Zig Bee technology is a widely used short-range and low-power wireless sensing network communication technology, the name comes from the information exchange method used by bees to transmit the azimuth distance of food between bees. Zig Bee is a highly reliable wireless digital transmission network, similar to CDMA and GSM networks. Each tiny sensor can communicate data with the other through the coordination of the Zig Bee network. The protocol adopted by Zig Bee is based on the IEEE 802.15.4 standard, and Zig Bee has three advantages [11]:

Low power consumption:

When the node is working in low-power mode, only two commonly used AA batteries can provide energy for more than half a year. This feature has become a capital for Zig Bee manufacturers to rely on in promotion and publicity.

Low cast

The cost of a single Zig Bee node is extremely low, and the number in actual work is limited, so the total expense is extremely low.

The network capacity is large:

The node capacity of the Zig Bee network is as high as 65000, and the topology types of the node combination are diverse, which can effectively meet the requirements of large scale networks.

The Zig Bee digital transmission module is similar to the mobile network base station. The communication distance ranges from the standard 75m to hundreds of meters and kilometers, and supports unlimited expansion.

The Zig Bee network contains three different function devices: of Network coordinator, the Full-function device and the Reduced-function device. In Zig Bee network, the Network coordinator plays an important role as a manager, and there is only one. It is a necessary device to start and configure the network. The full-function device is usually used as a repeater in the network, and it is the relay of the Network coordinator and the Reduced-function device. It is a device that supports the association that only other devices can be added to the network through it. The role of the Reduced-function device is especially limited compared with the other two devices. The topological structure of ZigBee roughly includes three detailed introductions to these three structures (Figure 4).

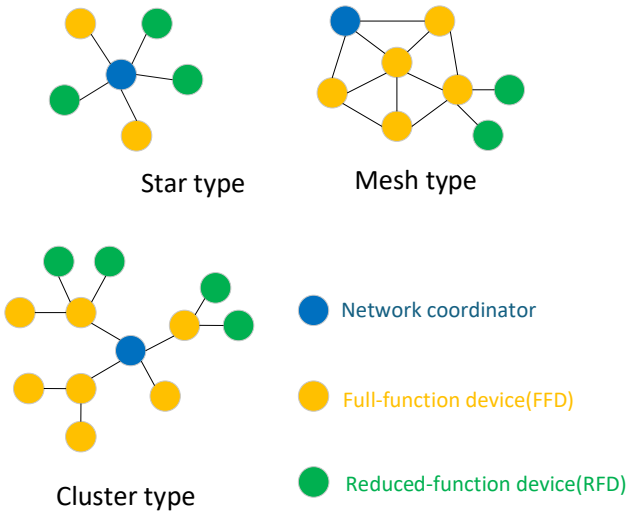

Figure 4: Three types of Zig Bee network topology type

In Figure 4, we can obviously find the biggest feature of the star type topology is that its structure is extremely simple. Because the Network coordinator is the core of the whole topology, the working

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state of the Network coordinator directly affects the operation status of the whole system. So the star type structure has a typical disadvantage, which is the poor flexibility of the structure. Furthermore, because the core of the structure lies in the Network coordinator, other devices must be within the communication range of the Network coordinator. So the wireless communication coverage of the whole network is limited.

The cluster type topology can be regarded as a relative special topological network structure composed of multiple of star type topologies, which can only have one network coordinator. The Full-function device and Reduced-function device in cluster type topology do not have to be directly connected to the Network coordinator. The cluster type topology can contain multiple routers and multiple different terminals. The advantage of the cluster type topology is that it can continuously increase the coverage of the network to meet the range of requirements. However, the disadvantage is that the Network coordinator is located at the starting point, and the communication process between devices will be accompanied by a relatively long delay.

The mesh type topology also has one Network coordinator, but it is different from the star type topology and the cluster type topology. Because in mesh type topology, this independent Network coordinator will be used as an ordinary Full-function device after the construction of the network system. The disadvantage of the mesh type topology is that the Network coordinator must be working all the time, which is relatively power-consuming. In addition, it does not have a defined routing direction. And the advantages of the mesh type topology are reducing the data delay, which is suitable for applications that transmit a large amount of data.

In many experiences, the Zig Bee technology applied in tunnel communication has been proven, and can easily combine with other communication technology.

2.6. Application of WiMAX technologies

Global microwave interconnection access technology (WiMAX) is an emerging broadband wireless access technology that can provide high-speed connection to the Internet. And there are seven standards, including 802.16, 802.16a, 802.16c, 802.16d, 802.16f, and 802.16g, which can basically be divided into fixed WiMAX and mobile WiMAX [12]. Fixed WiMAX can provide broadband wireless reception (BWA) at a speed of up to 75Mbps for fixed stations within a distance of 50km. Mobile WiMAX can provide broadband wireless connection of 5~15km for mobile stations (such as laptops, mobile phones, personal media players and PDAs) people.

WiMAX networks can not only be used as a supplement to the operator's network, covering existing networks deployed with mature communication facilities, but also as the main means of receiving wireless broadband in areas where other solutions are too expensive or difficult to achieve. It proves that WiMAX is a diversified technology that can design and develop corresponding reception points and infrastructure to meet the needs of operators. These advantages, coupled with global technical support, make WiMAX the preferred choice to quickly and effectively open ultra-fast broadband wireless pick-up in areas where the global business is not covered. So these features of WiMAX technology can make it a good choice to use in tunnel communication.

3. Conclusion

This research mainly discusses the MIMO technology, GPRS technology, SDH technology, collaborative relay technology, Zig Bee technology and WiMAX technology apply in tunnel communication technology. In the analysis of the tunnel communication technology, it shows that the wireless technology will develop in the direction of high broadband, intelligent and multifunctional. Therefore, when developing tunnel communication technology, we must pay close attention to new wireless communication technology. Through the improvement of tunnel

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communication technology, we can achieve effective compatibility with the platform, simplify communication equipment, save costs and resources on the basis of ensuring safety, and bring more convenience to people's lives. However, this paper does not use experimental methods to conduct an in-depth analysis of tunnel communication. In future research, people can focus on anti-signal attenuation to obtain higher communication quality.

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