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ORIGINAL ARTICLE

Research and design of data communication subsystem of urban rail transit CBTC system

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Abstract With the intensive development of urban rail transit in China, urban rail transit has increasingly become the preferred mode of transportation for citizens due to its convenience and speed. The design and construction of an efficient and highly reliable urban rail transit system has become an urgent requirement for urban rail transit construction. This article mainly introduces the research and design of the data communication subsystem of the urban rail transit CBTC system, and intends to provide some ideas and directions for studying the data communication subsystem of the urban rail transit CBTC system. This article uses a variety of methods, such as consulting literature and information research on trademark system suppliers. The development status of CBTC system and data communication subsystem is analyzed, and the importance of data communication subsystem and the necessity of the entire CBTC system are analyzed. The experimental results of this article show that in the design, development and application engineering of the CBTC system, the DCS subsystem accounts for 55%, the system is complex, and the environment is changeable, occupying an important position. When the DCS has a problem, it may cause drive failure, affect normal functions, cause greater losses, and even cause huge safety accidents. Therefore, the reasonable, reliable and safe design of the DCS subsystem is of great significance.

Keywords Urban rail transit · Communication-based train control (CBTC) system · Data communication system · Backbone network

1 Introduction

As a safety computer system that ensures the failure of the communication-based train control system (CBTC), the safety of its derived data information is a necessary condition for the safe operation of the entire train. Therefore, it is necessary to meet the safety failure characteristics to ensure high reliability and safety. With the rapid development of the computer industry, the research on safety computer systems has gradually deepened. The birth and development of the train control system is to ensure transportation safety and the basic technology and equipment to ensure driving safety. As a large-capacity and high-density public transport, city railway intersections require safe and reliable train control systems. Otherwise, the safety of trains will be endangered when the system fails, and personnel and property will also be lost.

The CBTC system realizes complete two-way, large-capacity, two-way continuous information transmission between trains and ground equipment, more accurately controls train operation, greatly improves operating performance, greatly reduces line side equipment, saves costs and maintenance costs, and improves Transport capacity and increase the safety factor. In recent years, the CBTC system has become a solution for many subway and subway engineering railway operation control systems. Some major foreign cities have begun to convert CBTC into the original subway and light rail systems. China's urban rail transport has also begun to convert, and the design and adoption of the CBTC system has begun. Therefore, with

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the development and implementation of China's urban railway transportation management system, the development of a CBTC urban railway transportation system with independent intellectual property rights has become a top priority, which is an improvement in the important realization of improving urban railway transportation capacity and reducing operating costs.

Shen W believes that urban rail transit has played an important role in urban economic vitality. Convenient public transportation keeps people away from private cars and thus reduces traffic congestion. Therefore, it is necessary to understand the urban rail transit system from a quantitative and systematic perspective, such as establishing my country Data subsystem model of urban rail transit system. Shen W used structural equation modeling method and partial least square method to estimate the model; established an evaluation index system including three levels of indicators to measure passengers' satisfaction with rail transit operating company's services, and used the satisfaction index to Passenger satisfaction is quantified; the IPA matrix is used as an auxiliary tool to analyze the advantages and disadvantages of rail transit services. But his research is more one-sided and does not have a certain degree of persuasiveness (Shen et al. (2016)). He L found that the operation of urban rail transit has moved from single-line to multi-line, urban transportation network operations have undergone quantitative and qualitative changes, and operation management is facing rapid internal and external changes. He L first systematically analyzed the characteristics of subway operation scale, urban rail transit ratio, surge in public demand, operational service capability guarantee, operational governance structure reform, and rapid expansion of personnel, as well as the development of urban rail transit network knowledge and skills; Several countermeasures are proposed for the challenges faced by the network, such as: establishing an innovative network operation management system, strengthening the management foundation, formulating a plan to improve operational capabilities, strengthening security risk management and equipment quality management, formulating crisis public relations countermeasures, and applying information Technology; then systematically elaborated on the operational mechanism to improve the operational capacity of the transportation network, the countermeasures to innovate the operational capacity of the network, the establishment of a production service evaluation system, the continuous improvement of the transportation service level, the establishment of a quantifiable safety evaluation system and equipment quality indicator model, and the strengthening of safety and equipment quality control, extensive use of information technology to ensure the healthy operation of the urban rail transit network, and implementation of sustainable development measures. This research lacks experimental data support (He et al. 2016). In view of the complexity of the CBTC system, Wang K proposed a formal method based on the combination of the communication sequence process (CSP) and the B method, that is, to establish a one-to-one mapping between the communication events of the CSP and the abstract machine operation of the method. The relationship is achieved by controlling the operation of the abstract machine to achieve the purpose of communication events affecting the state of the abstract machine, and thus realize the synchronization of the CSP and the B method. However, there are some errors in his method, resulting in inaccurate results (Wang 2018).

The innovations of this article are: (1) Not only does it propose a brand-new intelligent rail transit system, it also proves that the introduction of the communication system into the rigorous signal system provides a new development direction and performance improvement method for the development of the signal system. (2) Based on the theoretical basis of this article, the network data communication subsystem, wireless network and network security have been planned in detail, focusing on the design of wired backbone network, the design of wireless network access points, and the protocol standard design technology adopted by wireless networks.

2 Research and design method of data communication subsystem of urban rail transit CBTC system

2.1 Data communication subsystem

The data communication subsystem is the DCS subsystem, and safe and reliable two-way communication between the vehicle and the ground is the basis for the CBTC system to achieve many advanced functions (Wang et al. 2016). As a subsystem that completes the transmission of important information such as train status and control commands in the CBTC system, the DCS subsystem plays an important role in the entire system. In the CBTC system, the DCS subsystem is the channel and carrier of data communication, and its effectiveness and reliability directly affect the overall performance of the CBTC system (Saidi et al. 2016; Wang et al. 2020).

The DCS subsystem itself does not perform safety functions, but a large amount of safety-related information will be sent through the DCS subsystem (Liu et al. 2018). Therefore, the DCS subsystem not only needs to ensure that the information is sent to the destination quickly and accurately, but also must ensure the security and reliability of the information (Kim 2017).

(1) Ground backbone network of DCS subsystem

(2) The DCS backbone network is connected to the central control equipment, central database, and trackside network controller. Each access point connects to the ground through wireless network and other equipment, and undertakes data transmission and the promotion of all ground-to-ground communications, including the following functions:

a. To promote the operation of information from point to point (Wen et al. 2018). The data information sent from any connected device to another connected device can accurately reach the destination device, but the connected device of other devices will not respond to the information.
b. The function promotes information from one point to multiple points. In order to achieve specific management/control functions, the ground backbone network should also support multiple transmissions/transmissions, that is, connected devices can simultaneously send data with the same content to all connected devices or a part of designated connected devices and the ground network; Copy and forward to the corresponding recording device to ensure that non-target devices will not correspond to the information.
c. Access to the operation of the radio data communication system (Sakaguchi et al. 2019). The ground backbone network should be able to access the wireless data communication system of the DCS subsystem, and be able to send and receive communication data for ground vehicles through the radio data communication system.
d. Operation of universal connection. Without changing the existing ground equipment, equipment connected to the universal network interface of the ground equipment should be provided, that is, the transmission mode of the equipment should be transparent.
e. Clock synchronization function. Because the DCS subsystem transmits train status information and control information in real time, it has high real-time requirements. This requires that all devices in the CBTC system have a synchronized clock (Kwok and Chek 2017). As a network system that directly connects most of the equipment to the CBTC system, the DCS subsystem should provide clock synchronization services for the connected equipment (Choi et al. 2016; Omar et al. 2017).

(3) The wireless data communication system of the DCS subsystem

In order to realize the ground communication application of the CBTC system, it is recommended to use wireless communication in the train control system. During the development process, CBTC adopted various wireless data communication methods. With the rapid development of main railway wireless communication, data communication, and computer technology, CBTC mainly uses the GSM-R system as a wireless data communication solution. In urban railway transportation, WLAN technology is mainly used as a wireless communication solution (Huang et al. 2019).

According to the relevant CBTC standard, the DCS subsystem transmits train status information and mobile phone authorization information, which is necessary for safe driving and efficient driving. In order to ensure the reliability, safety and efficiency of the entire system, WLAN equipment should meet the following requirements: Availability requirements of wireless LAN radio equipment: high-speed services can ensure that the transmission rate meets the system requirements, and the high-speed movement of wireless data transmission packet WLAN rhythm will not affect The efficiency of the system and the delivery time do not affect the reliability of the system. The transmission power of the equipment is adjusted. The local area network radio equipment can adapt to the operating environment and can provide safe communication guarantees (Munster et al. 2017).

2.2 Train control and data communication subsystem model

Cross-layer optimization design needs to use train control model, communication channel model and communication delay model (Tian et al. 2019).

(1) Train control model

The system compares the real-time operation curve of the train with the optimal operation curve, and controls the train through traction and common braking commands so that the train moves along the optimal operation curve. According to the train dynamics model, the train's motion state equation can be described as:

$$\begin{cases} q(k+1)=q(k)+v(k)*T+\frac{u(k)}{2M}T^2-\frac{w_i(k)+w_r(k)+w_w(k)}{2M}T^2 \\ v(k+1)=v(k)+\frac{u(k)}{M}*T-\frac{w_i(k)+w_r(k)+w_w(k)}{M}T \end{cases} \tag{1}$$

Among them, T is the vehicle-ground communication cycle, $q(k)$ and $v(k)$ are the train position and train speed at time k, M is the train quality, $w_i(k)$ is the gradient resistance, $w_r(k)$ is the curve resistance, $w_w(k)$ is the wind resistance, and $u(k)$ is the train control Traction (Fajjari et al. 2016). Then the formula (1) can be written as:

$$x(k+1) = Ax(k) + Bu(k) + Cw(k) \tag{2}$$

Among them, A, B and C represent three different matrices, in formula (2):

$$A = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix}, B = \begin{bmatrix} \frac{T^2}{2M} \\ \frac{T}{M} \end{bmatrix}, C = \begin{bmatrix} -\frac{T^2}{2M} \\ -\frac{T}{M} \end{bmatrix} \tag{3}$$

Assume that the train controller of the system is linear and time-invariant, and has the following state space model:

$$\begin{cases} x_c(k+1) = A_c x_c(k) + B_c y(k) \\ u(k) = C_c x_c(k) \end{cases} \tag{4}$$

There are many indicators that can reflect the control performance in the control system. This article chooses the linear quadratic cost function as the performance indicator of the controller. The design goal of the controller is to minimize the following formula:

$$J = \sum_{k \to \infty} \left[(z(k) - \tilde{z}(k))' Q (z(k) - \tilde{z}(k)) + u'(k) R u(k) \right] \tag{5}$$

(2) Communication channel model
In the CBTC system, due to railway and train restrictions, neither the ground antenna nor the vehicle antenna can be installed too high (Hau et al. 2018). The Fresnel zone of signal transmission is cut off by the ground, and signal transmission is restricted. David B. Green et al. proposed a propagation model of signals close to the ground:

$$P_{loss} = 20\log_{10}(f) + 40\log_{10}(d) - 20\log_{10}(h_t * h_r) \tag{6}$$

Among them, f is the signal frequency, P_{loss} is the path loss, h_t and h_r are the height of the vehicle-mounted and ground antennas, and d is the distance between the two antennas (Rahman et al. 2018). Combining large-scale path loss and small-scale fading, we can calculate the received signal SNR λ as:

$$\lambda = P_t - P_{loss} + \vartheta + 10\log_{10}(\alpha) + G_t + G_r - P_{noise} \tag{7}$$

Among them, is the signal transmission power, a Gaussian random variable with a mean value of 0, representing shadow fading, α is a Rayleigh random variable with a mean value of 1, representing small-scale fast fading, G_t and G_r are the gains of the transmitting and receiving antennas, respectively. P_{noise} is the noise power (Pagadrai et al. 2016).

(3) Communication delay model
In order to obtain the WLAN-based CBTC vehicle-to-ground communication delay, first calculate the data transmission rate and link frame error rate that the MIMO system can provide. For a given spatial multiplexing gain r, through all mechanisms, the corresponding optimal diversity gain is the maximum achievable diversity gain (Van Heddeghem et al. 2016; Perelló et al. 2016). $d^*(r)$ can be expressed as;

$$d^*(r) = (M_A - r)(M_S - r) \tag{8}$$

Equation (8) can be approximately written as an integral function:

$$d^*(r) = (M_A - r)(M_S - r), 0 \le r \le \min(M_A, M_S) \tag{9}$$

Given a received signal-to-noise ratio γ, when the multiplexing gain is r, the link's achievable capacity $C(r)$ and the corresponding bit error rate $BER(r)$ can be expressed as:

$$C(r) = k_c r * \log_2(\gamma) \tag{10}$$

$$BER(r) = k_p * \gamma^{-d(r)} \tag{11}$$

The frame error rate of the link can be obtained through an empirical formula:

$$FER = 1 - (1 - BER)^{L_{fr}} \tag{12}$$

When the loss of the data packet is caused by channel deterioration, we calculate that when the retransmission is q times, the transmission delay of the data packet is:

$$\begin{aligned} T_{delay}(q) = {} & T_{difs} + T_{data} + T_{sifs} \\ & + T_{ack} + T_{difs} + T_{backoff(1)} \\ & + T_{difs} + T_{data} + T_{ack} \\ & + T_{difs} + T_{backoff(2)} \\ & + T_{data} + T_{sifs} + T_{ack} \\ & + \cdots + T_{difs} + T_{backoff(q-1)} \\ & + T_{data} + T_{sifs} + T_{ack} + T_{transfer} \end{aligned} \tag{13}$$

Among them, the sending time of the data packet has the following relationship:

$$T_{data} = \frac{L_{fr}}{C(r)} \tag{14}$$

Equation (13) gives the transmission delay for q retransmissions. The actual system retransmission times are related to the current link FER. When the current link FER and the maximum retransmission times R are given, the average link delay has the following relationship:

$$\mathrm{T}_{\text{average}} = (1 - FER) * \mathrm{T}_{\mathrm{MAC}}(0) + FER(1 - FER) * \mathrm{T}_{\mathrm{MAC}}(1) + \cdots + FER^{R-1}(1 - FER) * \mathrm{T}_{\mathrm{MAC}}(R - 1) \tag{15}$$

The method part of this paper uses the above method to research and design the data communication subsystem of the urban rail transit CBTC system. The specific process is shown in Fig. 1 (Li et al. 2017).

3 Research and design experiment of data communication subsystem of urban rail transit CBTC system

3.1 Database outline design

(1) System design principles

The overall structure design of the system follows the following principles: security. As a subsystem of the CBTC system, the CBTC database system is an important part of the CBTC system, and the security of its data is very important; concurrency, due to the system's interaction with multiple sub-systems, the system is connected and the system is highly operational. The system has a large amount of visits and frequent concurrent operations (Nie et al. 2016; Rocha and Sasaki 2017). When designing, we use database connection pool technology and multi-task structure to ensure its concurrency; stability, because the system needs to ensure 7*24 h without downtime, so the stability requirements are also very high, the system adopts modular design and Dual-machine hot backup technology to ensure the stable operation of the system; maintainability, this system combines the maintainability of CBTC and its own maintainability to design, through the analysis and processing of fault alarms, and the playback of event records to improve The maintainability of the system (Khalili et al. 2017).

(2) System architecture

The database system is mainly composed of database server, client and switch. The database server and the client establish a local area network through the switch for data interactive access. The database server uses dual networks, and the server is equipped with two network ports, which are bound by network cards. At the same time, the database adopts a dual-system hot backup structure, which realizes the dual-system hot backup function through HA and provides a service IP to the outside. Through the analysis of the database function and combined with the operating environment of the system, this system adopts a client–server two-tier architecture, namely: server and client; server is the data layer, and the client is the presentation layer and the function layer (Liu et al. 2019).

(3) System module design

Through the demand analysis of the CBTC database, the system can be divided into five modules: database management module, dual-computer module, interface module, data storage module and report generation module. The database management module is responsible for database maintenance, database table space, concurrent number and database user management. The dual-system module mainly completes the dual-system hot backup function of the database platform. The interface module completes the interface between the system and the external system. The data storage module mainly includes storage data

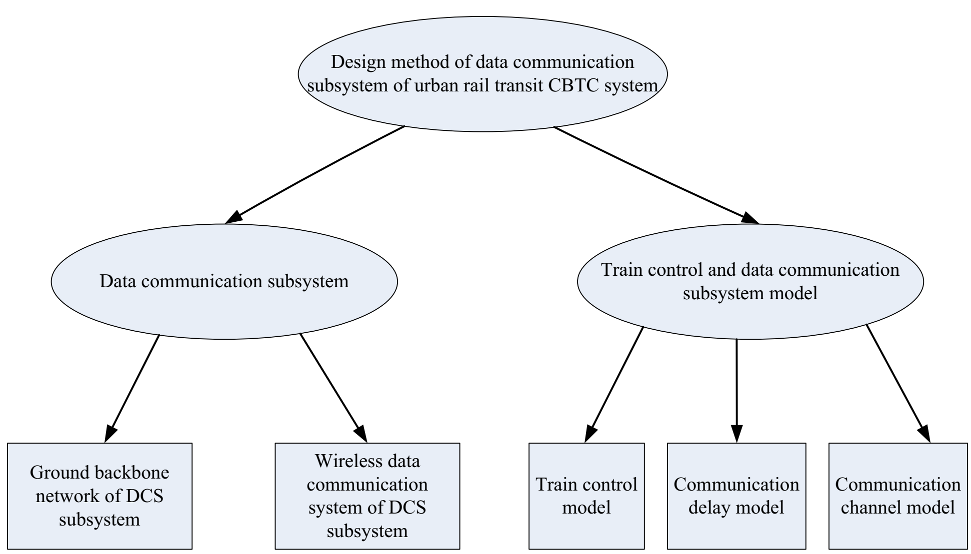

Fig. 1 Part of the technical flow chart of this method

processing and data storage interface, responsible for the storage of timetable, train operation information, user information, event record information and other information. The data analysis module mainly includes data query interface and query data processing and display, and is responsible for automatically generating reports.

(4) Interface design

The database not only completes the data management of the CBTC system, but also because the DCS subsystem in CBTC communicates with the PIS system through the TCP/IP network. Comprehensive monitoring sends traction power supply information and fire information to DCS; DCS sends train location information and plan information to comprehensive monitoring. Therefore, it is necessary to provide an interface to the database so that the integrated monitoring system can share the required information and send information to the monitoring system through the interface server. For interface design, it is necessary to complete the definition of the message category and the definition of each message and the definition of the sending message format.

3.2 Design of data communication subsystem

The data communication subsystem must realize ground line information, train target speed, target distance, route status, train number, destination number, driver number, train location information, status information of on-board equipment, door switch status information, and train stop information, Station pass information, train operation adjustment information and ground information transmission function. The data communication subsystem should be mainly composed of wired and wireless networks, all of which are configured in accordance with redundant networks. The backbone network is constructed by switches or dedicated transmission equipment. The signal system vehicle-ground wireless communication adopts WLAN technology, and its main line equipment should include access switches, outdoor trackside wireless access equipment, optical cables and other equipment. Configure a network management platform for the entire line to ensure network management of equipment at each layer of the data communication subsystem, and to manage, authenticate and monitor the entire line of wireless AP equipment.

(1) Architecture requirements

The trackside wired network is composed of a backbone network and an access network. The backbone network is constructed by switches or dedicated transmission equipment; the access network is responsible for connection with wired communication equipment and wireless communication equipment, communication and transmission, and is connected through the backbone network communication equipment of each node. Access to the backbone network is mainly composed of access switches. As a backbone network node, the control center configures backbone network communication and transmission equipment; at the same time, it configures an access network switch to connect the control center ATS equipment to the backbone network. The train-to-ground communication equipment shall adopt redundant configuration and have redundant functions. The wired backbone transmission network of the depot is uniformly set up with the main line and connected with the nodes set up on the main line to form a self-healing ring network structure of the whole line to realize data transmission between the backbone nodes of the whole line. In order to realize the daily inspection project of the parking train inspection garage and the continuity of wireless communication between the main line and the depot, full wireless coverage is realized in areas such as the entry and exit depot line, the throat area of the depot and the train inspection garage.

(2) Technical standards and performance indicators

The wireless network uses the open system IP standard and can send information within the DCS required by the mobile subsystem and the fixed subsystem. The network technology, data transmission technology, and computer technology adopted by the system all comply with international standards. The transmission frequency band, transmission speed, other indicators, configuration and deformation functions, and bit error rate shall comply with relevant international or domestic standards.

(3) Wireless vehicle-ground communication requirements

The wireless vehicle-to-ground communication transmission method should meet the signal system's requirements for real-time, safety and reliability of data transmission; wireless transmission must ensure stable and reliable vehicle-to-ground communication when the train is running at high speed; wireless system trackside and on-board equipment should It adopts a redundant structure and has a load sharing function to ensure that a redundant port connection fails, and other connections will seamlessly take over the load; it must comply with the protocol standards and safety standards of the world's relevant wireless networks; The interference of the system or portable equipment should have anti-interference measures; the information transmission of the signal system should adopt advanced encryption algorithms to ensure the security of the system; and so on.

The experimental part of this article proposes the above steps for designing the data communication subsystem of the urban rail transit CBTC system. The specific process is shown in Table 1.

4 Research and design analysis of the data communication subsystem of the urban rail transit CBTC system

4.1 System file transfer analysis

Since data security processing requires time overhead, data security is at the expense of transmission performance. SD should provide adequate security protection under the premise of ensuring real-time information transmission. In this respect, it also needs to undergo rigorous testing. Due to the lack of network performance testing software in the system, this article only analyzes the transmission delay caused by SD by testing the file transmission time. Two computers with SD components are added, one as FTP server and one as FTP server. Both computers use 300 M network cards. They are directly connected through twisted pair cables to transfer files of the same size and measure the transmission. Time, each group is tested three times, and finally the average value is taken. Draw the specific situation into a table, as shown in Table 2, Fig. 2.

The test results show that the transmission rate decreases with the increase of the security encryption strength, and the transmission rate is reduced to more than half of that when the security application is not used. The proportion of the original payload load in the data transmitted on the network transmission line decreases, and the addition of security applications needs to be occupied The system processing time of the transceiver device. Therefore, compared with data transmission without adding a safety application, the time consumed by SD to transmit the same amount of data is much longer.

4.2 Quantitative analysis of CBTC system reliability

The measurement requirements for system reliability in this project are mainly MTBF, MTTR, and availability. MTBF is the mean time between failures, which refers to the repairable equipment or system that can continue to work after repairs or replacement parts. The average working time between two failures; MTTR is the mean time to repair; availability is the repairable product Operation rate.

After each subsystem is implemented according to the design, refer to the reliability index of each subsystem and summarize the reliability of each subsystem. The reliability analysis does not consider the related failures between the systems. The results are shown in Table 3 and Fig. 3:

The whole communication system depends on the shortest subsystem. The shortest reliability index among the above subsystems is the broadcasting subsystem, so the time of the whole system is hours.

4.3 Risk assessment of urban rail transit communication system project

The risk assessment of this project is mainly to quantify the risk elements adopted in the risk determination, with special attention to the possibility of risk occurrence and the degree of impact caused by the risk.

In the urban rail transit communication system project, the probability of risk occurrence is calculated as a percentage, and the degree of impact caused by the risk is mainly reflected in the project cost and its absolute value.

The initial value of the probability of occurrence and the degree of risk impact should be jointly assessed by project team members and relevant stakeholders. In the process of project implementation, the project manager must continuously monitor and evaluate the status of project risks, the potential of dynamic information and the value of scope.

Once there is any possibility and degree of risk, the cost of risk can be calculated and the emergency fund reserve of the project is promised according to the total cost of risk, as shown in Table 4 and Fig. 4:

After the risk assessment is over, it is necessary to formulate corresponding countermeasures for different risks. There are four ways to solve project risks: evasion, transfer, mitigation and acceptance. After identifying and

Table 1 The experimental procedure of this article

Design experiment of data communication subsystem of urban rail transit CBTC system	Database outline design	1	System design principles
		2	System architecture
		3	System module design
		4	Interface design
	Design of data communication subsystem	1	Architecture requirements
		2	Technical standards and performance indicators
		3	Wireless vehicle-ground communication requirements

Table 2 File transfer time test

	Security protocol	Encryption algorithm	Authentication algorithm	Transmission time(Seconds)	Transmission rate(Kb/s)
Test 1	AH + ESP	3DES	AH:MD5 ESP:SHAI	187.31	4728.01
Test 2	ESP	DES	SHAI	171.09	5031.24
Test 3	ESP	DES	SHAI	104.73	7462.72
Test 4	ESP	DES	MD5	98.24	7507.81
Test 5	AH	–	MD5	57.28	9423.14
Test 6	Not use	–	–	49.36	9827.16

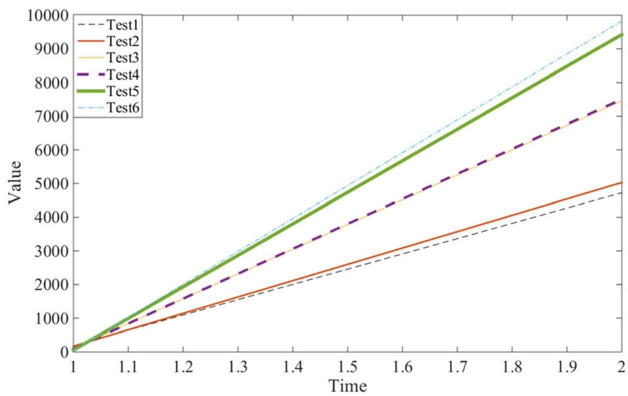

Fig. 2 File transfer time test

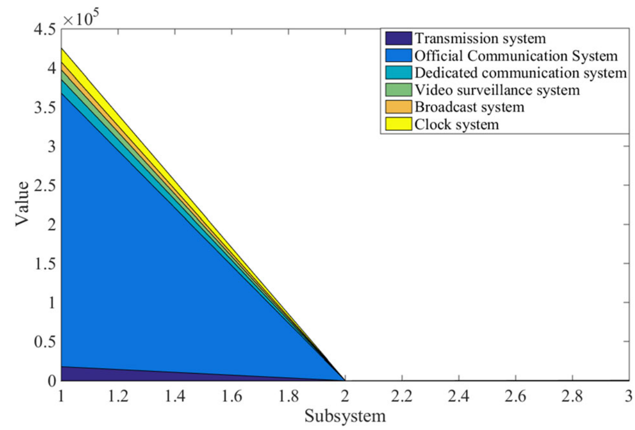

Fig. 3 Reliability comparison of data communication systems

assessing project risks, countermeasures will be taken in accordance with the above sequence. These risks are different.

The project emergency reserve should be collected as part of the cost of the analysis results and can be used by the project manager for risk management. When a risk arises, the project cost of the risk increase can be paid by the reserve fund, without affecting the profit of the entire project; if the foreseeable risk is not realized, the corresponding risk cost can be released as the improvement of the project profit.

4.4 Safety and reliability analysis of communication-based train automatic control system (CBTC)

Polarization diversity is a technology with great potential. The horizontal transmission and vertical transmission of the same signal are statistically inconsistent. Under normal circumstances, the performance of diversity can be measured by analyzing signal cross-correlation and discrete cross-polarity (XPD) values.. Different antenna arrays will produce different correlation values and XPD values. Table 5 and Fig. 5 show the measurement results of GSM 900 MHz using polarization diversity with a horizontal and vertical angle of 45°, antenna beam bandwidth of 3 dB and spatial diversity with antenna spacing of 5 m.

Table 3 Subsystem reliability statistics table

Subsystem	Transmission system	Official communication system	Dedicated communication system	Video surveillance system	Broadcast system	Clock system
MTBF(h)	18,000	350,000	17,500	12,000	10,000	18,000
MTTR(h)	3	2	3	5	5	5
Availability(%)	98.5	98.9	99.1	99.3	99.6	99.9

Table 4 Project risk assessment table results

Serial number	Risk name	possibility	Degree of influence	Risk cost
1	Customer asks for payment in advance	18	19	5
2	Plan delay	9	99	11
3	Stagnation Customs Margin	89	11	10
4	Increased waterproof requirements	48	11	6
5	The user asks us to pay for the trial shipment	60	11	8

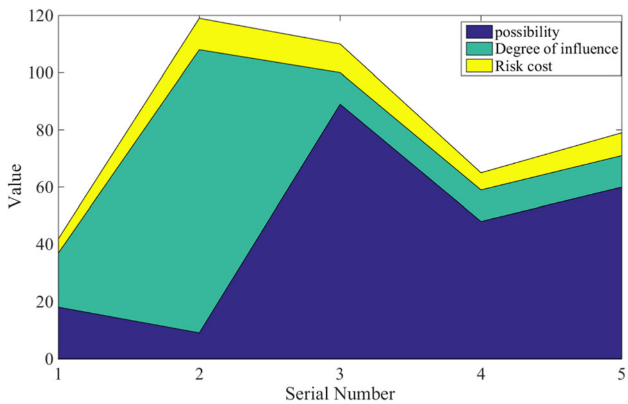

Fig. 4 Risk assessment of urban rail transit system project

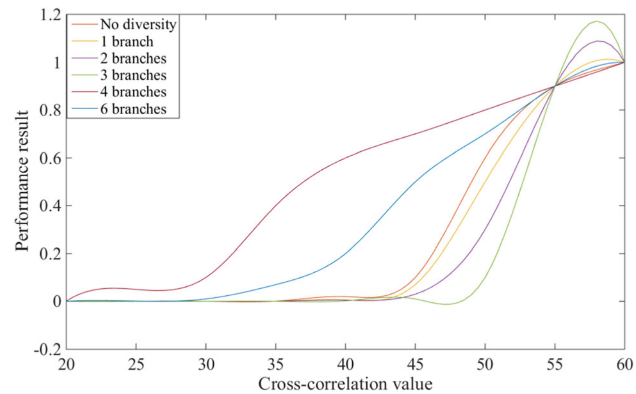

Fig. 5 Comparison of space diversity performance of different branches

There are multiple reflection paths of electromagnetic waves outdoors, which will increase the randomness of the signal in the polarization plane, so the performance of polarization diversity is better than space diversity. In the measurement, the received signal indicates that the stronger one of the two diversity branches is used, and the range of RSSI is $-95 \sim -110$ dB, which is close to the receiving sensitivity of the base station. The reception quality of the signal is measured by the method of maximum ratio combination, which is divided into seven levels, corresponding to a bit error rate of less than 0.2% and greater than 12.8%. The comparison results of polarization diversity and space diversity are shown in Table 6, Fig. 6.

Equalizers usually use a training mode to evaluate channel characteristics, before receiving channel deformation and weakening characteristics and then use this information to correct the received signal. The training method is to send a training sequence before delivering user information. The training sequence is known at the end of training or is an incorrect random sequence. When the receiving end of the receiving end receives the training sequence, it compares it with the original data signal to receive the channel information characteristics, and then passes a specific information-based algorithm. In order to ensure the effective elimination of inter-symbol interference, the equalizer should be regularly trained. It is often placed to complete the baseband or intermediate frequency part of the receiver.

Table 5 Space diversity performance results of different branches

Different branches	20	25	30	35	40	45	50	55	60
No diversity	0.001	0.05	0.1	0.4	0.6	0.7	0.8	0.9	1.0
1 branch	0.00001	0.001	0.01	0.07	0.2	0.5	0.7	0.9	1.0
2 branches	0.00001	0.0001	0.0003	0.0007	0.02	0.1	0.6	0.9	1.0
3 branches	0.00001	0.00007	0.0002	0.0005	0.006	0.07	0.5	0.9	1.0
4 branches	0.00001	0.00006	0.0001	0.0003	0.005	0.03	0.3	0.9	1.0
6 branches	0.00001	0.00004	0.00007	0.0001	0.002	0.01	0.1	0.9	1.0

Table 6 Comparison of centralized diversity and spatial diversity

RSSI	− 110	− 109	− 108	− 107	− 106	− 105	− 104	− 103	− 102
No diversity	7	6	6	6	5	5	5	4	4
Space diversity	7	6	6	5	5	4	4	3	2
Polarization diversity	7	6	5	5	4	3	3	2	1

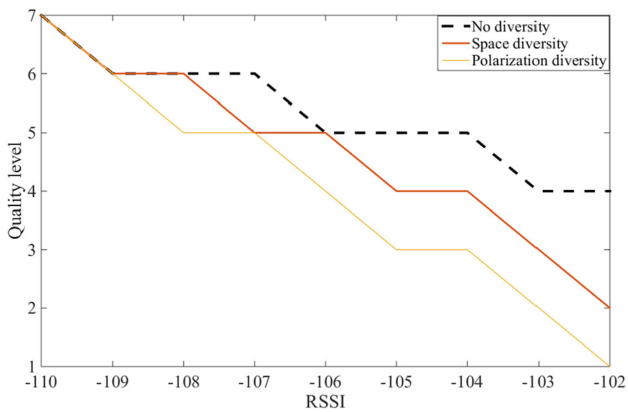

Fig. 6 Comparison results of centralized diversity and space diversity

5 Conclusions

With the modernization of our country and the continuous development of cities, urban traffic problems have become increasingly serious. At present, many large cities in China are building or planning to build subways to alleviate the increasingly severe traffic problems. In recent years, in the selection of urban rail transit signal systems, more and more lines have adopted communication-based train control systems, namely CBTC systems. The CBTC system is an advanced train control system with large-capacity ground vehicles for two-way communication to realize the transmission of train control information and train status information. The Data Communication Subsystem (DCS) is the core of the CBTC system and is the key container and equipment in different locations for the two-way information exchange between CBTC ground equipment. In the design, development and application engineering of the CBTC system, the DCS subsystem covers a wide range, the system is complex, and the environment is changeable, occupying an important position.

The communication-based train control system in this article can transmit information between trains and ground through real-time two-way data communication, provide control commands for trains through real-time two-way channels and feed back train information to the control center in real time, which can achieve shorter operating intervals.. Improving operational efficiency is the development direction of urban rail transit, which can ease the increasingly tense urban traffic. The data communication subsystem is an important part of the CBTC system, and it is the basis for the safe and efficient operation of the CBTC system. The safety and reliability of the data communication subsystem is not only the guarantee of the safe operation of the system itself, but also the entire urban rail transit. Guarantee of reliable, safe and efficient operation.

Based on the construction process of the new urban rail transit system project, this article has carried out an operational plan for the transmission of transmission lines and communication systems, official telephone systems, private telephone exchanges, video surveillance, and transmission components; and the specific application of the clock system The procedure was carried out to verify the appropriateness of the design.

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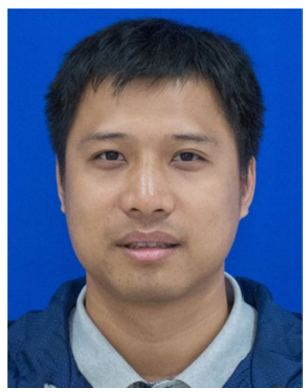

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