Research on the Application of Beijing Metro Wireless Communication and Dispatching System Based on TETRA

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Abstract. Communication system is one of the core technologies for urban rail transit operation, and it is also the fastest growing field nowadays. The Beijing Metro wireless communication dispatching system based on TETRA is designed to solve the problem that the expensive cost of purchasing English dispatching consoles in dedicated wireless communication system and the lack of replacement of the internal dedicated PCBs. The system is based on the existing wireless communication private network operation and main tenance auxiliary decision-making system, and is developed twice by using the API (application program interface), which is provided by MOTOROLA, and realizes the function of using PC to install the secondary development software instead of the English dispatching console dedicated PCB. It provides technological support for the upgrading of operation and maintenance in the field of rail transit communication and broadens the direction of practice.

1. Introduction
With the development of science, technology and economy, wireless communication technology has become an indispensable technology in modern life, and wireless communication technology has developed to a new period and is receiving new challenges. The core of the metro is the wireless communication dispatch system of the metro. [1] It not only plays a decisive role in the performance and price of the whole wireless communication system, but also has a great influence on whether it can meet the requirements for the expansion of the communication system due to the later projects of the metro. Therefore, it is meaningful to carefully design and optimize the system scheme and properly handle the relationship between current construction and development in the future. At present, there are three technical systems that are widely used worldwide to solve the problem of dedicated wireless dispatching communication: GSM-R (railway mobile communication system), TETRA (terrestrial trunked radio system) and MPT1327 analog trunked communication system [2].

2. Analysis of the Current Situation
Presently, the daily number of passengers who are transported by Beijing subway has been stabilized at more than 10 million. The dedicated wireless communication system plays an important role in traffic control, passenger traffic management, disaster prevention and emergency response and other aspects. At the moment, each line has a large number of wireless handheld stations which are used in passenger guidance and daily work. But the communication range of wireless handheld station is limited to a certain exchange center range, cannot achieve the interoperability of the whole network. In
addition, due to the early construction of the 1, 2, 13, Batong, 5, 10 and Airport lines, the network scheme of the system is mainly based on the 4-digit or 5-digit numbers, which cannot visually reflect the lines and their attributes of users, and some numbers duplicate with the numbers of other exchanges. Although the other backbone lines use the maximum 7-digit numbers that the system can support in network programming and also reflect the numbering of the lines in the numbers, they have insufficient professional coverage and cannot fully support the current wireless terminal usage regulations of the operating companies.

At present, special wireless communication system equipment for 15 lines (except airport line), except for Line 1 and Line 2, the traffic dispatching console, maintenance dispatching console, disaster prevention dispatching console and wireless dispatching console of signal building of vehicle section of each line all adopt the combination of English original dispatching console of MOTOROLA and Chinese secondary development Chinese dispatching console. The English original dispatching console is responsible for completing the call operation of wireless system, mainly handling services by the internal special-purpose PCB, while the Chinese secondary development dispatching console is responsible for realizing Chinese interface, displaying the information of ATS, and sending and receiving the calls of vehicle unit number and vehicle number as well as Chinese short messages.

According to the statistics, there are 71 English original dispatching consoles in each line at this moment, and there are no dedicated PCB as replacement parts, so the faulty PCB needs to be returned to foreign production place for testing and maintaining, which takes about 6 months each time, and the cost is about 3-10 million RMB depending on the faulty condition, and many of the faulty original manufacturers refuse to maintain, so it is suggested to purchase new dedicated PCB according to scrap processing. The purchase of the new dedicated PCB is quoted by the manufacturer at 35 million RMB, and in accordance with the current usage, 3 pieces of dedicated PCB should be purchased every year as replacement parts, which together with daily maintenance will cost about 1 million RMB per year, and after preliminary investigating, the existing problems are as follows.

(1) The original English dispatching console has been discontinued, and the same type of spare parts cannot be purchased now in China, and it is difficult to maintain.

(2) It is impossible to meet the requirements of mobile command as required by the dispatch console.

(3) It is unable to adjust the interface to meet the requirements of users.

3. Communication Design
The dedicated wireless communication system is a product based on the Motorola Dimetra core network and scheduling interface. The dispatch interface server (as shown in the box MCC7500C), which is deployed in the Dimetra core network, communicates with systems outside the core network by receiving dispatch requests from outside the core network via border routes, as well as sending the results of the execution of external requests and status updates of core network resources (such as intercoms and talk-groups).

There is a firewall (included in existing MSO solutions) between the Dimetra core and the border routers to prevent attacks on the core and to keep the core data safe.

The hardware composition of the entire Dimetra core network and the deployment of the dedicated wireless communication system is shown in Figure 1. The red part is the newly installed dispatch interface server, and the blue part is the newly deployed private radio communication system for train dispatching. The dedicated wireless communication system consists of one dispatching server and several dispatching consoles.
The communication interface of the entire system is divided into three main parts.

The first part is the communication between the existing core network of Motorola and the dispatching interface server, which follows the original communication mode of the system, which means that it only needs to be installed and configured according to the requirements of products of Motorola.

The second part is the communication between the dispatching interface server and the newly designed dedicated wireless communication system. Since the dispatching interface server is an existing product, the communication in this part follows the API of the existing dispatching interface server. That is, the dedicated wireless communication system sends packets of a specified format to the dispatching server to request related resource operations such as focusing on a talk group, and the dedicated wireless communication system receives responses and events from the dispatching interface server and parses the response results and event types, and so on.

The third part is the internal communication of the private wireless communication system. The dedicated wireless communication system consists of a dispatch server and several dispatch consoles. The scheduling server is responsible for the unified management of resources and configuration of all scheduling consoles, and the scheduling console is responsible for the interaction of the user interface and the transmission and playback of voice. The scheduling server and the console use the HTTP protocol to transmit data. When the console initiates a login request or a call request, it needs to send data according to an internally defined interface format. The internal interface is composed of the resource and configuration request interface and the voice signaling interface.

4. Functions and Implementation of Secondary Development
In rail transit, secondary development based on the interface of the system and the special requirements of rail transit is a major feature, especially the secondary development of the dispatch console.

4.1. Application Programming Interface API and Software Descriptions
The system provides a number of API functions, the parameters and return values of these functions are very reasonable and easy to use. The input and output parameters of API functions contain
important information, such as logical channel LCID, URID, assigned talk group URID, etc. The parameters are organized into a corresponding structure, which are easy to understand and read, and each API function has its corresponding environment, so a deep understanding of the interface function parameters and the using environment is the key to use these API functions well [3]. After invoking the API function, the response processing is very critical and complex. The system uses a message mechanism for the response to the function, i.e., the scheduling system invokes the API function, the system returns the response in the form of a message, and then the scheduling system processes the received message. It is similar to the generic response mechanism in MFC, which allows the function to be processed in modules for each call, making it easy to solve problems efficiently. However, this mode is not efficient, when the messages are received at the same time, it will increase the system processing burden, or even crash, in order to overcome this situation, a message queue is made, each time a message is processed, although there may be a certain delay, but this delay is very short can be ignored, the important thing is to reduce the burden on the system, so as to achieve the correct handling of the message. TCS provides a simple interface that connects the user's voice, data, and applications to the CASSIDIAN TETRA system. This interface is called the TCS API [4]. The TCS API provides all the basic CASSIDIAN TETRA operations to the application through its well-structured and simple programming interface. With the TCS API, the development of custom applications is quick, easy and cost effectively, simpler and more economical. By using TCS, the entire network range of services can be implemented through a single connection point.

4.2 Treatment Mechanisms

The scheduling system can carry out multiple actions and processing in parallel, such as initiating a group call, remote death and other tasks at the same time of initiating an emergency call, so the scheduling software development adopts a multi-threaded processing mode and uses thread synchronization technology to achieve synchronous processing of multiple threads. Each module is encapsulated, and each module is composed of one or more threads according to the situation, such as one module for login, one module for group paging, and one module for individual paging, etc. It should be noted that there may be different working states in each module, and multiple states need to be processed. Therefore, it adopts the design pattern of state machine to ensure the coordination and correct processing of each state, for example, there are multiple states in the login module: registration state, authorization state, activation state, available state, etc. Each state inherits from the state base class, and then adopts the factory mode to generate each state. Different states are used in different operations [5].

4.2.1 Registration and deregistration

When the console logs in, it registers as a client with the system, and the system activates the client and verifies the legitimacy of the user. The system activates the client and verifies the legitimacy of the user. If the legitimacy of the user passes, the system allocates system resources. Only then the client can communicate with other modules. The opposite is true for logging out, where system resource allocation must be cancelled at first.

(1) Registration

Clients can only communicate with each other and with the CDI to send and receive messages after they have successfully registered with the CDI. The diagram illustrates the registration process of the dispatching system. The group call function is implemented.

The dispatcher program invokes APx function MediRegisterelientEx() to register with eox, and CDI returns MedielientRegistrationstauS message response. If the client registration is successful, the system returns the clientID message, and the system will send the registration message through the MediclientRegistrationstatus to all other registered clients. The client can now query the registered client through MediclientRegistrationstatus, the CDI responds to the MediclientRegistrationstatus to return. During the registration period, the CDI will periodically send a
message and the client will respond with the MediRegistrationstatusupdate to return. The client must receive other client registration messages before it can communicate with other clients [6].

![Diagram of dispatching system registration]

**Figure 2.** Dispatching system registration

(2) User Activation

The console consists of multiple interconnected processes that work together. The interdependency of the processes requires that the CDI provide a technique or method to ensure that the activation and de-activation (release) of the processes are coordinated and synchronized in a certain order. In order to work in the multitasking environment of the CDI, the processes need to operate in different situations depending on their activated and deactivated states [7]. The diagram explains that the user activation process system coordinates the work of multiple dispatchers by broadcasting activation messages MediActivateClient and MediDeactivateClient to react to the activation status of each dispatcher. After a client completes registration, the system sends a broadcast activation message to all clients. When a client receives a MediActiveClient, first of all, it determines whether the type, ID, and other parameters of the client are consistent with the parameters of the broadcast activation message. If the parameters are the same, it means that the client has been activated in the system, and then returns MediIservice to notify the system that the client has officially started using it; if they are not the same, it means that some other clients of the same type are already in the service, and other actions can be taken according to the situation, for example, if one type of client has been activated, then other clients of the same type can be logged out [8].

Similarly, after the client is logged off, all clients receive MediDeactivateClient, which matches its type and 10 and other parameters with the parameters of the broadcast message, if they are consistent, it means that the client is no longer in service, and then sends back MediOutofService to notify the system; if they are inconsistent, other dispatchers can do the corresponding process of coordination.
4.2.2. Group call
The group call module implements the call with the talk-group and monitors the voice of the talk-group. To implement the group call function, it is necessary to allocate resources firstly, and then select the corresponding resources, if it is unsuccessful, it needs to return to reallocate. The diagram shows the flow of group call, which requires resource allocation and after it is successful, the group can be selected to call. The diagram illustrates the flow of resource allocation for a call group.

![Figure 3. User Activation](image)

![Figure 4. Call flow](image)
The dispatch console initiates a MediAssignEx request for resource allocation, and the API responds to return messages such as allocation resource status, URD, and LCID through MediAssignstatus [9]. When the resource cannot be allocated, the API will return an error message or an alert message. The console can initiate MediDeassign to offload the resource allocation for the group, and the API responds to offload resource status and other messages through MediAssignstatus. When the allocated resource cannot be unloaded, the API returns the appropriate error or alert message. When the resource is successfully assigned, the PTT is pressed to transmit, and the PTT is released to end the transmission, the diagram illustrates the process of initiating and disconnecting the group call.

**Figure 5. Call resource allocation process**

The dispatch console initiates a MediAssignEx request for resource allocation, and the API responds to return messages such as allocation resource status, URD, and LCID by MediAssignstatus [10]. When the resource cannot be allocated, the API will return an error message or an alarm message. The console can initiate MediDeassign to offload the resource allocation of the group, and the API responds to offload resource status and other messages by MediAssignstatus. When the allocated resource cannot be unloaded, the API will return the corresponding error message or alarm message. When the resource allocation is successful, the PTT is pressed to transmit and the PTT is released to end the transmission. the diagram explains the process of initiating and disconnecting the group call.
The dispatcher initiates immediate transmission via MediBeginInstant, and the API returns the state of immediate transmission; when immediate transmission cannot be initiated, the API responds to return an error message via MediBeginInstantError. The system client initiates MediEndInstantTransmit to end the immediate transmission; when the immediate transmission cannot be ended, the API responds to return an error message via MediEndInstantError. When the system member presses the PTT key to talk, if there are other users on the call, it is necessary to call queue; this can be performed by initiating a high-priority call to hijack the channel. The scheduling system client initiates the setting of the priority through MediselectPriority, and the API responds to return the status message through MediPriorityStatus. If the priority cannot be set, it will respond MediselectPriorityError to return an error message.

5. Conclusion

Communication system is one of the core technologies for urban rail transit operation, and it is also the fastest growing field nowadays. The Beijing Metro wireless communication dispatching system based on TETRA is designed to solve the problem that the expensive cost of purchasing of English dispatching consoles in dedicated wireless communication system and the lack of replacement of the internal dedicated PCBs. The system is based on the existing wireless communication private network operation and maintenance auxiliary decision-making system, and is developed twice by using the API (application program interface), which is provided by MOTOROLA, and realizes the function of using PC to install the secondary development software instead of the English dispatching console dedicated PCB. The advantages are as follows.

(1) Concise and clear tele-traffic
The single-page displays the call status, caller ID, and call history record of each group, which helps to quickly understand the real-time operation and usage of the system.

(2) Flexible configuration of seats
Talk-groups of each train can flexibly allocate to each seat, and depending on the need, each seat can focus on part of the talk-group of the train and initiate the call. For each agent, it is also possible to categorize and name the talk-groups according to the control panel, and define the members of the talk-groups, so that the agent can pay attention to only some of the information of the talk-groups in a certain period of time, which effectively improves the work efficiency of the agent.

(3) Deep integration with train scheduling management.
Based on the information between the information of the trains and talk-groups, the train dispatching system can initiate various calls through the console interface adapter according to the needs of service, monitor the real-time status of each train talk-group and grasp the real-time information of trains, thus to provide more powerful support for dispatching.

(4) Web-based access
The authorized computer client can access the system just by using Internet Explorer, which is completely in Chinese, simple and convenient, and its upgrade, management are carried out in the background to ensure a perfect experience for customers.

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