

Tackling Key Technological Problems and Advancing 5G Technology Application in Railway

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***A**bstract: The paper summarizes the development of mobile communication of domestic and foreign railways, and proposes the priorities for tackling key technological problems of railway 5G private network according to the technical routes of railway next-generation mobile communication determined by China State Railway Group Co., Ltd. From the aspects of work objectives, principles, technical routes and innovative working methods, the paper elaborates the ideas of railway 5G scientific and technological research, puts forward the contents and plans of scientific and technological research on railway 5G private network, systematically organizes the achievements in the scientific and technological research stage of railway 5G private network, and sets forth the key contents of next-step scientific and technological research.*

Keywords: railway mobile communication system; railway 5G private network; tackling key problems in science and technology on 5G private network

(This paper is selected from *China Railway*)

1 Introduction

The relevant services of traffic safety such as railway traffic command and train operation control must be carried by the private network of railway mobile communication, which is the consensus of the global railway industry. Railways of different countries have all been attaching great importance to the construction and management of railway private mobile communication system with the representative technologies including GSM-R and LTE-R, among which GSM-R is the railway digital mobile communication system jointly led by the International Railway Union (UIC) and the European Railway Administration (ERA). Currently, over 130 000 km tracks have been covered in different European countries to carry mainly the services including train control and dispatching communication so as to realize the cross-border railway interoperability and popularize the comprehensive application of GSM-R technology. The European railways have been actively carrying out researches on railway new-generation mobile communication technology with the technical development and industrial evolution. The 5G-RAIL project funded by the European Union started on November 1, 2020^[1]. Meanwhile, the decision of ECC (20) No. 02 was promulgated by the European Post and Telecommunication to expand the 1 900–1 910 MHz frequency band for using in the railway mobile radio, coordinate the unified frequency of railway mobile radio, and achieve the cross-border transportation on the basis of GSM-R frequency, for which all member countries had been required to start implementation on May 20, 2021^[2], marking the entrance into the express development of European railway 5G private network. The European railways have planned the stages of standard formulation, and test and verification for the development of 5G private network and it is estimated to start the deployment of application in 2025^[3]. China is a big country in rail-

way transportation, for which the operating mileages of the national railway have exceeded 150 000 km including over 40 000 km of high-speed railways by the end of 2021. GSM-R has been playing the important role in railway transportation and production, which is the important guarantee for train operation safety and also the important means to uplift the efficiency of transportation and production. China's GSM-R has been deployed on the railway lines of over 80 000 km covering all high-speed railways and part of the conventional mainlines to carry the key services of CTCS-3 level train control, and dispatching and command.

The technical evolution for the railway private-network mobile communication system has always been the important research area for railway scientific and technological innovation, for which the main driving forces are in three aspects including the daily-increasing new demands, the constant development of new technologies and the rapid replacement of industrial chains. In the aspect of demands, development of intelligent railway is the inevitable choice to achieve the transformation and upgrading of railway from the traditional capital construction to the new one^[4]. The 3-aspect services of intelligent construction, intelligent equipment, and intelligent operation and maintenance have high requirements for bandwidth and real time of the mobile communication network, for which the GSM-R system cannot meet the technical requirements of the intelligent broadband services. Regarding the aspect of new-technology development, the 5G network has been in scaled commercial use with the technology being matured day by day and the design of its new characteristics mainly focusing on the applications of the industry in addition to the possession of technical characteristics for the large bandwidth, thus laying technical foundations for the railway application. With respect to the support to the industrial chains, China's railway mobile communication is con-

fronted with great challenges, for which the railway GSM-R belongs to the 2nd-generation digital narrow-band technology shares the industry and technology with the GSM of the public network. Furthermore, The GSM of the mainstream operators from the countries and regions such as the USA, Europe, Japan and Korea has been basically withdrawn for the service, while for the Chinese operators, the GSM system for the China Unicom had been basically withdrawn for the service in 2021^[5], and that for the China Mobile will also been withdrawn for the service in the years to come. The entire industrial chains will experience abrupt shrinkage with the rapid withdrawal of service for the GSM of the public network, so it is imminent to carry out research and development for the new-generation mobile communication system.

To implement the requirements of the country's new capital construction, China State Railway Group Co., Ltd. (CHINA RAILWAY) proceeded from its own practical conditions and demands in 2020 and determined to adopt the 5G technical system of the railway new-generation mobile communication, thereafter promulgating *Implementing Measures of CHINA RAILWAY on Accelerating Promotion of Railway Application Development for 5G Technology*^[6] and *Three-year Action Program of Tackling Key Problems in Science and Technology for Railway 5G Technology Application*^[7] and thus taking shape the programmatic document for advancing the railway 5G development. With the active support to the research work on railway 5G technology from all professional fields of the industry, and the close attention and active involvement from the departments and enterprises concerned of the society for the development of railway new-generation mobile communication, positive exploration and practices had been carried out in the aspects of researches on the key technologies and equipment research and development, thus providing powerful support for the

completion of the work in tackling key problems in science and technology and the next-step deployment for the entire network.

2 Ideas of Tackling Key Problems in Science and Technology for Railway 5G Private Network

2.1 Establishing the work objectives

The work in tackling key technological problems for the railway 5G private network has been carried out according to the *Three-year Action Program of Tackling Key Problems in Science and Technology for Railway 5G Technology Application*, and in the way of following the principles of application traction, safety and reliability, independent innovation, and opening and sharing^[7], based on the application demands and characteristics of the railway, and in combination with the progress of 5G international standards and the support from the public network industry. The technical systems for the railway 5G private network mobile communication system have been built with innovation through the work of tackling key technological problems including pushing forward key-technology researches, equipment R & D, standards formulation, test verification, etc., thus laying the technical foundations for the scaled construction deployment and service application of the railway 5G private network.

2.2 Determining the work principles

The successful experiences for the related projects in tackling key technological problems have been taken for reference with the following principles for advancing the work being put forth so as to ensure the scientific, orderly, high-effective and continuous advancement of the work.

(1) Demand orientation. The service demands carried by the railway 5G private network can be summa-

rized as follows: undertaking the GSM-R service and making smooth transition around the application demands of intelligent HSR, meeting the new demands relating to train operation safety such as for train-train communication and over-the-horizon boarding, and decoupling the communication system with the service so as to ensure their independent evolution and no constraint from each other.

(2) Opening and cooperation. Actively following up the domestic and foreign innovative applications, absorbing the scientific research and development forces from inside and outside the railway sector, and making joint efforts to carry out researches on the railway 5G technology.

(3) Fusion application. Advancing the fusion development of the 5G technology with the intelligent railway and big-data technology, enhancing the fusion applications of public and private networks, and attaching importance to the safety protection between the systems.

(4) Standardized development. Building the standard systems, and standardizing the product R & D, test verification and engineering application; advancing the implementation in scientific and orderly way with demonstration followed by popularization, mainline followed by branch line, side by side advancing for HSR and conventional-speed railway, and orderly advancing of the terminal followed by the network; and laying stress on achieving coexistence and compatibility of the railway 5G private network with the GSM-R on-board equipment.

2.3 Determining the technical routes

In order to advance the sound research on the railway 5G private network technology and the equipment development, efforts should be made to take the research and test experiences for the railway LTE-R in the period between 2015 and 2018 for reference by following the objective law of the scientific research work, and formulate the technical routes of tack-

ling key problems in science and technology for the 5G private network in accordance with the overall requirements of the *Three-year Action Program of Tackling Key Problems in Science and Technology for Railway 5G Technology Application*^[7] (refer to Fig. 1). Wide-ranging and deep-going investigation and research on the railway mobile communication services and the functional operation scenarios should be carried out by starting with the status and development needs of operation and management for railway transportation. The overall technical schemes should be worked out and the equipment for special use developed according to the railway characteristics on the basis of studying the domestic and foreign generally-applied technical standards and the operators' application experiences. Through the test verification, the technical schemes and equipment are optimized and finalized to take shape the technical standards and carry out checking for trial use so as to provide technical and equipment supports for the formal conducting of engineering application.

(1) Demand analysis. Taking the application as the leading force to comb the service demands, analyze and summarize the key indices and parameters such as the service classification and attribute, application scenario, communication mode, service user, service flow direction, continuity, priority-level distribution, delay, packet loss rate and bandwidth, build the service model, and further cast light upon the functional demand and the frequency resource demand of the communication system.

(2) Overall scheme. Working out the overall technical schemes of the railway 5G private network including those for system architecture, system function, networking, service application, etc. based on the demands of the railway sector.

(3) Equipment R & D. Carrying out research and development for the core network, wireless network, terminal and key application equipment of the 5G private network in accordance

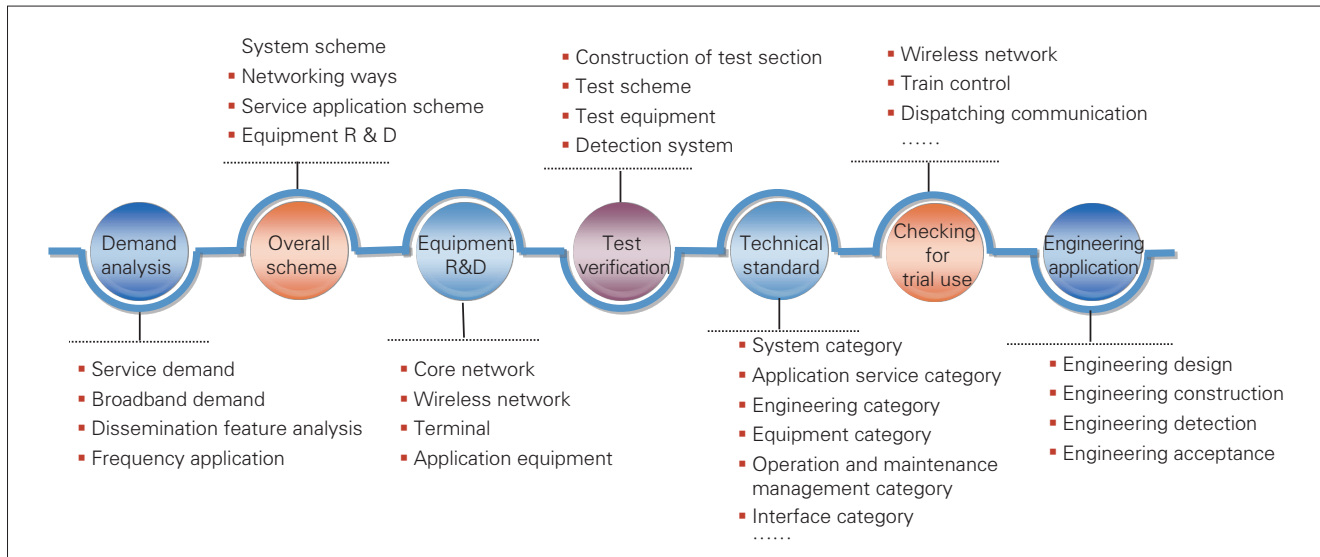


Fig. 1 Technical routes of tackling key problems in science and technology for railway 5G private network

with the technical requirements of the system schemes so as to provide equipment support for the follow-up test verification and checking for trial use.

(4) Test verification. Fostering the test environment to carry out the tests in two stages in accordance with the overall schemes. Firstly, the test verification in the indoor dynamic and outdoor medium- and low-speed scenarios will be carried out on the loop railway track of China Academy of Railway Sciences Corporation Limited (CARS) with the stress being laid on the achievements for verification of equipment functions, interface interconnection, and networking; and then the high-speed test sections will be selected to give priority to conducting the tests on high-speed adaptability and carrying capacity.

(5) Technical standards. Optimizing the technical schemes and building the complete set of the technical standard system based on the test results so as to provide technical bases for the follow-up work.

(6) Checking for trial use. Selecting the high-speed railway test sections or other suitable tracks to carry out the checking for trial use for the key equipment such as the wireless network of the 5G private network, train control, and dispatching communication and complete all the prepara-

tory work before the engineering application.

2.4 Innovating the work mechanism

The working mechanism of “taking ourselves as the dominant factor with multiple-side involvement, competition and cooperation, and sharing of achievements” to bring into play the leading role of CHINA RAILWAY in science and technology of the industry. CARS is taken as the main technical subject to actively unite itself with all forces of research from the authoritative departments inside and outside the railway sector and of all the related fields including domestic scientific research institutes, institutions of high learning, design institutes, railway administrations, and the main manufacturers for the 5G technical products, and form the technical teams covering production, academic, research and application. By relying on the scientific research topics of CHINA RAILWAY and bringing into play the technical advantages of all sides, collaborative cooperation will be implemented to tackle the difficult problems of key technologies for the 5G private network, jointly advance the work of technology research and equipment development for the railway 5G private network, and make overall planning to formu-

late standards and specifications so as to take shape the technical systems and serial special equipment for the railway 5G private network with individual intellectual property rights and provide supports for the railway 5G private network construction and application.

Research and development of the private network equipment is a key link in fulfilling the task of the three-year action program for tackling key problems in science and technology. The communication equipment of the 5G private network mainly include the core network, wireless network, onboard equipment, hand-held terminal for special use, SIM card, etc. and the research and development work should be carried out by fully taking for reference the general-use technologies for the 5G industrial chains and be custom-made in the light of special demands for railway. Excellent enterprises should be selected by taking into account the factors such as the market share, enterprise scale, technology leadership and R & D capability to jointly be involved in the research and development of communication equipment for the 5G private network, for which there will be generally the involvement by not less than three enterprises for each product so as to mobilize and bring into play the initiatives of the enterprise

and advance rapidly the R & D work of the equipment through implementing the mechanism of “striving to be the first as the horse racing”.

3 Work Stresses of Tackling Key Problems in Science and Technology for Railway 5G Private Network

3.1 Key contents

(1) Private network adaptive frequency. The radio frequency is the prerequisite for developing the railway 5G private network and needs to put forth the dedicated frequency adapting to the railway application scenario from the angles of technology and economy. The researches on the technical characteristics of frequency mainly include the characteristics of electromagnetic wave propagation, channel model, electromagnetic compatibility and interference avoidance measures.

(2) System scheme. System schemes are worked out from the angle of the system in general to carry out the researches on the service and functional demands of the 5G private network, the system demand of the 5G private network and the overall technical requirements of the system, which will be taken as the top-level architecture of the follow-up technical research work.

(3) Key technologies. It is necessary to lay emphasis on studying the way of system redundancy networking, the equipment-level redundancy requirements, equipment functional and performance requirements, the co-existence evolution tactics of the railway 5G private network and the GSM-R system based on the requirements of railway high reliability and smooth transition.

(4) Key services. Researches on the Mission Critical Services (MCx) scheme for the railway 5G private network, the technical scheme for train control service, the technical scheme of train approaching alarm for train-train communication, the technical

scheme for train over-the-horizon boarding, the multiple priority-level and service quality security measures, and the interconnection of GSM-R with the service systems are carried out around the key services such as traffic command, train operation control and traffic safety.

(5) Key equipment. Custom-made development of the core network, radio network, terminal equipment and key service equipment for the railway 5G private network are carried out in combination with the characteristics of the railway so as to provide equipment support for conducting test verification and engineering application.

(6) Detection evaluation technologies. Researches on the detection technology of wireless network field strength coverage and service quality for the railway 5G private network including the wireless network field strength coverage, service quality and application service detection methods and indices to build the detection system and provide the bases and means of detection and evaluation for the follow-up tests.

(7) Safety protection and control technologies. With the consideration of achieving multiple service access and fusion application of public and private networks by using the 5G private network, it is necessary to carry out the researches on the network security protection and service isolation control technology with the stresses being laid on the research work directing against the security protection and control technologies of access domain, network domain and application domain.

(8) Test verification. It is classified into two stages, i.e., tests on the loop railway track and site tests of HSR. Firstly, the test environment of the 5G private network is built by relying on the loop railway track to conduct tests on the system function and performance, interface interconnection, and feasibility of the key service schemes. Then the test sections of HSR are selected to carry out the tests on the high-speed adaptation and key service performance indices for the

system.

(9) Standard systems. Technical standards are formulated based on the relevant research work achievements of the system schemes, key technologies, key services, equipment R & D, and operation and maintenance to build the technical standard systems of the railway 5G private network and further take shape the complete technical systems.

(10) Checking for operation. Checking for trial use for the key application equipment such as the 5G private network system and train control, and the dispatching communication is conducted according to the management flow of scientific and technological achievements to complete the equipment finalization and lay foundation for the formal engineering application.

3.2 Main plans

The work of tackling key problems in science and technology can be completed in three stages including research and development, test verification, and checking for trial use (refer to Fig. 2) based on the requirements of *Evaluation Management Measures for Scientific and Technological Achievements by China Railway Corporation* (TZKJ [2014] No. 68)^[8] and in combination with the characteristics of technical research for the railway 5G private network.

(1) R & D stage: Carrying out researches on the key technologies, completing the equipment development, laying stress on completing the work of equipment R & D and commissioning for the 5G private network, and working out the overall standards for the system category.

(2) Test verification stage: Carrying out lab static tests and medium- and low-speed dynamic tests by relying on the loop railway track and the 5G innovation lab of the CARS; selecting the site test sections of HSR to conduct the test verification of high-speed adaptation for the 5G private network, laying stress on completing the site tests of high-speed railway for the key service applications for the

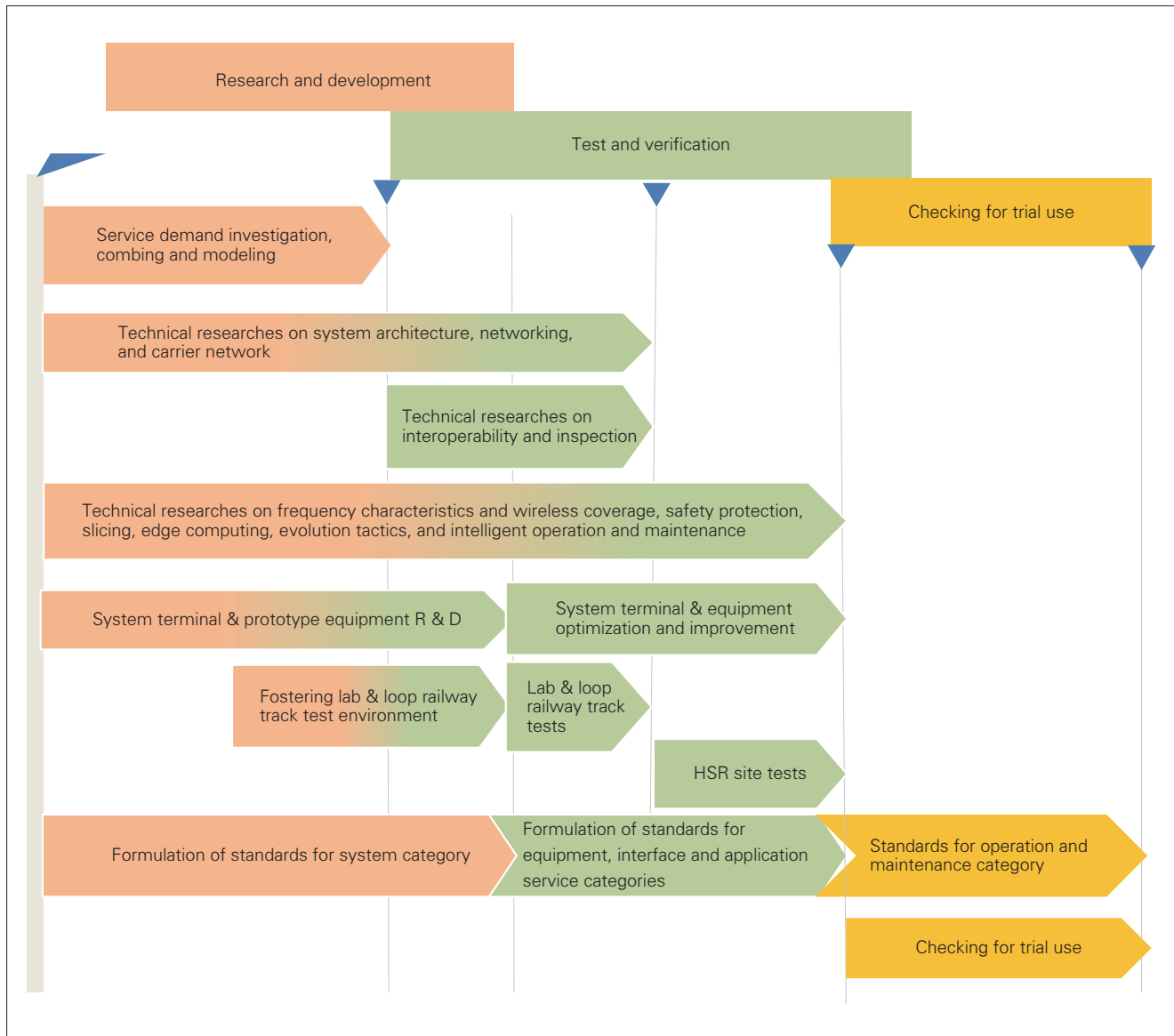


Fig. 2 Overall plan of tackling key problems in science and technology for railway 5G private network

5G private network system and train control, dispatching communication, etc., and establishing and improving the standards for equipment, interface and key service categories.

(3) Checking for trial use stage: Carrying out the trial-use checking for the 5G private network system, completing the 5G private network system and the terminal product finalization, formulating the standards for the operation and maintenance category, further improving the technical standard system, and building the technical systems of the 5G private network in combination with the HSR construction.

Planning as a whole for the arrangement of the scientific and technological topics and test items for the 5G private network, and advancing the work of tackling technological problems for the railway 5G private network in scientific, orderly and step-by-step way based on the above-mentioned plan.

4 Main Achievements

4.1 Basically forming the standard system architecture

Following the international standardized general technologies and building the railway private network

in combination with the railway application characteristics are the technical routes of UIC. The technical routes of China's railways and UIC are identical, with which efforts have been exerted to make full use of the standardized technologies and the industrial support conditions based on the 5G standard systems put forth by the 3GPP standardization organization, advance the research work on the technical standards for the 5G private network in accordance with the railway application characteristics and the particular demands, build the standard systems of the railway 5G private network which is advanced and

adaptive, standardized and unified, complete in structure, and compatible and inclusive, and bring into play the fundamental and leading role of the standardization work in advancing research and development, and tackling of key technical problems for the 5G private network.

The standard systems of the railway 5G private network are divided into three levels according to the major category, minor category and concrete standards with the planning for a total of 7 major categories (refer to Fig. 3). Among them, the equipment category (including technical requirements and test methods) is classified into five minor categories including the core network, wireless access net-

work, users' equipment, application interface/access management equipment, and operation and support system according to the classifications of equipment; the interface category is classified into six minor categories including the general-use interface, interfaces for users' equipment and network, interfaces for wireless access network and core network, interfaces between core networks, internal interfaces for the core networks of the CR local company, and interfaces between the core network and the other systems according to the classifications of interface.

Ways such as the new and revised compilations are adopted to complete the standard system con-

struction in stages, standardize the research and development, construction, and operation and maintenance management for the 5G private network system, and provide technical bases for the work covering product development, network planning, engineering design, tests for acceptance, and operation and maintenance. Furthermore, technical standards for the application category and the equipment category will be replenished and expanded to advance the work of standard formulation and revision systematically, and improve continuously the standard systems of the 5G private network in accordance with the future needs of development.

Compilation for a total of 15

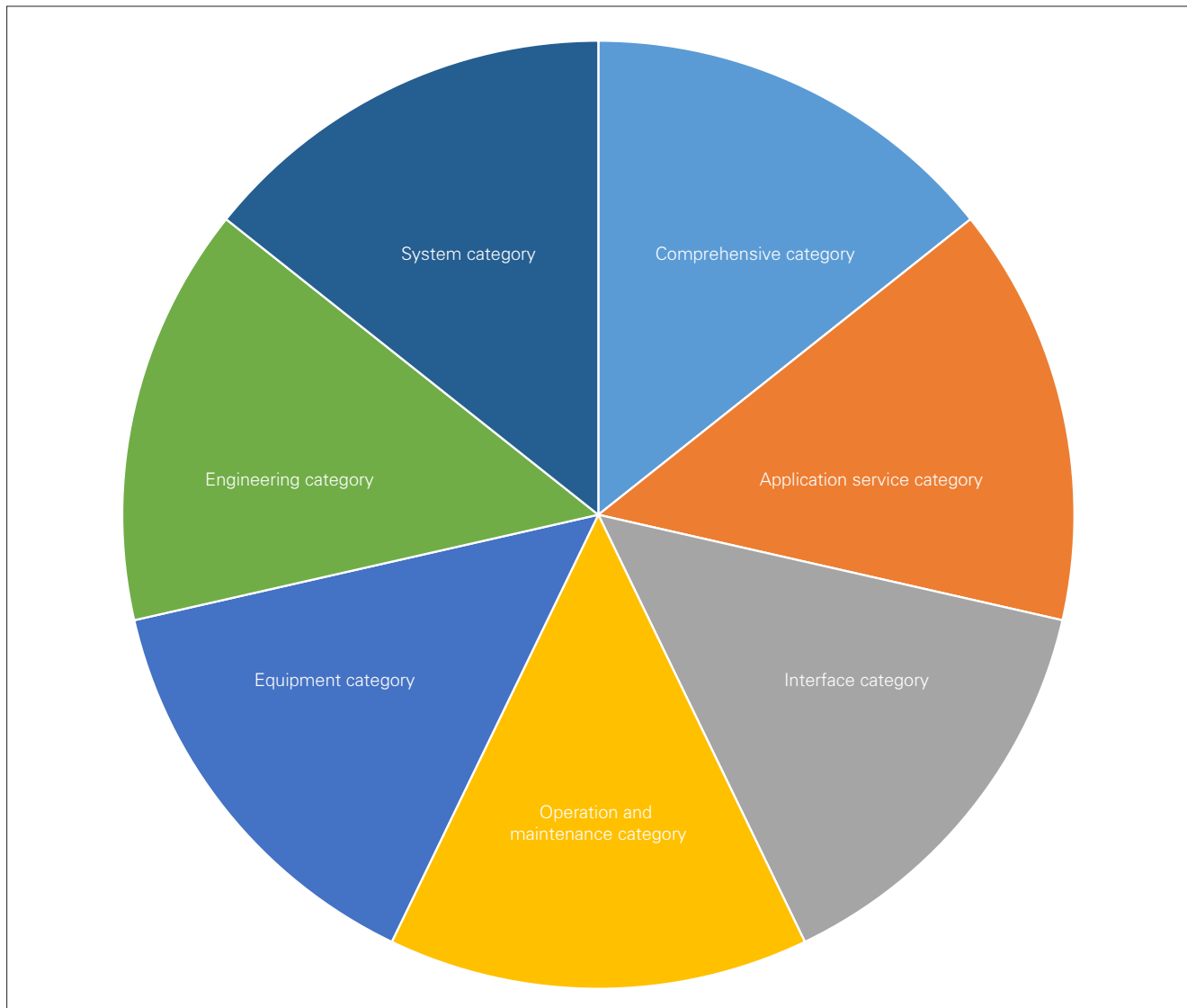


Fig. 3 Standard systems of railway 5G private network

items of the technical standards with respect to the system category and equipment category for the 5G private network has been completed so far to provide the bases for current-stage dedicated equipment research and development. Among them, 2 items of technical standards for the system category have been promulgated, 1 item of technical standard for the system category has been completed to submit for examination, and 12 items of technical standards for the equipment category have been completed as the text for soliciting comments. At present, compilation of technical requirements for the key application services covering train operation control and traffic command is on the way. Researches on the technical standards for the operation and maintenance management category will duly start as needed so as to provide supports for putting the network into formal operation afterwards.

4.2 Achieving breakthroughs in key technology research

Tackling key technological problems for the railway 5G, carrying out research to take shape the technical schemes, and putting forth proposals for application so as to provide supports for the scaled and engineering deployment for the 5G private network in the light of characteristics with respect to the operation environment and organizational management.

4.2.1 Research on frequency characteristics

Having completed the simulation analyses on the characteristics of electromagnetic wave propagation for the targeted frequency sections of the 5G private network system, built the channel simulation wane model in the condition of HSR typical scenario, and put forth the requirements for the base station/terminal electromagnetic performance indices; and having fulfilled the simulation analyses on the electromagnetic compatibility between the targeted frequency sections of the railway 5G private network and the adjacent frequency section system, thus providing technical supports for

the follow-up formulation of the test schemes.

4.2.2 Research on technical schemes for railway 5G private network system

Researches on the top-level design and overall planning for the 5G private network technology will be carried out in combination with the ways of production organization to take shape the *Technical Schemes for the Railway 5G Dedicated Mobile Communication (5G private Network) System* so as to provide guidance and bases for the technical standard formulation, equipment R & D, and test verification of the 5G private network system. (1) Having designed the 5G private network system architecture, which is composed of 5 parts including the core network, wireless access network, application interface/access management equipment, users' equipment, and operation and support system. (2) Having worked out the networking scheme, for which the entire railway sector has been making concentrated efforts to deploy the common-use equipment of the sector for the off-site disaster-tolerant backup, and all railway administrations have been deploying the core network for the disaster-tolerant backup of different addresses in the same city with the adoption of the equipment redundancy networking way for the wireless network along the railway lines so as to meet the requirements of railway reliability and realize the maximized utilization of the frequency. (3) Having put forth the interconnection schemes of the 5G private network with other systems including the interconnection schemes of the 5G private network with the systems for train operation control, CTC/TDCS, GSM-R, and multi-media dispatching communication as well as the requirements for service moving and smooth transition between GSM-R and the 5G private network. (4) Having made clear the technical requirements for the system equipment, the priority-level distribution scheme for the services and users, as well as the synchronous scheme of systems.

4.2.3 Research on field strength coverage and service quality detection technology

Having put forth the field strength coverage detection technology and indices for the wireless network, and studied on and worked out the corresponding methods for index collection, data processing and statistics; having put forth the network service quality indices for the 5G private network including the performance indices for the handling capacity, delay, and packet loss rate; having put forth the service quality indices for the 5G private network services including the performance detection indices for the services of carrier train control, dispatching communication, etc.; having put forth the service quality detection indices including the access performance, mobile performance, and channel-keeping performance; having put forth the proposals on detection methods and technical specifications for the field strength and service quality of the 5G private network; and having developed the detection equipment for the railway 5G private network. The above-mentioned achievements of work will provide bases and means of detection evaluation for conducting the tests afterwards.

4.3 Achieving effects in key service R & D

4.3.1 Adopting 5G key technology in carrying over-the-horizon train

Having completed the formulation of technical schemes, prototype development and tests of the public network 5G. Having fulfilled the related matching with the train position through the video and danger information by accession to the comprehensive video monitoring system, natural calamity and foreign matter invasion monitoring system, perimeter invasion alarm system, earthquake alarm system and automatic monitoring and alarm system for track barrier. The video and danger information of the environment for the track with certain distance in the forward direction of the train operation are sent through the 5G network to the onboard termi-

nal mounted on the driving panel of the EMU driver to extend the visual scope of the driver so as to find out the danger in advance and raise the efficiency of danger disposal. Having developed the wayside server, onboard comprehensive transmission platform and onboard indication terminal, conducted the service tests of the 5G public network for carrying the over-the-horizon train on the Beijing-Zhangjiakou HSR with further tests to be carried out in the environment of the 5G private network afterwards.

4.3.2 Adopting 5G technology in carrying train-approaching alarm of train-train communication

Having completed the technical scheme of the system and prototype development, and carried out the tests in the lab. Multi-source fusion positioning of “Beidou satellite+5G network+passive balise+speed sensor” is adopted to build the train-train communication network based on the train location; and conduct the real-time computing of the train tracing distance and achieve the train approaching alarm function by taking the onboard equipment as the main subject. Dynamic tests of function for the prototype train-train communication server and onboard alarm processing equipment are carried out in the environment of the railway 5G innovation lab private network.

4.3.3 Key technology of train control system adaptive to 5G private network conditions

Researches on the technical schemes and key technologies are being carried out, which cover the system composition, working mode, interface requirements, communication process, key scenarios, redundancy mechanism and transition schemes. Researches are further focused on risks of network security for the train control system using the 5G private network, the architecture for network security and the demands of safety function, and the safety requirements of double-module MT and SIM card as well as technologies of safety control and security for the GSM-R and

5G private network. Analyses on adaptability for the current CTCS-3 train control system, the ATO system of HSR, and the new-type train control system are conducted in the condition of the 5G private network. Researches on the scheme of moving from the GSM-R toward the 5G private network and the viability of further use of equipment for the train control system are also carried out.

4.3.4 Key technology of railway 5G private network in carrying multimedia dispatching communication services

Having completed the formulation of technical schemes, prototype development and lab dynamic test. Having put forth the architecture designs of communication system and application decoupling, and formulated the realizing scheme for the MCx end-to-end technology; made breakthroughs to the key technologies for the broadband cluster, calling control, carrier control, media transmission control, soft exchange, and fusion dispatching, built the railway MCx system, and provide communication means for the train dispatching, remote command, and intelligent operation and maintenance. Having developed the prototype MCx equipment for broadband cluster communication and conducted the lab static tests in the environment of railway 5G innovation lab private network.

4.4 Orderly advancing development of railway private network equipment

To enhance the control over the life cycles of equipment for the system by CHINA RAILWAY and take into account the factors for appropriate competition, priority is given to the selection of 19 equipment manufacturers to carry out the research and development for the essential products in 5 major categories and 15 kinds. Up to now, the prototype development has been completed and the related work for the test evaluation is being conducted in good order.

In the course of product development, appropriate custom-made devel-

opment for the products relating to the special demands of the railway sector and the scenarios of special use should be carried out on the basis of the general-use products. (1) For the common-use equipment and core network of the entire railway sector, stress needs to be laid on the custom-made development in the light of the particular functions and redundancy reliability of the railway sector. (2) For the equipment of wireless network, custom-made development is to be conducted mainly in the aspects of redundancy and high-speed algorithm. (3) For the equipment of the terminal, stress is laid on the development of the onboard comprehensive wireless transmission equipment (WTP) and the onboard multi-mode comprehensive antenna to make unified access of the services for non-train-control category on the train to WTP for the train-wayside transmission. On the one hand, the demands of the vehicle-top antenna are dropped from 22 pieces to 8 pieces to save the mounting space; and on the other hand, all services are accessed to WTP through the standard interfaces to realize the decoupling of the services and communication system and the unified temporal-spatial datum.

4.5 Basically completing the fostering of test environment

The railway 5G innovation lab started its construction in July 2020 and was completed by the end of the year 2021. By relying on the loop railway track test base of the CARS and making full use of the available resources, the test environment with complete system, abundant scenarios, and opening and sharing is fostered with the characteristics of internal and external field combination, public and private network coexistence, and consideration of both dynamic and static tests. The indoor areas for the railway 5G innovation lab are nearly 1 300 m², which are divided into 7 areas covering tests for the system, radio frequency simulation tests, computer room for equipment, etc.; and the outdoor wireless access network

achieves the seamless coverage along the loop railway track to foster the typical complex scenarios for redundancy coverage and tunnel coverage. The railway 5G innovation lab can provide the basic conditions for the development of all equipment of the full industrial chains, which will play the important roles in future in the aspects of tackling key technological problems, technical service, inspection and detection, and talent training. At present, tests for over 300 items such as the core network, base station, carrier network, and equipment for terminal as well as the interconnection of interfaces have been carried out by relying on the environment of the railway 5G innovation lab to lay foundation for further researches and tests on the 5G private network.

5 Conclusions

The decision and deployment of the accelerated advancement for the application of the 5G technology in railway sector by CHINA RAILWAY will be implemented in a deep-going way to keep firmly in mind the historical mission of making the country strong in transportation and taking the

railway sector as the forerunner, and spare no effort to advance the tackling of key technological problems and innovative application for 5G technology closely around the requirements of safety and operation for railway transportation and production.

Intelligence is the development orientation of railway and the adoption of the 5G technology can build the multi-specialty and multi-scenario intelligent connection platform for the brain platform of intelligent railway, the intelligent construction, intelligent equipment, and intelligent operation^[4]. Bringing into full play the advanced technical characteristics of 5G will be advantageous to promote the realization of the network intelligent operation, resource intelligent management, system intelligent maintenance, and service intelligent application and can provide powerful supports for the upgrading of the intelligent railway technical system including the intelligent communication.

Driven by the constantly-emerged new demands and industrial replacement, it is particularly urgent to speed up the advancing of the innovation for the railway 5G technology. It is imperative to make firm, scientific

and orderly efforts for carrying out researches, development and tests so as to lay solid foundation for the scaled deployment. Efforts are needed to not only accelerate the researches and development of the new technologies that have not yet mastered, but quicken the pace for advancing the application transformation of the achieved technical results. The work of tackling key problems for the railway 5G technology has achieved so far the results in stage in the aspects covering the building of standard system, formulation of system scheme, researches of key technologies, application of innovative services, dedicated equipment research and development, and fostering of the test environment. With the advancing and completion of technical research and equipment research and development, the test verification and checking for trial use will also be confronted with new challenges, for which it is necessary to persevere in conducting deep-going researches and making solid advancing so as to ensure the high-quality fulfillment of the task for tackling technological problems of the railway 5G technology.

(Translated by ZHENG Mingda)

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