Intelligent railway transport radio communication based on neural networks

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Abstract. The article is devoted to the features of GSM-R as a basis for organizing a digital radio communication system on the railway to apply the European Integrated Radio Communication for the railways of Uzbekistan. The role of GSM-R for the interaction of digital radio communication with the European integrated system for expanding the functions of railway radio communication and safe movement of high-speed trains is shown.

The article identifies the possibilities of building modern digital communication of the railway. The GSM-R communication network, its services and architecture for organizing digital communication were also defined. Recommendations on the use of GSM-R on the railway of Uzbekistan are given. It has been established that mobile communications should be a heterogeneous (heterogeneous) architecture. Also, it must have a variety of access networks that could operate in any frequency ranges.

1 Introduction

The digital railway area needs modern functional and operational applications that are required for safe train traffic control systems and other information systems compared to the general telecommunication sector.

The basis for the development of railway transport is the use of digital technologies. The digital system includes a whole range of information technologies: control of the movement of freight and passenger trains, station complexes, signals and switches, traction rolling stock. Of particular importance is the management of freight and passenger flows, signaling and communication systems. Today, the signaling lines are being modernized; that is, the worn out systems of relay electrical interlocking are replaced with microprocessor devices. Therefore, building digital communication in railway transport using modern technology is relevant [8, 9, 10].

The goal of the work. To show the advantage of the GSM-R standard and its compatibility with ERTMS UIC with ERA and the possibility of introducing the European Railway Traffic Management System (ERTMS) into the organization of digital communication of the railway of Uzbekiston Temir Yullari JSC

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For the transition to the European system of railway transport management, it is necessary to use the standard for the movement of trains in the driver's cabin (ETCK) and mobile communication for the management of freight and passenger traffic (GSM-R) [2, 3].

Integrated Railroad Mobile (GSM-R) provides a diversified set of services, interoperability, broadband 4MHz bandwidth, and 876-880MHz range. This allows mobile and base stations to transmit and receive information in the frequency range from 921 to 925 MHz. from a base station to mobile.

Functional communication without interruptions with the European Control System (ETCS) is carried out for train speeds up to 500 km / h. When using the global system of digital railway communications (GSM-R), special attention is paid to the safety and improvement of the quality of the equipment of these networks. Interference occurs when using broadband 3G and 4G / LTE mobile networks. In this regard, it is necessary to develop a new mobile communication system FRMCS (Future Railway Mobile Communication System), in which packet switching of the two LTE and R systems would replace LTE-R and 5G-R. Implementing the new version of LTE Release 12 will help create a variety of standardized interfaces on digital railways [20, 21, 22].

2 Materials and Methods

Packet switching LTE and R can become a receiver of the GSM-R network, which will be equipped with 5G equipment. Frequency allocation may be a problem for future digital railroad communications [14, 15]. Therefore, until this problem is resolved in digital communication systems, GSM-R wireless networks can be used.

The wireless network allows:

- Carry out communication Dispatcher - Engineer;
- Use point-to-point and group call architecture;
- Provide the level of priority calls;
- Remotely control the movement of freight and passenger trains;
- Maintenance of tracks.

Thus, GSM-R allows digital data transmission, replacement of existing wired communication systems and railway radio networks that are incompatible with each other [26].

Usually, ETCS is used to signal moving objects. Let's use the Fixed Block Signaling method. The blocks determine the distance between two signals and prevent objects from colliding. Each moving object (train) can be in its own block. Figure 1 shows the blocks and indicates the directions of train movement [24, 25].

Fig. 1. Fixed Block Signaling for moving trains

ETMS technology is being introduced gradually according to the levels: Level 1; Level 2; Level 3.

There are three parts to this system:
The terminal is connected to the driver's computer.
Tags (Travel transponders).
The communication system of the driver with the control center.
The computer allows the driver to communicate with the GSM-R terminal. Tags determine the location and speed of the train, the curvature of the track, various speed limits along the route. GSM-R radio communication provides communication between the driver and the control center.

Fig.2. Level 1

Level 1 equipment (Fig. 2) determines the train's location, its speed, track curvature, serves as radar, and GSM-R communicates between the driver and the control center.
Level 2 is the same as level 1. It differs in that it receives signals from the control center via the GSM-R radio network about the presence of a busy path, which is determined by their equipment.

Fig.3. Level 3

The computer (level 3) (Fig. 3) of the driver receives the signals from the tags and determines the commands of the control center.
For high-speed trains based on GSM-R, BT base station (BTS) locations are designed to overlap adjacent cells. This is due to the exclusion of loss of communication between train crews [16, 17]. Loss of radio communication will cause the train to stop. The ring connection of elements and devices (GSM-R) is carried out by an optical cable and is shown in Fig. 4. This figure shows the connections of base transceiver stations (BTS), base station controllers (BSC) and mobile switch (MSC) [18, 19].

Fig. 4. Ring connection of base stations.

A transceiver station (BTS) carries out radio communication in a specific area. Controllers (BSC) control channels, encode and decode, modulate and demodulate information signals, and can adjust the sequence and data rate. The GSM-R system using group (VGCS-Voice Group Call System) and circulation (VBS-Voice Broadcast system) calls can provide additional services. The priority mechanism (eMLPP-Multi-Level Precedence and Pre-emption Service) can provide up to 5 priorities, i.e., zero to four. For emergency calls, priority 0 can be used.

Integrated European Railway Radio System (EIRENE is capable of providing multiple services, operational compatibility and broadband frequency data transmission. The multicast channels of this system contain five call classes: normal

PIP Call (Point-to-Point Call); group call VGCS (Voice Group Call System); broadcast mode VBS (Voice Broadcast System); Railways Emergency Call (REC) SEC (Shunting Emergency Call).

Their content for digital railway radio communications. Therefore, the use of GSM-R for digital railway communication is an urgent task.

Let's consider some of the possibilities of the GSM-R standard. This wireless communication standard is based on the GSM standard. The introduction of the GSM-R standard will increase some of the functions of data transmission for the commercial technologies of the needs of the railway of Uzbekistan. The introduction of this technology will make it possible to establish communication between the train and the control center and communication between the driver - dispatcher and specialists in the conference format (group calls) [29, 30]. The use of GSM-R will enable the transmission of ETCS data. The European project of integrated railway radio communication with improved networks together with MORANE (mobile radio communication for railway networks in Europe) makes it possible to functionally use radio communication on high-speed railways (up to 500 km / h) [27, 28].

The peculiarity of this system: the establishment of radio communication train - driver; conference calls using point-to-point topology; the ability to automatically control trains; setting the level of priority calls; the ability to remotely control trains; maintenance of the track and the presence of a railway emergency call. Digital transmission of information using GSM-R makes it possible to replace all wired systems and analog networks, especially since it can transmit voice signals and transmit the information. GSM-R provides Group Call (VGCS) and Broadcast (VBS) functions, localized calls and interruptions in case of failure and lack of resources. It is also capable of ETCS level 2 and 3 transmitting information about railway signals to the driver, making it possible to organize the movement of trains with a higher speed train movement and optimize traffic while

maintaining safety. About thirty-eight states have chosen GSM-R as it is compatible with the ERTMS project.

UIC together with ERA (Interoperability Officer). The connection establishment time requirement for the GSM-R standard is presented in Table 1.

Table 1. Connection setup time GSM-R

Call type	Connection establishment time, s
Emergency call	<2
Calling the driver from the dispatcher or the attendant	<5
Group calls between drivers in the same area	<5
All operational calls from the mobile terminal of the driver to the terminal of the attendant or dispatcher	<5
Challenge compiler - machinist and machinist - compiler	<5
Call compiler - duty officer and duty officer - compiler	<7
All operational calls from a stationary terminal to a mobile and from a mobile to a landline, not related to the above	<7
All operational calls from a mobile terminal to a mobile, not related to the above	<10
All low priority calls	<10
Calls compiler - machinist and machinist - compiler and calls compiler - duty officer and duty officer - compiler after initial communication establishment in a special mode of operational work	<2

Messaging in GSM-R can be carried out not over a simplex channel, one for all subscribers, but over a duplex channel for organizing individual connections. It is also possible to organize group duplex and half-duplex connections. The use of the European project EIRENE significantly increases the efficiency and reliability of voice connections and improves the quality of speech.

The distance between trains determines the number of free blocks. GSM-R is equipped with a new CBTC (Communication Based Train Control) train control method [7]. In this system, the number of moving blocks (Moving block signaling) determines the distance between trains. In this case, it becomes possible to control the safety of the movement of trains one after another. The economic benefit of the system is that many elements of the analog transmission system become unnecessary [5,6].

GSM-R can provide voice and signaling services and new applications, such as cargo monitoring, video surveillance of trains and railway stations, which will provide additional services for passengers.

The entire GSM-R system can be divided into subsystems: onboard, station, control center. Each subsystem has solutions for various problems. For the control center, the task of adjusting the order of the rolling stock is defined; onboard devices - train traffic control; stationary - performing tasks of control of points and approaches to platforms and crossings.

Subsystems have access to radio communications to communicate with each other. For the safety of the subsystems, a single database has been formed. The work of subsystems with a single database allows you to save all information. It contains both topological information (line model, location of arrows and crossings) and data of permissible speeds and addressing of radio communications.

Cells of the GSM-R network are located along the track or at the station itself. Each cell contains radio transmitting and receiving devices, providing an interface with other cells of stations with a connection for communication between the base station and the control

center (MSC). Each controller has a cell number. Figure 5 shows a diagram of GSM-R devices.

It includes OCR (Group Call Register) - call grouping register; SMS (Short Message Service) - short message services; VMS (Visitor Management Server) - motion management server; OSS (Operation System Server) - control center servers; SCP - communication service control center; IN (Intelligent Network) - intelligent network; PABX (Private Automatic Branch Exchange) is an automatic switch of leased lines. There is a relationship between the mobile station and the service center, which includes the interfaces of the GSM-R network. The interconnection of the service center - the mobile station consists of the GSM-R interfaces (PSTN PDN, ISDN), which are included in the general network. Continuity of communication is ensured by the switching station when the mobile station moves from one cell to another. The movement of trains on rough terrain leads to communication losses due to the Doppler effect, multipath propagation of radio waves and the shadow effect. To prevent loss of communication, block coding is adopted in GSM-R [1, 2].

Fig.5. Devices GSM-R

GSM-R mobile applications and fixed terminals are equipped with a Decision Support System (DSS), which enables the road crews to make the best solutions to emerging problems. This intelligent system allows you to sort out difficult situations and suggest unexpected answers. The sources of these systems can be powered by solar panels, which reduce fuel costs and facilitate the installation and operation of these systems. In foreign literature, the DSS system is called the Decision Support System (DSS). The system (DSS) solves the problem of helping to compile models and select methods, formation a criterion in the formulation of tasks, performs calculations and produces results, restores decisions of past accepted results and their consequences. Currently, third-generation DSSs have appeared, which have new computational models that use biological processes, such as neural networks, fuzzy logic, and genetic algorithms. In the scientific literature, they are combined into "soft computing". These networks are used to build human-machine dialogue systems. The DSS model is shown in Figure 6.

3 Results and Discussion

DSS model uses artificial neural networks, which represent a simple processor based on the work of a cerebral cortex cell. Figure 7 shows the connection between artificial and natural neural systems.

Fig. 6. Model DSS

Fig.7. Interconnection of neural networks: A) natural; B) artificial

The mathematical model of an artificial neuron is represented by some function $f(S)$, where S is an argument, that is, the totality of all input signals. The resulting value is output to a single output.

There are input, output, and hidden layers in an artificial neural system, which can be several. The structure of neural centers is shown in Figure 8.

Fig.8. The structure of neural centers

Fuzzy logic, which represents boolean logic, can be used in logic problems. It allows you to operate not only zeros and ones but also intermediate values [3].

The DSS system includes the following elements: mobile terminal; stationary, installed at a railway station; external transmission line mobile terminal. The DSS system diagram is shown in Figure 9.

Fig. 9. Diagram of the DSS system

The transmission line (TRL), located at the place of occurrence of an emergency, with the help of a mobile terminal, transmits parameters about the current situation. The station element of the GSM-R mobile network receives information about emergencies in the form of SMS messages and sends the coded information to the mobile interval by external TRL. Mobile terminals decode information [23].

The stationary element of the DSS consists of stationary element 1, an interface for receiving information 2, a wireless channel interface for receiving and transmitting information GSM-R. The interface for receiving and transmitting is connected to an automated workstation 5, 6, 7. This connection structure is shown in Figure 10.

Fig.10. Block diagram of a stationary DSS

The connection diagram of the DSS elements using GSM-R is shown in Figure 11. The following designations are added to the diagram:

1 is stationary DSS; 2 is interface for receiving information; 3 is data transfer interface; 4 is system receiving and transmitting interface; 5 is input block; 6 is module of the neural system; 7 is module of common blocks; 8 is subsystem of an artificial neural system; 9 is general output block; 10 is tuning block of an artificial neural system; 11 is block, which includes three artificial neural systems 17,18,19; 12 is block for assessing the meteorological situation; 13 is block for searching solutions of the neural terminal of action; 14 is block for informing external decision-makers; 15 is subroutine search block; 16 is block of formation and issuance of recommended actions; 17 is block that determines the presence of chemically hazardous elements; 18 is block defining explosive materials; 19 is block defining oil tankers; 20 is block containing information of the neural terminal of actions; 21 is block for storing the scenario of informing; 22 is block of subroutines of calculation methods; 23 is block of decoding of SMS messages; 24 is coding unit; 25 is receiving and transmitting unit; 26 is block of generation of intelligent systems; 27 is traffic safety block; 28 is testing unit [4].

Fig. 11. The structure of the stationary element of the DSS

4 Conclusions

Increasing the capacity of railways and reducing transportation costs is possible only with the use of GSM-R networks. The ERTMS control system makes it possible to control the train's movement in the driver's cabin. GSM-R provides a secure and reliable rail network. GSM-R - integrated and interchangeable with other communication systems. GSM-R - the basis of an intelligent communication system on the railway in the form of a neural network.

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