The Model of the Communication Channel with Mobile Objects using the Temporary Switch

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Keywords: Telecommunication network, radio network, information, subscriber, activity, telecommunication network structure, communication channels, fault endurance, technological process.

Abstract: The article is devoted to the consideration of the dynamic model of the train communication radio channel (PRS). A block diagram of the model, a temporary switchboard (VC) taking in account the nature of the movement of subscribers, expressions for reliability parameters are presented and described, comparative calculations with the traditional calculation method are presented, ways to increase the reliability of the PRS network are presented.

1 INTRODUCTION

During recent years, the argument that information technologies have the most direct impact on the state and the development of the economy has become almost universally recognized. The computer world became networked decades ago. The network infrastructure makes it possible to quickly exchange data and access information resources, both at the local level and on a global scale. The problem is the weakness of the telecommunications infrastructure. In many cases, the use of wired or fiber-optic communication lines is impossible or economically impractical. In this situation, one of the most effective solutions to the communication problem, and often the only possible one, is the use of radio data transmission networks.

2 MANUSCRIPT PREPARATION

The traditional variant of the wireless communication is the conventional communication systems, which are implemented by the radio stations that are not integrated into any technical system that provides resource management, signaling and other coordinating procedures.

Today, a lot of conventional radio systems are in operation around the world. The systems of this type have been, and continue to be, the most popular type of terrestrial mobile radio communication systems.

Due to the simplicity of implementation, conventional systems are widely used to solve the mobile communication problems, which are built on the principle of "point-to-point" and "star" (with a base radio station) without access to public telephone networks.

GSM-R technology, described by the European Telecommunications Standards Institute (ETSI TS) in ("Russian Railways", 2011), makes it possible to transfer train and manoeuvre radio communications to a new powerful unified digital system platform and is designed to replace a lot of different heterogeneous radio communication systems.

GSM-R equipment allows for continuous communication between the driver and the dispatcher at a rolling stock speed of up to 350 km/h and therefore allows you to remove one of the main barriers to the creation of high-speed trains. GSM-R integrates with GPRS to provide packet-based switching services. Thanks to this, it is possible to receive real-time telemetry information from any locomotive, any station or stretch of road. Information about the location and speed of the train is transmitted via the GSM-R network to the control centre, which will fully automate the process of regulating train traffic. The use of such a system in the passenger complex will greatly increase the safety of passenger transportation.

Separately, it is worth noting cellular radio communication solutions based on the DMR standard. The first release of the standard was released in 2005 (Digital Mobile Radio (DMR)

Knyshev, I. and Saprykin, D.
The Model of the Communication Channel with Mobile Objects using the Temporary Switch.
DOI: 10.5220/0011580100003527
In *Proceedings of the 1st International Scientific and Practical Conference on Transport: Logistics, Construction, Maintenance, Management (TLC2M 2022)*, pages 124-128
ISBN: 978-989-758-606-4

Systems, 2019) describing the radio interface (Part 1), as well as the voice and basic functional features of the standard (Part 2). The third part of the DMR standard was added, describing the packet data transmission protocol.

Now the network of JSC "Russian Railways" is transposed and uses equipment for various purposes: base radios, automatic telephone stations (ATS), multi-level multiplexers, spectral compaction equipment, packet switching equipment, servers of various architectures, both cable and fiber-optic communication lines. For the security purposes, equipment from various manufacturers has been introduced. The combination of embedded communication devices forms a huge communication structure.

One of the most important parameters of communication systems is the reliability of information exchange channels between subscribers. The reliability parameters become important in communication systems with mobile subscribers, when messages, commands and data used in the process of controlling the movement of objects are transmitted through the channel. In this regard, the question of determining reliability indicators when a subscriber moves in such a large and diverse network arises acutely.

Previously, reliability indicators were determined by the classical method. The most important characteristics of the communication channel are known: failure rate, operating time for failure, recovery rate, etc. When determining reliability, we relied on the prerequisites specified in (Almazyan, 2011). The radio network was a closed system, the elements of which are homogeneous in parameters.

The reliability scheme of the PRS network shown in Fig. 1 clearly shows the fundamental elements of the reliability of the train dispatcher–driver communication channel (DNC-PM). The network structure is radio conductive. The administrative station (AS) of the train dispatcher (DNC) is connected to the base stations (BS) of each station attendant (DSP) via a wired communication channel (CC). The radio stations carried on mobile units (PS) establish the connection of the driver (PM) with the BS via the radio channel (RC) throughout the entire dispatching section (circle).

The classical approach in (Almazyan, 2011; Roenkov, 2017) to determine the reliability of the communication channel is based on a static model, which includes all the elements forming the communication channel, and when the subscriber moves and changes the elements of the model or its parameters, this is reflected as a set of model variants.

According to (Rules of technical operation of railways of the Russian Federation, 2010), DSP-PM radio communication should be provided on the entire stretch adjacent to the station. This leads to a complete overlap of communication zones on all stages of the dispatch circle.

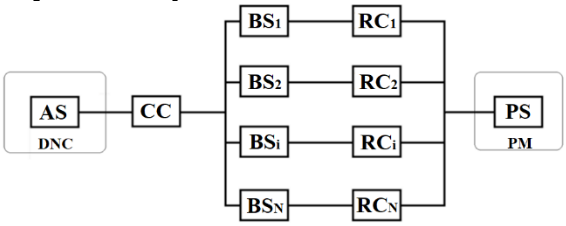

Figure 1: Probabilistic model of the PRS network for calculating the value of the traditional radio network availability coefficient.

In (Almazyan, 2011), it is proposed to define K_{rDNC} as one of the reliability parameters of the DNC-PM channel as follows:

$$K_{rDNC} = 1 - (1 - K_{rPS}) - (N-1)(1 - K_{rBS})^2 \quad (1)$$

In view of such large-scale systems, it is incorrect to determine reliability by the traditional method due to the movement of the subscriber, and it is necessary to introduce an amendment for the duration of the locomotive radio station's stay in the service area of a particular BS and the influence of only this BS on reliability indicators. In (Knyshev, 2021), it is proposed to use a dynamic definition of reliability that takes in account the subscriber's schedule. According to the study of signal levels in the work (Almazyan, 2011; Roenkov, 2017; Knyshev, 2021a), it is proposed to delimit the service areas and present them in the form of cells to simplify calculations, as shown in Fig. 2.

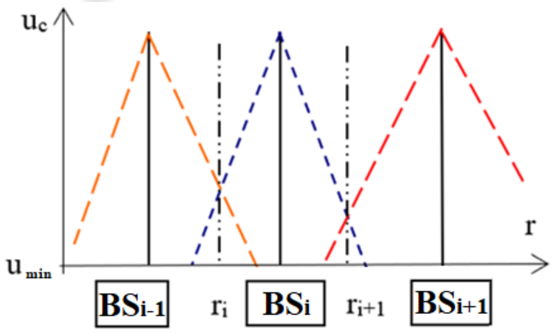

Figure 2: Base station service areas.

To reflect the subscriber's transition from one BS zone to the service zone of another BS in work (Knyshev, 2021b), it is proposed to include a virtual switchboard (VC) in the reliability model, which switches the BS serving the subscriber in accordance with the subscriber's traffic schedule. The block diagram of the PRS network using VC is shown in Fig. 3.

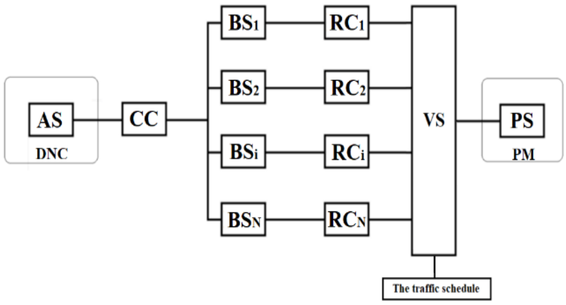

Figure 3: Dynamic model of the PRS network using VC to calculate the integral value of the radio network availability coefficient.

The principle of time switching is to move the subscriber from the coverage area of one BS to the coverage area of another with the implementation of the "handover" procedure. In other words, this is a temporary shift of the subscriber's position. At each moment of time, the territorial information of the identified subscriber is transmitted. If this information is transmitted to another BS, then this means moving the subscriber to the area of operation of another BS. An element of the reliability model that implements the principle of time switching is called a virtual switch VC. The virtual switchboard is characterized by such parameters as: the number of base stations, respectively, the number of radio channels connected to the VC inputs, the number of switched portable radio stations connected to the VC outputs, and the subscriber traffic schedule that determines the switching order. An example of a traffic schedule is given in (Knyshev, 2021).

Thanks to the handover, the subscriber is not tied to a specific BS, but is given the opportunity to move within the coverage area of the radio network without disconnecting the connection. When moving a subscriber in existing conventional networks, the VC does not have a technical implementation of such a procedure and is due solely to the movement of the PS.

In the case of cellular systems that implement the handover procedure, there is a corresponding piece of software and hardware that implements the switching of the subscriber station to another BS.

There may be several reasons for the need to implement a handover:

- moving the subscriber to the service areas of different BS,
- when the current BS cell is overloaded, subscribers are transferred in the overlap zone to the neighboring BS, freeing up the capacity of the current BS cell for subscribers with whom it is possible to maintain communication only within the boundaries of this BS,
- when the communication channel of the BS used is noisy,
- when the subscriber's movement speed changes (the subscriber's speed is directly proportional to the cell of the larger area).

Depending on the reason, it is customary to distinguish several types of handover:

- Within one BS.
- In case of failure or overload of one of the transceivers within one sector.
- Between sectors that screw up one BS.
- Between several BS.
- If one of the BS controllers or the BS itself fails inside one automatic telephone exchange (ATS).
- If the ATS malfunctions, the load is transferred to the nearest ATS with the ability to service the necessary zones.
- With BS of various cellular communication standards.

Depending on the reason, the type of handover and the network standard, various analyses are already being put forward to the reliability indicators of load switching (subscribers). The handover procedure can be accompanied by failures, failures and can be characterized by a certain probability of success or failure, which also provides for a temporary VC switch of the model presented in Fig. 3.

The value of the readiness coefficient of the communication channel on the entire trajectory from point A to point B can be determined by the weighted sum of KrBSi for all values of i:

$$K_r = \sum_{i=1}^{N} K_{ri}\gamma_i. \tag{2}$$

The weighting coefficients γ_i are defined as the fraction of the time Δt_i of staying in the service area BS_i of the total time T of moving from point A to point B:

$$\gamma_i = \frac{\Delta t_i}{T}, \tag{3}$$

where Δt_i – time spent in the BS_i service area;
T – full driving time from p. A in p. B.

According to the traffic schedule, the total travel time T is determined, and it is also possible to calculate the time spent in the BS_i service area.

As a rule, the subscriber is given a certain speed of movement on each stage, which he must observe. It is possible to determine the total time of movement of the rolling stock T. The dependence $v(r)$ is expressed analytically.

$$T = \int_0^{r_B} \frac{r}{v(t)} dr + \sum_{i=1}^{N} t_{sti}, \qquad (4)$$

where r – the whole way of the subscriber from p. A in p. B;
$v(r)$ – the dependence of the subscriber's movement speed on its trajectory;
t_{sti} – total time of stops in the BS_i zone.

In this case, the weighting coefficients γ_i will take the following form:

$$\gamma_i = \frac{1}{T}\left[\int_{r_{i-1}}^{r_i} \frac{r}{v(r)} dr + \sum_{i=1}^{N} t_{sti}\right], \qquad (5)$$

where r_i и r_{i-1} – define the BS_i service area.

As an explanation, it makes sense to consider an example of the simplest dependence $v(r)$ with significantly different speeds of several subscribers. On railway transport, it can be a passenger train and an express train. We will use a hypothetical section for the movement of trains with outdated equipment of communication systems and equipment that is planned to be installed on this section in the future. For clarity, we will determine the reliability indicators by both the traditional method and the one proposed taking in account the subscriber's movement.

Section A-G is equipped with RS-46MC base stations. It is planned to modernize the section of the RVS-1-46 radio station. Let's make calculations for two variants of the site:

- option 1 – only RS-46MC type BS are installed on the site, each of which has a failure time of $T_{0BS} = 7000$ hours;
- option 2 – partial modernization and more modern BS of the RVS-1-46 type have already been installed at some stations (B, C, D), having an operating time for failure $T_{0BS} = 45000$ hours.

As portable radio stations for both options, we will use radio stations of the RV-1M type with a failure time of $T_{0PS} = 8000$ hours. The readiness coefficients of radio stations are shown in table 1 when the recovery time t_{rec}= 5 hours.

Table 1: The availability coefficients of the specified radio stations.

t_{rec}, hours	5
$К_{rRC-46MC}$	0.999286
$К_{rRVS}$	0.999889
$К_{rRV-1M}$	0.999375

Table 2 shows the schedules of a passenger train with all stops and a fast train (express), respectively. For convenience, the train schedule is presented in the form of a table.

Table 2: The train schedule.

Distillation	Distance, km	Driving time, min	Parking, min
Passenger train			
A-B	7	11	3
B-C	8	11	2
C-D	11	14	2
D-E	13	17	3
E-F	9	11	1
F-G	10	12	1
Express			
A-C	15	15	3
C-E	24	22	1
E-G	19	17	1

Additionally, for example, let's take a freight train moving non-stop from the station A to the station G with an average technical speed of 40 km/h (travel time 1 hour 27 minutes)

The time spent in each service area is determined as the sum of the ratio of the distance traveled in this zone to the speed of movement along this section and parking time. The calculation is performed in a written program in the high-level programming language Python. The results of the calculations of Δt_i and γ_i are summarized in table 3 for each of the variants, respectively, additionally $К_{ri}$ is given for each BS.

According to the weighted formula, the results of the coefficients of readiness $К_{ri}$ on the section from st. A to st. G for passenger trains, express trains and freight trains are summarized in table 4.

Since the radio stations carried on each train are the same, the static reliability coefficient of the A – G section, calculated by the method (Almazyan, 2011), will be the same for any type of train.

For all basic radio stations of the RS-46MC type (the first option) static $К_{rBS} = 0{,}999372$, in the mixed case (the second option) $К_{rBS} = 0{,}999375$. The obtained values coincide with the results of determining reliability by static (classical) methods, which is to be expected in a network with identical parameters of all elements.

Table 3: The results of the calculations of Δt_i and γ_i for integral parameters

№ BS	St	Δt_i, ч	γ_i	$К_{rBSi}$ option 1	$К_{rBSi}$ option 2
Passenger train					
1	A	0,09167	0,0625	0,999286	0,999286
2	B	0,23333	0,15909	0,999286	0,999889
3	C	0,24167	0,16477	0,999286	0,999889
4	D	0,29167	0,19886	0,999286	0,999889
5	E	0,28333	0,19318	0,999286	0,999286
6	F	0,20833	0,14205	0,999286	0,999286
7	G	0,11667	0,07955	0,999286	0,999286
Express					
1	A	0,05444	0,05632	0,999286	0,999286
2	B	0,11667	0,12069	0,999286	0,999889
3	C	0,19625	0,20302	0,999286	0,999889
4	D	0,18333	0,18966	0,999286	0,999889
5	E	0,18308	0,18939	0,999286	0,999286
6	F	0,14167	0,14655	0,999286	0,999286
7	G	0,09123	0,09437	0,999286	0,999286

Table 4: The availability coefficients of the specified radio stations.

№ option	Passenger train	Express	Freight train
1	0,999286	0,999286	0,999286
2	0,999601	0,999596	0,999588

3 CONCLUSIONS

The integral values of the operating time for the failure of T_{0BS} and $К_{ri}$, and, especially, the influence of the subscriber's movement, will largely depend on the ratio of the failure rates of the model elements in Fig. 3. So, if the RV-1M radio station with T_{0BS} = 8000 hours is used as a locomotive, and the RVS-1 or RLSM-10 with T_{0BS} = 45000 hours is used as a BS, as well as with digital, highly reliable CP and CC equipment, then the reliability of the train dispatcher's communication channel will be almost completely will be determined by the parameters of the PS radio station. The situation seems more realistic when a subscriber of the Russian Federation has a highly reliable radio station, BS are implemented on different types of radio stations (partly on RS-46MC with T_{0BS} = 7000 hours, partly on RVS-1 or RLSM-10). In this case, the influence of the subscriber's movement will affect significantly.

An example of calculating the dynamic coefficient of readiness for a different site is presented in (Knyshev, 2021c). The qualitatively obtained results are identical: integral reliability parameters more accurately reflect the reliability of communication systems.

Theoretically, by changing the subscriber's schedule and increasing the speed of movement in areas with low reliability of equipment (BS), it is possible to increase the integral reliability parameters of the system.

REFERENCES

Technical requirements for the digital system of technological radio communication of the GSM-R standard of the Open Joint Stock Company "Russian Railways", 2011.

DMR - ETSI TS 102 361 v1.10.1. Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems, part 1, 2, 2019.

Almazyan, K., Verigo, A., Knyshev, I., 2011. Reliability of train radio communication channels. *Proceedings of JSC "NIIAS"* 9, pp. 175-184.

Roenkov, D., Shmatchenko, V., Yaronova, N., 2017. *Automation, communication, computer science* 7, pp. 22-27.

Rules of technical operation of railways of the Russian Federation, 2010. Order of the Ministry of Transport of the Russian Federation.

Knyshev, I., Roenkov, D., Saprykin, D., 2021. *Automation, communication, Informatics* 10, pp. 35-38.

Knyshev, I., Saprykin, D., 2021a. *The reliability of channels in communication networks with mobile subscribers*, p. 227.

Knyshev, I., Saprykin, D., 2021b. The reliability model of a communication channel with mobile objects, *International Scientific and Practical Conference «Railway transport and technologies, RTT 2021)».*

Knyshev, I., Saprykin, D., 2021c. *The reliability of channels in communication networks.*