Archives of
Transport System
Telematics

Volume 7

Issue 3

September 2014

Radio network planning of GSM-R in polish railways standards

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ABSTRACT
The article presents some problems for the radio network planning rail system digital mobile GSM-R. There is a description of the architecture of the system, a set of available services and the different ways of data transmission. Then there are presented certain conditions that should be taken into account for the link and the requirements for network dimensioning for the purpose of determining the physical capacity of the network. Volume generated within the base station telecom traffic affects not only the number needed to handle the movement of resources, but also implies a number needed to allocate frequency channels.

KEYWORDS: system, GSM-R, planning, dimensioning

1. Introduction

GSM-R (*Global System for Mobile Communications-Railways*) is an international wireless communications designed for railway communication. It provides digital voice communication and digital data transmission and offers extensive functionality of the GSM system. Infrastructure of GSM-R is characterized by localization only near the railway lines.GSM-R is designed to support systems introduced in Europe: ERTMS (*European Rail Traffic Management System*) and ETCS (*European Train Control System*), which is designed to continuously collect and transmit data on a rail vehicle, such as speed or geographical location. The GSMR a transmission medium for ETCS, mediates the transmission of information to the driver and other rail services [1].

By implementing the above schemes significantly the safety of rail traffic is improved and also it is possible to diagnose vehicle in real time and to introduce monitoring shipments and wagons. Moreover, by clarifying the distance between trains can greatly increase the bandwidth on individual lines [8], [14].

One of the key issues in the implementation of GSM-R radio network planning taking into account both the requirements for coverage of the radio signal for ETCS second level on defined railway lines, but also in terms of dimensioning of the capacity for voice and other services in the GSM-R system.

The article presents selected issues related to the analysis of the GSM-R network and issues dimensioning of the network in terms of providing opportunities for data and voice. There are certain conditions that should be taken into account for the link. Volume generated within the base station telecom traffic, affects not only the number needed to handle the movement of resources, but also implies a number needed to allocate frequency channels..

2. The structure of the network and services of GSM-R

2.1 The structure of GSM-R

The basic infrastructure of GSM-R is very close to the infrastructure of the GSM system. However, for functional reasons is enriched with a few items that do not appear in public systems. This involves a typical rail services such as targeting or functional classification of individual subscribers by groups validity, applied here a special database called the registry addressing key. GSM-R infrastructure is also enriched with components cooperating with the system and automatic train control unit designed for using dispatchers. In this system required the implementation of group

calls, dispatching, and high-priority calls which time the statement should not exceed one second. In addition to the GSM-R mobile terminals, known from GSM systems, also used the so-called transportable terminals installed in locomotives rail vehicles.

Arrangement of base stations in the GSM-R system can take place in four different ways depending on the required security. The choice of placement and connection of base stations should be dictated by class and purpose of the railway line, its capacity and the required level of safety. The GSM-R systems, we can distinguish three basic types of cells used. The first are cells, which by definition only covers the area of the railway line. They are characterized by a long shape and a small width. The second type of cells are overlapping station's areas and some railway lines. They typically have a circular or elliptical shape. The third type of cells are large, covering other areas such as railway sidings, railway buildings, complexes, etc.

Each of the cell types supports all types of radios. The size and shape of cells may be varied by adjusting the power level and the use of omni-directional antennas and large or very small half-power angles. The GSM-R is the use of the service, so it does not provide radio coverage areas other than railway areas.

In order to ensure the efficient location of mobile subscribers in the GSM-R network adopted a complex hierarchical structure (Fig. 1).

The structure of the GSM-R is distinguished by the following layers [11]:

- Network GSM-R (GSM for Railways Network or GSM for Railways Service Area) - the area covered by the range of services of GSM-R. Geographically, it corresponds to all countries (operators), in which the system operates GSM-R. The connections between the GSM-R network and the public telephone network shall be held by one of the transit GSMC;
- The GSM-R (PLMN service area) - Action GSM-R network managed by a single operator. If a country has several operators, there are several parallel systems, GSM-R, which communicate with each other via the public telephone network;
- MSC service area - part of the GSM-R system, supported by one of the MSC. Incoming calls to the mobile station are routed to the MSC working in this service area, in which is currently a mobile station;

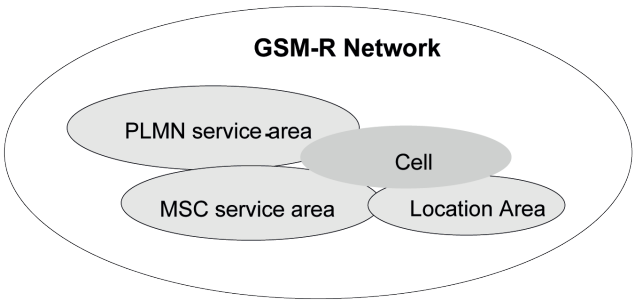

Fig. 1. The hierarchical structure of the GSM-R network [11]

- Location Area (LA) - part of the area, in which a moving mobile station does not need to pass to the system updated data about your position. Specify the size of location area is related to the efficient use of radio channels.
- Cell - the smallest fragment of GSM-R. A collection of cells creates an area of recalls. Each cell corresponds to one base station.

2.2 Services of GSM-R

The GSM-R performs all the basic services of the GSM standard and additional services, complemented by standard GSM Phase 2+ (Voice service diffusion, group calls, GPRS, priority calls). This allowed the introduction of the following services [7], [8], [9], [12]:

- Voice Broadcast Service (VBS) - consists of transmitting voice information to a specified, pre-defined group of customers, without the possibility of return voice confirmation of the information received
- Voice Group Call Service (VGCS) - allows simultaneous and mutual communicate with each other in advance of a defined group of users (SIM), where each participant can activate or deactivate your participation in this type of connection. Supervision of the formation of the group, the choice of active participants and oversee the conduct of all service names are the initiator of the meeting or the dispatcher.
- Enhanced Multi-Level Precedence and Preemption (eMLPP) - the service is to give priority to certain users of the network in the realization of connections and is used in emergency situations. Time of connection setup, the priority should be short (less than 2s, including the termination of an existing connection).
- Functional Addressing (FA) - is the connecting railway employees addresses associated with the functions they perform. This allows for communication with the user by means of a number identifying the appropriate function, not a physical terminal. With this feature you can, for example, to connect with the driver of the train, not only by its individual address, but also mentioning the train or locomotive.
- Location Dependent Addressing (LDA) - provides communication to an employee performing a specific function depending on the location of the train and the area associated with the paging function. The use of this type of addressing, for example, allows to connect to the train driver with the emergency motion at the touch of a button.
- General Packet Radio Service (GPRS)is used mainly in the transmission path-to-vehicle (ETCS);
- Enhanced Railway Emergency Call (EREC) - Emergency calls inform drivers of traffic on duty and other required staff about the dangers of requiring eventual halt traffic on a given area or take other actions. Defined are two types of railway emergency calls: Emergency calls for trains (not related to maneuvering operations) and emergency calls related to the operation maneuverability. Type-initiated connection is established automatically based on the operating mode of the terminal initialization. Emergency call for trains must be communicated to all drivers and traffic remaining on duty in a defined area of operations.
- Shunting mode - provides communication between staff involved in shunting operations.

- Direct mode - refers to a situation in which the mobile terminals communicate with each other without going through a GSM-R network. This is a function provided for situations such as network failure or lack of coverage of GSM-R.
- Data transmission in GSM-R supports four main groups of services: text messages, the main applications of data transmission, automatic fax machines and applications in support of control train. Data service is associated with a remote control and on-board traction, automatic control the movement of trains, security control rail traffic and applications designed for passengers. The GSM-R network methods are used packet GPRS and EDGE solutions known to the public.

3. Selected aspects of planning and network dimensioning of GSM-R

3.1 The elaboration of the energy balance of the link

The projected budget for specific conditions links and calculations regarding the useful range of individual base stations should take into account the following parameters [2], [3], [4], [5], [9]:

- The required minimum signal level and the probability of signal coverage,
- The height of the suspension of the base station antenna and the antenna mobile station
- Margin call transfer (handover) and power margin for dropouts,
- Margin of safety,
- Losses in the radio channel,
- Gain antennas and a gain resulting from the use of spatial diversity reception and polarization (diversity),
- The expected ranges of base stations,
- Planning of radio channels.

Margin is the transfer of the material to the radio planning parameter, since its value affects both the energy balance as well as the link speed handoffs. Its too large value may cause unnecessary density of base stations as well as the delay in the transfer of calls. Too small margin of call transfer, or its lack, will cause unnecessary switching. In practice radio planning that power margin for signal dropouts in the flat, open the suburban area is approximately 5dB. However, in the case of the planned system GSM-R due to a variety of characteristics of the land should be greater, eg 7-10 dB.

It should be taken into account that the resulting interest rate correctly completed the transfer of the type of services must be at least 99.5% at standard operating conditions (weather, network load, etc..).

The margin of safety in accordance with the recommendations of Eirene is 3dB and included in this parameter factor aging infrastructure of GSM-R.

Similarly to the public network in the radio channel losses should include the power loss between the output of the input terminals of the transmitter and base station transmit antenna. Those losses consist of insertion of flexible cables, connectors and coaxial cable attenuation. Antenna gain of the mobile device that should be taken to link the budget to 0 dBi, while for base station antennas should be taken to link the budget of the standard most often as a dozen dBi antenna gain. The target value of the link budget of profit resulting from the use of spatial diversity reception and polarization (diversity) in public networks is typically 3dB. However, due to the fact that the profit resulting from the use of spatial diversity reception and polarization is smaller in an open environment (and a large part of the GSM-R system in such an environment is built) to the budget of the link should take smaller values.

The GSM-R from a technological point of view, is a system designed for the needs of rail traffic, and therefore having specific requirements for access to transmission resources. Used here, two-sector base stations to provide network coverage along the railway lines. Useful range of the base station on the location ranges from approximately 2.5 km (urban area) for approximately 9.5 km (open area). The system operates redundantly, the so-called. double coverage – the use of the reserve MSC and "overlapping cells" can provide the power of supporting, at least at the level of -95dBm with a probability of 95% even in a situation where half of the base stations of the basic infrastructure is excluded (Fig. 3). Plan allocation of frequency channels for GSM-R requires the creation for each base station identification relations with neighboring base stations, which are necessary to ensure the transfer of calls between sectors. Relationships should be established with regard to the specificity of the GSM-R, and in particular linear and not the territorial nature of radio coverage on the railway lines and the need for handover in case of simultaneous failure of the station from the pool even or odd.

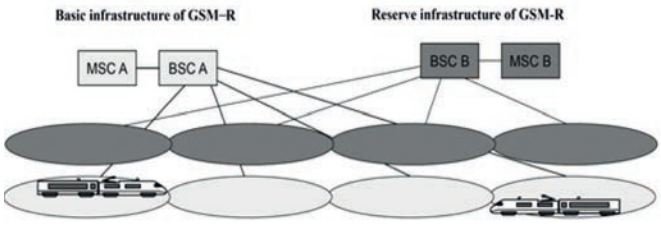

Fig. 2. The use of double coverage and backup infrastructure in the GSM-R network [6]

3.2 Network capacity dimensioning

Network GSM-R must provide support for different types of services that generate different types of network traffic. Therefore, all of the profiles of movement should be considered at the stage of network dimensioning. Size offered traffic can be defined as the product of the number of requests per unit of time (usually referred to the busy hours GNR) and the average duration of a call. Calculation of traffic generated should take into account both the traffic generated by voice and data transmission circuit switching [2], [3], [7].

At this stage it is also necessary to designate the busy hours (GNR). As a result, you can determine the amount of the offered

traffic in the area. The calculations must take into account the presence of trail maintenance personnel and teams maneuvering, which also generate traffic.

In order to properly dimensioning the network for the purpose of determining the volume of telecommunications traffic take into account the classification of the main sources of traffic resulting from distinguished by Eirene uses GSM-R network in relation to a typical modern rail network [13], [14]. Sources of telecommunications traffic in the GSM-R network are:

- Control and Monitoring: Automatic and train control, remote control elements of the railway network.
- Connectivity Technology: dispatcher – the driver, emergency calls, connectivity maneuvering, communication driver, connectivity to maintain the trail, train staff communication
- Local connectivity on the pathways and nodes.
- Communication Area non-operational.
- Connectivity passenger in the passenger information.

Network GSM-R must provide support for different types of services that generate different types of network traffic. Therefore, all of the profiles of movement should be considered at the stage of network dimensioning. Size offered traffic can be defined as the product of the number of applications per unit of time (usually referred to the busy hours GNR) and the average duration of a call. Calculation of traffic generated should take into account both the traffic generated by voice and data transmission circuit switching.

Data transmission in the GSM-R system can be divided according to the procedures used in the transmission. In general, the traffic generated by the data can be determined based on the amount of sent messages per unit of time and the size of a single message. Additionally, it should be taken into account the intensity of transmission – whether it is a continuous transmission, or are broken. You can distinguish the following mechanisms to ensure data transmission in GSM-R:

- SMS text – sizing, use the amount of messages, regardless of the medium-sized messages (up to 140 bytes)
- Packet transmission - you can take an average message size of 64 bytes,
- Additional services data-used for the registration and de-registration of the mobile station for the purpose of addressing the function - the unit is here the number of messages
- Transmission data using a circuit-switched-can be dimensioned in the same way as a voice call,
- ETCS data transmission.

The primary means of data transmission in GSM-R is ETCS.

The implementation of ETCS Level 2/3 requires the transmission medium providing communication between train and track-side equipment . Network GSM -R, as part of the ERTMS / ETCS system allows for two-way exchange of information between devices on rail vehicles , RBC Radio Control Center and Radio Team updating the RIU . It requires relatively low bandwidth (up to 9600 bps). RBC Radio Control Center to train sends small messages (up to 200 bytes) periodically every 30 s train reports to RBC with 32 bytes (user data) messages transmitted every 10 seconds worth noting that the most important from the point of view of ETCS is to provide minimum transmission delay in both directions as well as its reliability. Currently transmission is achieved by circuit switching , which means that each transmission channel ETCS is one timeslot. Each of ETCS train occupies the slot for the duration of the train route, which can cause problems with the capacity of the network junction stations. Depending on the type of traffic generated, the geographical location of users and their function within the organization can be divided into different groups of users GSM-R network. But first, you must specify which types of traffic can be expected in the GSM-R. Can be distinguished [8]:

- voice and point-to-point data transmission circuit switching, expressed in units of telecommunications traffic [Erl]
- voice group calls [Erl], point-to-multipoint [Erl]
- short text messages SMS [number of messages/h],
- circuit switching [number of messages/hour]
- communications package [number of messages/h],
- communication point – the point of using location-based addressing [Erl], expressed in Erlangs,
- switched data transmission links using location-based addressing [Erl].

Offered traffic refers to specific areas and includes traffic generated on the train as a sum of the traffic generated by staff and data transmission systems as well as the movement of the other users of the system, both stationary and mobile, defined as the number of active terminals. From the point of view of the functionality of GSM-R system can be divided into four groups of users and their profiles mobility.

Telecommunications traffic is related to train staff. Train traffic is generated by the driver with the emergency call traffic to other drivers and staff present in the train. In addition, the driver is a member of the group call VGCS and dissemination stations VBS. Assuming the standard traffic model you can expect the traffic generated by the driver of 0.02 – 0.1 Erl. Each train using ETCS allocates 1 timeslot on the transmission of data on the duration of the train route, which means that 1 Erl should be reserved for each train. Communication is carried out mainly at the stations and to a small extent on the trail.

Teams maneuvering. Group based on the maneuvering area or control room, involved in the organization of the train composition.. Voice calls carried out by members of the group are characterized by long duration and include group calls VGCS between group members and VGCS communication with the emergency motion. It can be assumed that the traffic generated by the staff will contain in the range 0.1 - 0.5 Erl.

Staff maintain the trail. The traffic generated by employees involved in the maintenance of the rail trail. Average traffic generated is about 0.05 Erl per user. This includes maintenance workers as well as carrying out construction work, security services, drivers of construction equipment.

Personnel working at the station. The traffic generated at the stations is initiated by workers engaged in activities related to ensuring the proper operation of the railway station. These include, among others, the control room staff, dealing with logistics, baggage protection. This movement is mostly local within the station (95%) and includes point-to-point connections (90%).

Traffic model determines the amount of voice and data traffic associated with applications railway operator as well as the geographical distribution of traffic in the network. Since the

generated traffic is an individual characteristic of users is difficult to define a universal model. It should, therefore, result from the analysis of network traffic during peak GNR / BHCA (Busy Hour Call Attempts). Due to the characteristics of the movement and its intensity should be in determining network capacity variants organizations GSM-R network. Thus:

- Railway network nodes in terms of their size,
- Train stations. In the analysis of telecommunications traffic generated at the railway stations in the GSM-R network should be taken into account: the number of rail lines coming into the station, the number of platforms used at the same time, the number of lines through, the number of workers on the platforms, the number of employees performing work outside platforms (maneuvers within the station)
- Number of shunting locomotives, the number of employees in teams maneuvering and other users in the areas of maneuvering.
- Railway lines of distinction on railway lines with high traffic and railway lines with little traffic. In the analysis of telecommunications traffic generated in the GSM-R network on railway lines should take into account the number of lines, the frequency of trains, the maximum speed of trains and the distribution of trains (close to each other in the vicinity of the station, more distantly between stations).
- For telecommunications traffic in the railway network nodes consists traffic generated by the trains which are contained within the station and the local traffic generated by employees. For terminal stations or the initial number of stores during peak hours will be equivalent to the amount used platforms simultaneously. It can be assumed that for most stations the number of trains at the station will be linked with an average occupancy of platforms. The resulting number of configurations must be multiplied by the average value of telecommunications traffic generated by a single composition. This will serve to identify traffic generated by the trains at the station. The next step is to determine the traffic generated locally at the station by the station staff and a group of maneuvering.

For the purpose of determining the volume of telecommunications traffic on the railway lines, you can use the relationship, taking into account the number of trains per hour and a maximum speed of composition. This gives the number of trains per kilometer, which from the point of view of GSM-R network is important to determine.

4. Conclusion

The GSM-R is a component of the ERTMS system, which provides for the safe running of the train. Therefore, the GSM-R system must be securely operating system for the transmission of information (voice and data), which should be higher than in the public system, GSM, and reliability of operation which is ensured by additional measures (redundancy of equipment, adequate coverage of the electromagnetic field).

The paper presents selected issues related to the analysis of the GSM-R network and the problems of planning and dimensioning of the network in terms of providing opportunities for data and voice in the conditions of Polish railways. Requirements capacitive allowing the estimation of the number needed transceivers at each base station direct result of the number of devices, which also will benefit from the station.

Current frequency allocation uses only 7 of the 19 channels provided for the GSM-R system. Such channels may be insufficient for networks designed according to the requirements described, particularly in the major railway junctions. Using these seven channels can not fulfill the basic requirements for the separation of allocated channels. As a result, you can claim for adverse events associated with interference.

Bibliography

[1] BIAŁOŃ A.: Masterplan of implementation of ERTMS in the national and Community perspective. Transport and Communications in 2010, No. 2 (2010)
[2] GSM-R Radio Planning Guidelines, JERNBANEVERKET UTBYGGING Document number 3A-GSM-036, (2006)
[3] GSM-R Radio Planning Guidelines, JERNBANEVERKET UTBYGGING Document number 3A-GSM-038 (www. trv.jbv.no/tidligere-utgaver - T6009b00.pdf), (accessed: 28.07.2014)
[4] HAMMUDA H.: Cellular Mobile Radio Systems: Designing Systems for Capacity Optimization. John Wiley & Sons Ltd (1997)
[5] JAJSZCZYK A.: Introduction to telecommunication. Publ. WNT Warsaw (2009)
[6] Network Rail. Guidance on GSM-R Cell Planning Consultation. Association of Train Operating Companies (2007)
[7] MANDOC D., KONRAD K., WINTER P.: ERTMS Training Programme 2009 – Handbook, UIC, Paryż, (2009)
[8] NOLDUS, R.: CAMEL – Intelligent Networks for the GSM, GPRS and UMTS Network, Wiley, Chichester, (2006)
[9] PKP Polish Railway Lines SA "Pre-planning of the radio GSM-R for railway lines covered by the National Implementation Plan of ERTMS in Poland", Warsaw (2012)
[10] SIERGIEJCZYK M.: Selected issues of traffic control systems and communication for High Speed Rail in Poland. Logistics 3/2012. Poznań (2012)
[11] WESOŁOWSKI K.: Mobile radio systems. Publishing House of Transport and Communications, (2006)
[12] WINTER P.: International Union of Railways, compendium on ERTMS, Eurail Press, Hamburg, (2009)
[13] The choice of requirements for GSM-R for PKP (Polish State Railways) with EIRENE FRS FRS 7.0 and 6.0. Materials PKP Polish Railway Lines SA Warsaw, July (2009)
[14] www.era.europa.eu/Document-Register/Documents/EIRENE-SRS-v15.pdf (accessed: 12.03.2012)