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Safety and security, availability and certification of the GSM-R network for ETCS purposes

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ABSTRACT

This paper presents selected aspects that affect information security in the GSM-R digital mobile phone network. With respect to telecommunications safety, selected methods and mechanisms have been analysed that make it possible to ensure the required level of radio coverage, reliability, availability and continuity of services in the GSM-R network. The paper also discusses selected modules for EC procedures for assessment and verification used in the technical specifications for interoperability.

KEYWORDS: GSM-R system, rail transport, transmission, safety, security, certification

1. Introduction

Digital GSM-R networks are already being used by many railway administrations both in and outside Europe. Now the process of constructing the GSM-R network is starting in Poland. Analogue radio communications using the 150 MHz band, used by Polish railways up to the present time, have become technically and morally obsolete and thus neither meet modern technical requirements, norms and standards nor offer the required functionality [13].

The primary intention of the International Union of Railways (UIC – Union Internationale des Chemins de fer) is to unify European railway communication systems through the introduction of the EIRENE (European Integrated Railway Radio Enhanced Network) project [5], [6]. The implementation of the GSM-R standard brings tangible financial benefits for the rail segment. It considerably improves the capacity of railway lines and minimises the time required to cross state borders, thus improving the quality of services provided (e.g. by introducing shipment tracking). GSM-R is a digital mobile phone system used for rail transport purposes. It offers the extensive functionality of a GSM system and its infrastructure is located exclusively in the vicinity of railway lines. GSM-R is designed to support the rail traffic management system being implemented in Europe, i.e. the ERTMS (European Rail Traffic Management System), which in fact includes two systems:

- ETCS (European Train Control System), which is designed to continuously collect and transmit data on railway vehicles such as their speed or geographical location;
- GSM-R, which serves as a transmission system for ETCS and performs an intermediary role in the transfer of information to the driver and to other rail services [1].

The implementation of the aforementioned systems significantly improves rail traffic safety, enables real-time vehicle diagnostics and makes it possible to implement the tracking of shipments and wagons. Moreover, the precise determination of distances between trains may considerably increase the capacity of individual lines [9], [10].

GSM-R enables digital voice communication and digital data transmission. The pattern of base transceiver station location in GSM-R systems may vary depending on the required safety level of the telecommunications services provided (voice and data transmission). The locations selected for base transceiver stations and the connections between them should be dictated by the class and purpose of the railway line, its capacity and the required safety level. Cell size and shape can be varied by adjusting the power level and by using omnidirectional, wide-angle or linear antennas.

The GSM-R system will be used for rail network management purposes, so only railway infrastructure will be covered by the network [11], [15].

The GSM-R system has been constructed on the basis of the public GSM system, which ensures its continuous development with respect to technical solutions that result from the technological advances implemented in public GSM networks. At the same time, it should be noted that the GSM-R system serves as a tool for more efficient rail traffic management, command, control and signalling, and thus has much greater "responsibility" than public GSM systems. Therefore this system requires additional solutions to increase its safety. Hence, the important issues of ensuring continuous system operation, proper coverage of railway infrastructure and information security should be discussed.

2. Information transmission security in the GSM-R network

Key issues that affect system security include the security of the RF interface and that of the elements directly related to it (e.g. transceivers).

All information transmitted by radio is susceptible to eavesdropping and interception. Therefore connections should be encrypted so that their contents are not open and cannot be read by unauthorised parties. Encryption does not apply to RECs (Railway Emergency Calls) owing to the required rapid call setup time. Encryption requires the use of an appropriate digital cryptographic algorithm both on the network and on the mobile station side. Before information is encrypted, however, the network needs to identify the user by performing the authorisation (authentication) procedure. This is based on the electronic signature concept. Authentication involves the use of the AuC (Authentication Centre) register and the SIM (Subscriber Identity Module) card, which store the Ki authentication key [14].

Terminal verification is an important factor contributing to security. All wireless terminals on the network should be monitored for the legality of their use, and their IMEI (International Mobile Equipment Identity) numbers should be included on one of three lists – white, grey or black. All the aforementioned mechanisms, i.e. authentication, encryption, protection against the use of unauthorised terminals and access to SIM contents, contribute to security and are standard mechanisms implemented in all GSM networks. The security of information transmitted in the GSM-R system is also ensured by the use of a frequency band different than that used by the GSM system. The GSM-R system operates in the 876–880 MHz band (uplink – data sent to the network) and in the 921–925 MHz band (downlink – data sent to terminals); these bands are effectively separated from the public band.

Information transmission reliability in the GSM-R system is enhanced by ensuring appropriate network coverage along the railway line, which is dependent on train speed; for train speeds lower than 220 km/h, the coverage level should not be less than -95 dBm and for speeds greater than 280 km/h, the coverage level should not be less than -92 dBm. The probability of these coverage levels being achieved should not be lower than 95% for every 100 metres of the railway line, and handover between two cells along the railway line should have a success rate of at least 99.5% under normal conditions. Calls with the highest priority (alarm calls) should be set up in less than 2 seconds (for 95% of calls).

3. GSM-R network telecommunications safety

The purpose of any telecommunications network is to transmit information within a specified time and with the specified error rate. The GSM-R network is a telecommunications system that must exhibit high reliability and ensure a high level of security for the data transmitted in the railway environment. Reliable access to telecommunications services is very important for rail infrastructure managers, since it has a direct impact on the safety and flow of railway traffic.

Interoperability with ETCS Level 2 within the framework of the ERTMS imposes certain availability requirements on the GSM-R system; the maximum allowable system downtime is:

- for ETCS Level 2 and Level 3 – 4 hours per 10 years (i.e. an availability of 99.995%);
- for other voice and data services – 8 hours per year (i.e. an availability of 99.91%).

Telecommunications safety is understood as a set of methods and mechanisms, the use of which ensures the required network coverage level, service availability and continuity through the selection of an appropriate system structure and network topology. Owing to the purpose of the GSM-R system and its impact on rail traffic safety, designers must make the system resistant to damage and disruptions.

Those components whose failure may affect proper system operation to the greatest extent should be duplicated. These include individual cards and telecommunications links. In practice, it is recommended that all fixed telecommunications links, TRXs (transceivers) at BTSs (Base Transceiver Stations) as well as BSC (Base Station Controller) and TRAU (Transcoder and Rate Adaptation Unit) cards be redundant. The activation (and reconfiguration where required) of redundant equipment should be possible during system operation; where possible, activation procedures should also be initiated remotely from the OMC (Operation and Maintenance Centre).

During the network design process, certain scenarios are assumed where individual system components fail or are destroyed, e.g. as a result of a fire or natural disaster. Predicting such events makes it possible to determine the elements that are critical for the operation of the entire system and to select the appropriate method for protecting them. A natural method that increases network reliability, safety and availability is redundancy. It refers both to the information stored in the registers and hardware components of the network. The following may be redundant:

- the entire system;
- individual subsystems such as the BSS (Base Station Subsystem), NSS (Network and Switching Subsystem) or OMC (Operation and Maintenance Centre);

- individual system components such as the MSC (Mobile Switching Centre) or HLR (Home Location Register);
- individual parts included in system components such as MSC smart cards and interfaces.

Depending on network configuration and complexity, it is possible to restore full network functionality within four hours. It should also be remembered that in the absence of a redundant NSS (no "disaster recovery" application), the replacement of a damaged NSS can take several months.

Some functionalities of key importance for efficient traffic control require certain elements (e.g. IN – Intelligent Network – nodes) to be operational, and should be available even in the case of major failures. The duplication of NSS elements should be considered, taking key services and functionalities into account. In order to ensure the performance of functions such as LDA (Location Dependent Addressing) or REC (Railway Emergency Call), which are obligatory from the point of view of interoperability of European railways, the elements responsible for these functions should be duplicated [7]. Critical GSM-R system devices can be identified and their redundancy can be ensured on the basis of priority service levels that must be maintained following their restoration.

These include individual cards and telecommunications links. In practice, it is recommended that all fixed telecommunications links, TRXs at BTSs as well as BSC and TRAU cards be redundant. The use of two MSCs and a single BSC is not a solution recommended for railway communication because:

- in the event of MSC failure restoring network functionality requires the controller to be switched manually to the backup centre;
- in the event of BSC failure, the entire GSM-R system fails.

In the case of a GSM-R system, BSS redundancy should involve the provision of double coverage by BTSs (either collocated or staggered) along railway lines that are ETCS equipped and multiple BSCs should be connected to either one or the other MSC. The number of BSCs included in the design should be such that each railway line equipped with ETCS is connected to at least two BSCs that are in turn connected to two different MSCs. On railway lines without ETCS, single radio coverage is acceptable and BTSs may be alternately connected to two different BSCs, which should be, where possible, connected to two different MSCs [16], [18].

4. GSM-R system availability

The analysis of reliability models for technical systems demonstrates that for the GSM-R system, two ways of enhancing availability can be suggested:

- by increasing the reliability of each individual subsystem (device);
- by reducing the mean time to repair (MTTR), which can be difficult, especially when devices in geographically distant locations have to be maintained.

It is obvious that the higher the redundancy, the more reliable the system, which means reducing system downtime per year. However, as redundancy increases, so do system maintenance costs; moreover, the impact of delays resulting from BSC and MSC switching has to be taken into account.

In theoretical calculations, assuming the quoted reliability of individual GSM-R subsystems (NSS, BSS, transmission systems – fibre optic links plus SDH equipment), the following downtime numbers were obtained for different GSM-R hardware configurations:

- single devices (NSS, BSS): reliability – 99.962386%; system downtime – 198 min/year;
- duplicated devices (NSS, BSS): reliability – 99.999945%; system downtime – 0.29 min/year.

As it has already been mentioned, for the purposes of ETCS Level 2 and Level 3, GSM-R system reliability should not be less than 99,995%. This condition is met for redundant NSS and BSS equipment. Single GSM-R equipment items should only be used for voice services and other data services that are not related to rail traffic command, control and signalling; in this case, reliability amounts to 99.91%.

It is recommended that reliability mechanisms be deployed where the GSM-R system is to interoperate with ETCS Level 2 or 3. GSM-R system architecture as well as SDH transmission systems allow designers to adjust the solutions employed to ETCS requirements.

5. Certification

The primary basis for carrying out the certification process is Directive of the European Parliament and of the Council 2008/57/EC of 17 June 2008 on the interoperability of the rail system within the Community as amended. The Directive was adopted to "establish the conditions to be met to achieve interoperability within the Community rail system in a manner compatible with the provisions of Directive 2004/49/EC. These conditions concern the design, construction, placing in service, upgrading, renewal, operation and maintenance of the parts of this system as well as the professional qualifications and health and safety conditions of the staff who contribute to its operation and maintenance" [4].

The Directive defines the term "interoperability", which "means the ability of a rail system to allow the safe and uninterrupted movement of trains which accomplish the required levels of performance for these lines. This ability depends on all the regulatory, technical and operational conditions which must be met in order to satisfy the essential requirements". "Technical specification for interoperability" (TSI) has also been defined; this means "a specification adopted in accordance with this Directive by which each subsystem or part subsystem is covered in order to meet the essential requirements and ensure the interoperability of the rail system".

For the purposes of the Directive, the rail system has been broken down into the following subsystems:

1. 1. structural, i.e. infrastructure; energy; control-command and signalling; rolling stock;
2. 2. functional, i.e. traffic operation and management; maintenance; telematics applications for passenger and freight services.

The control-command and signalling subsystem includes all equipment necessary to ensure safety and to control rail traffic on the network, including the GSM-R system, which is an ERTMS component.

"Notified bodies" are the bodies which are responsible for assessing the conformity or suitability for use of the interoperability constituents or for appraising the EC procedure for verification of the subsystems;

The task of the notified body responsible for the EC verification of a subsystem begins at the design stage and covers the entire manufacturing period through to the acceptance stage before the subsystem is placed in service. It also covers verification of the interfaces of the subsystem in question with the system into which it is incorporated, based on the information available in the relevant TSI.

TSIs set all the conditions with which interoperability constituents and subsystems must conform, and the procedures to be followed in assessing conformity and suitability for use of interoperability constituents and EC verification of subsystems [4].

The modules to be used for conformity assessment of interoperability constituents and EC verification of subsystems based on the technical specification for interoperability (TSI) have been established and included in a single legal act, i.e. Commission Decision of 9 November 2010 on modules for the procedures for assessment of conformity, suitability for use and EC verification to be used in the technical specifications for interoperability adopted under Directive 2008/57/EC of the European Parliament and of the Council.

In Annex I of this decision, all Modules for the EC procedures for assessment of conformity, suitability for use and verification to be used in the technical specifications for interoperability are described, i.e.

- Module CA. Internal production control
- Module CA1. Internal production control plus product verification by individual examination
- Module CA2. Internal production control plus product verification at random intervals
- Module CB. EC-type examination
- Module CC. Conformity to type based on internal production control
- Module CD. Conformity to type based on quality management system of the production process
- Module CF. Conformity to type based on product verification
- Module CH. Conformity based on full quality management system
- Module CH1. Conformity based on full quality management system plus design examination
- Modules for Suitability for use of interoperability constituents
- Module CV. Type validation by in-service experience (suitability for use)
- Modules for EC verification of subsystems
- Module SB. EC-type examination
- Module SD. EC verification based on quality management system of the production process
- Module SF. EC verification based on product verification
- Module SG. EC verification based on unit verification
- Module SH1. EC verification based on full quality management system plus design examination

Pursuant to the Decision, EC verification procedures for the subsystems covered by the TSIs are chosen among the modules in accordance with the following criteria:

3. a. suitability of the module concerned to the type of subsystem;
4. b. the nature of the risks entailed by the subsystem and the extent to which EC verification corresponds to the type and degree of risk;
5. c. the need for the manufacturer to have a choice between quality management system and product certification modules;
6. d. the need to avoid imposing modules which would be too burdensome in relation to the risks [3].

The first railway line in Poland fitted with fixed GSM-R equipment is the Legnica–Bielawa Dolna section (ca. 84 km in length) of the E30 line. Within the framework of this project, two GSM-R subsystems within the command-control and signalling subsystem have been deployed:

- BSS – including 25 BTSs (base transceiver stations) deployed in 16 locations along the Legnica–Bielawa Dolna section of the E30 line and a single BSC installed in Wrocław;
- NSS – primary location in Warsaw, backup location in Poznań.

The certification of the entire infrastructure that was installed and commissioned was carried out in accordance with module SH1 – EC verification based on full quality management system plus design examination. Three certificates were issued:

- Quality Management System Recognition for the Kapsch CarrierCom AG company
- EC Design Examination Certificate for the GSM-R System, NSS20 and BSS18 version in the Legnica–Węgliniec–Bielawa Dolna section of the E30 rail line
- EC Verification Certificate for the GSM-R System, NSS20 and BSS18 version in the Legnica–Węgliniec–Bielawa Dolna section of the E30 rail line

5. Conclusion

The GSM-R system is a component of the ERTMS, which allows safe rail traffic control. Therefore the GSM-R system must exhibit reliability with respect to the transmission of information (voice and data), which should be higher than in the case of the public GSM system. This reliability is ensured by additional measures (equipment redundancy, adequate electromagnetic coverage). Moreover, the GSM-R system should prevent unauthorised access and ensure the confidentiality of transmitted information. The system should set up and switch calls and transmit data in accordance with the assumed time regime. In order for these requirements to be met, not only the wireless component of the GSM-R system is significant; also important is the fixed communication component, without which neither the entire GSM -R system nor the ERTMS could operate properly. Therefore self-repairing transmission systems must be used and backup transmission routes, synchronisation, integrated management system and access control, etc. must be ensured. Only comprehensive measures can ensure the safety of the GSM-R system and thus also the safety of the ERTMS.

Since each upgraded railway line (section) requires individual design, the line in question must have a separate EC verification certificate issued by a certification body (notified body – NoBo).

6. Bibliography

[1] BIAŁOŃ A.: Masterplan wdrażania ERTMS w perspektywie krajowej i wspólnotowej. Transport i Komunikacja 2010, nr 2 [in Polish].

[2] COMMISSION DECISION of 9 November 2010 on modules for the procedures for assessment of conformity, suitability for use and EC verification to be used in the technical specifications for interoperability adopted under Directive 2008/57/EC of the European Parliament and of the Council

[3] DING X., CHEN X., JIANG W.: The Analysis of GSM-R Redundant Network and Reliability Models on High-speed Railway. 2010 International Conference on Electronics and Information Engineering (ICEIE 2010). Kyoto, Japan 2010.

[4] DIRECTIVE 2008/57/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 on the interoperability of the rail system within the Community,

[5] International Union of Railways, Project EIRENE – Functional Requirements Specification, 2006

[6] International Union of Railways, Project EIRENE – System Requirements Specification, 2006

[7] MARKOWSKI R.: Pierwsze wdrożenia GSM-R w Polsce. Materiały PLK S.A.,Warszawa, 2010 [in Polish].

[8] LEHRBAUM M.: GSM-R Disaster Recovery, GSM-R Business Operations, Warsaw October 2009

[9] PAWLIK M.: Polski Narodowy Plan Wdrażania Europejskiego Systemu Zarządzania Ruchem Kolejowym ERTMS. Technika Transportu Szynowego 1/2007 [in Polish].

[10] PRZELASKOWSKI K.: Eksploatacja systemu GSM-R w kolejnictwie europejskim. Przegląd Telekomunikacyjny Nr 2-3, 2003 [in Polish].

[11] PUSHPARATNAM L., TAYLOR T.: GSM-R Implementation and Procurement Guide V 1.0 15.03.2009

[12] SAUTHIER E., POUTAS L.: Radio bearer capacity and planning for ETCS Solutions for BSS redundancy, 10th December 2003

[13] SIERGIEJCZYK M., GAGO S.: Zagadnienia bezpieczeństwa systemu GSM-R w aspekcie wspomagania transportu kolejowego. Logistyka Nr. 6/2012. Wyd. ILiM, Poznań 2012 [in Polish].

[14] SIERGIEJCZYK M., GAGO S.: Problemy zapewnienia bezpieczeństwa informacyjnego w sieci GSM-R K

[15] SIMON A., WALCZYK M.: Sieci komórkowe GSM/GPRS. Usługi i bezpieczeństwo. Wydawnictwo: Xylab, Kraków 2002 [in Polish].

[16] URBANEK A.: Komunikacja kolejowa GSM-R. Networld nr 1. IDG, Warszawa 2005 [in Polish].

[17] Uzupełnienie Studium Wykonalności w zakresie systemu cyfrowej łączności radiowej GSM-R, łączności technologicznej i systemów teleinformatycznych związanych z prowadzeniem ruchu na projektowanej linii kolejowej Pomorskiej Kolei Metropolitarnej. Opracowanie WT PW pod kierownictwem M. Siergiejczyka, Warszawa, 2011[in Polish].

[18] WINTER P.: International Union of Railways, compendium on ERTMS, Eurail Press, Hamburg, 2009

[19] YUAN C.: Reliability Analysis of CTCS Based on Two GSM-R Double Layers Networks Structures Communications and Mobile Computing, 2009. CMC '09. WRI International Conference on 6-8 Jan. 2009