ETSI TR 103 134 V1.1.1 (2013-03)

Railway Telecommunications (RT);

GSM-R in support of EC Mandate M/486 EN on Urban Rail

Reference
DTR/RT-0028

Keywords
GSM-R, Mandates

ETSI

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Railway Telecommunications (RT).

Introduction

While the Directive 2008/57/EC [i.8]on the interoperability of the Community rail system is applicable to both trans-European high-speed rail system and trans-European conventional rail system it explicitly gives the possibility to member states to exclude from the measures they adopt in implementation of this Directive Urban Rail (tramway, light rail, metro and all other rail guided urban transport systems).

In other words, whereas Standards for high speed and conventional lines are already approved and deployed by the European Community, there is no well defined Standard for Urban Rail. For this reason Directorate-General for Mobility and Transport of the European Commission issued Mandate M/486 EN [i.1] for programming and standardization addressed to the European Standardization Bodies in the field of Urban Rail.

In order to answer this mandate ETSI TC RT created the present document to indicate that GSM-R system, already answering the Control Command and Signalling subsystem of the Directive 2008/57/EC [i.8]as a bearer for ERTMS, is seen as a good candidate to ensure harmonization of Urban Rail systems.

1 Scope

The present document presents detailed information about GSM-R system and its evolutions as an answer to the European Mandate M/486 EN [i.1] which intends at defining Standards for Urban Rail.

It is reminded the architecture of a GSM-R network, the services available with such a radio telecommunication network, and the Automatic Train Control systems that are supported but GSM-R.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] EC Mandates M/486 EN: "Mandate for Programming and Standardisation addressed to the European Standardisation bodies in the field of urban rail".

[i.2] ETSI EN 301 515 (V2.3.0): "Global System for Mobile communication (GSM); Requirements for GSM operation on railways".

[i.3] ETSI TS 102 281 (V2.3.0): "Railways Telecommunications (RT); Global System for Mobile communications (GSM); Detailed requirements for GSM operation on Railways".

[i.4] European Integrated Railway Radio Enhanced Network: "UIC Project EIRENE Functional Requirements Specification" P0011D009 Version: 7.1 dated 1st June 2010.

[i.5] European Integrated Railway Radio Enhanced Network: "UIC Project EIRENE System Requirements Specification" P0011D010 Version: 15.1 dated 1st June 2010.

[i.6] ETSI TS 143 064: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Overall description of the GPRS radio interface; Stage 2".

[i.7] Urban Rail Platform: "Fundamental Reequirements for Urban Rail Systems Design, Construction, Manufacture, Operations & Maintenance".

[i.8] 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.

[i.9] ETSI TS 145 005: "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception".

[i.10] ETSI EN 300 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

[i.11] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD)".

[i.12] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[i.13] UNISIG SUBSET-093: "GSM-R Interfaces - Class 1 requirements".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following definitions apply:

Urban Guided Transport systems (UGT): which cover Metro, Tram and Light Rail, are defined as public transport systems permanently guided at least by one rail, intended for the operation of local, urban and suburban passenger services with self-propelled vehicles and operated either segregated or not from general road and pedestrian traffic

urban rail systems: cover both Urban Guided Transport systems (UGT) and other rail systems which might be excluded from the scope of the Interoperability Directive 2008/57/EC [i.8] (Article 1.3 (a) and (b))

a) Metros, Trams and other Light Rail systems.

b) Networks that are functionally separate from the rest of the rail system and are intended only for the operation of local, urban or suburban passenger services, as well as railway undertakings operating solely on these networks.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ASCI	Advanced Speech Call Items
ATC	Automatic Train Control
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CCTV	Close Circuit TeleVision
DCS	Digital Communication System
DPSK	Differential Phase Shift Keyed
DQPSK	Differential Quaternary Phase Shift Keying
EC	European Commission
EGPRS	Enhanced General Packet Radio Service
EGPRS2	Enhanced GPRS phase 2
eMLPP	enhanced Multi-Level Precedence and Pre-emption
ER-GSM	Extended R-GSM system
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
FFFIS	Form Fit Functional Interface Specification
GMSK	Gaussian Minimum Shift Key
GPRS	General Packet Radio Service
GSM-R	Global System for Mobile communication for Railways applications
IP	Internet Protocol
LTE	Long Term Evolution
MPLS	MultiProtocol Label Switching
MSC	Mobile-services Switching Centre
MTR	Mass Transit Railway
NSS	Network Sub System

OFDM	Orthogonal Frequency Division Multiplex
OTA	Over The Air
PCS	Personal Communication System
PDH	Plesiochronous Digital Hierarchy
PLMN	Public Land Mobile Network
QoS	Quality of Service
R-GSM	Railway Global System for Mobile communications
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
TDM	Time Division Multiplex
TETRA	TErestrial Trunked RAdio
UMTS	Universal Mobile Telecommunications System
UITP	International Association of Public Transport (Union Internationale des Transports Publics)
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
VRS	Voice Recording System
WCDMA	Wide band Code Division Multiple Access

4 General requirements

4.1 Mandated work in M/486 EN

Rationale of M/486 EN [i.1] is to reduce the greenhouse gas emissions, which comes for a large portion from urban areas and urban transport. Urban Rail is seen as one of the prominent solutions to offer to the public other ways of transportation while supporting a modal shift from private car and increasing demand for public transport thanks to the economies of scale and to the administrative simplification. This could also strengthen European rail industry as a world leader.

Today, more than 100 existing European standards are applicable to urban rail systems; however coherent harmonization process is only applicable to high speed and conventional rail systems, and standardization for Urban Rail is missing. CEN, CENELEC and ETSI are asked to fill in this gap.

The mandate M/486 EN [i.1] is only focusing on the systems listed in point a) and b) of the Article 1 paragraph 3 of the Directive 2008/57/EC [i.8], i.e.:

a) Metros, Trams and other Light Rail systems;

b) Networks that are functionally separate from the rest of the railway system and intended only for the operation of local, urban or suburban passenger services, as well as railway undertakings operating solely on these networks.

It is highlighted in the mandate that essential requirements defined for high speed and conventional rail systems are not applicable to Urban Rail. The representative rail associations of the sector UITP and UNIFE were tasked to assess the essential requirements of the interoperability directive against the scope of this mandate. They are currently defining a set of "fundamental requirements" [i.7] which are used as a basic reference for the execution of this mandate.

The first phase of the mandate will be focused on programming, where CEN, CENELEC and ETSI – in cooperation with UPR and the joint programming committee for railways (JPC-R) – will draw up a common standardization programme for Urban Rail. This should include a gap analysis of CEN, CENELEC and ETSI standards with the help of qualified urban rail experts, in order to formulate the terms of reference for developing a coherent minimum set of standards for voluntary use in the field of urban rail.

The second phase of the mandate, after an assessment of the programme by the Commission, will consist in CEN, CENELEC and ETSI producing the standards identified in the first phase, in accordance with the agreed timetable. Ongoing European research projects such as "LibeRTiN" (FP5), "MODURBAN" (FP6), "URBAN TRACK" (FP6) and "MODSAFE" (FP7) should be taken into account in this production.

4.2 Urban Rail Platform fundamental requirements

As pointed out in M/486 EN [i.1], UITP and UNIFE are responsible to define the set of "fundamental requirements" [i.7]. This can be found in a document dated from June 2011 produced by Urban Rail Platform "Fundamental requirements for Urban Rail systems design, construction, manufacture & operations (including maintenance)" [i.7].

In particular, it is defined what are "Signalling, Automatic Train Control and Operations Control Systems".

All the equipment necessary to ensure safe movements of trains including interlocking functions and to ensure safe passenger transfers between trains and platforms in stations or stopping places. These include:

- Signalling Systems, to display information to train drivers.
- Automatic Train Control Systems, to control and protect train movements and safe passenger transfers.
- Operations Control Systems, to manage and supervise train operations.

Later the requirements for such a "Signalling, Automatic Train Control and Operations control system" are detailed and safety is highlighed (see chapter 2.4 of [i.7]).

GSM-R system can provide a solution as a bearer for Signalling systems and Automatic Train Control systems (see clause 6) and as a standalone solution for Operations Control Systems, e.g. for emergency calls (see clause 5.1.2).

5 Description of GSM-R systems based on EIRENE

5.1 General description of the system

As of today, GSM-R (voice and data bearer) as part of the European Commission driven ERTMS program is deployed and in operation in 8 countries and cover more than 68 000 km of tracks in Europe. Following EC Directive other European railway are in tender or deployment process. GSM-R is recognized as an international standard outside Europe, such as in Algeria, India, Saudi Arabia, Turkey, Russia, Australia, other North African countries and China. Since its early deployment GSM-R has proven to fulfil Railways requirements for voice applications and also as ETCS L2 bearer, in an Interoperable way. GSM-R supports circuit switched data and packet data (GPRS) and is in usage in different frequencies, e.g. 900 MHz or 1 800 MHz. GSM-R based on standard GSM mass market products.

5.1.1 Architecture of a GSM-R system

As depicted in [i.5] a GSM-R network is based on the GSM architecture, composed of several elements:

- Base Station Subsystem composed of Mobile Stations (containing a SIM card) and Base Stations for the radio interface, Base Station Controller to handle allocation of radio resources and handovers.
- Network Subsystem composed of Mobile Switching Centres to handle mobility and security, Gateway MSC to interface the GSM-R PLMN with external networks, location and group call registers, as well as Operation and Maintenance Centre.
- General Packet Radio Service elements in both BSS and NSS, as well as Short Message Service Centre.
- Dedicated different types of terminals to fulfil railway operational requirements, e.g. locomotive voice and data cab radios, terminals for standard and specific applications like in rough environment or shunting, specific work stations for dispatcher.
- Specific equipment to support needed railway applications and services (VAS), e.g. VRS, OTA.

With this architecture, a GSM-R network is able to interact with other networks, such as private railway fixed networks, public operator networks, controller equipment, and specialized railway systems (e.g. train control systems).

5.1.2 Services offered by GSM-R

Relying on the above described architecture of a GSM-R network, several services are enabled:

- Point-to-Point communications in both circuit-switched or packet-switched domains.
- Voice Broadcast and Voice Group Call Services (e.g. Point-to-Multipoint communications).
- Enhanced multi-level precedence and pre-emption: ranking of communications based on their priority and possibility to pre-empt low priority communications for emergency calls.
- Functional numbering to ease dialling using functional numbers.
- Location dependent addressing to address calls based on the location of the train.
- Support of handovers to maintain communication as the mobile moves from area to area.
- Support of Automatic Train Control systems, especially the European Rail Traffic Management System.
- Roaming towards other GSM-R PLMNs.

5.1.3 Quality of service

One particularity of the GSM-R system is very high quality of service, which is natively mandated in the relevant Standards (see [i.4] and [i.5]). In particular the requirements on radio coverage are designed to ensure different type of railway environment including tunnels, high speed operations of trains, speech quality is equivalent to Integrated Services Digital Network, and call setup times enable quick emergency calls. Furthermore handover success rate is fixed to be at least 99,5 %.

Also as GSM-R relies on the GSM Standard, its inherent resistance to interferences coming from systems in adjacent frequency band is quite high. Among all modern wireless systems GSM has the specification delivering the higher robustness. For example, acceptable blocker ranges from -25 to -13 dBm when UMTS and TETRA are ranging from -52 dBm to -40 dBm, and LTE ranges from -52 dBm to -43 dBm.

Table 1: Robustness to interferences

Standard Modulation	GSM-R GMSK	TETRA π/4 DQPSK	UMTS WCDMA	LTE OFDM
	3 dB desensitization		6 dB desensitization	
Blocking close	-26 dBm	-40 dBm	-52 dBm	-52 dBm
Blocking far	-13 dBm	-25 dBm	-40 dBm	-43 dBm
C/I co-channel	9 dB	19 dB	NA	NA
NOTE: Values above are quoted from TS 145 005 [i.9], EN 300 392-2 [i.10], TS 125 104 [i.11] and TS 136 104 [i.12].				

Mobile Station transmits power: GSM = 33 dBm, TETRA 36 dBm, UMTS & LTE 23 dBm.

5.2 Standardized frequency bands for GSM-R

GSM-R is a system relying on the definition of the GSM system (see [i.2] and [i.3]), and as such any operating band defined for GSM could also be utilized by Urban Rail systems. GSM is a very robust standard since it is defined for very high blocking performance, and wide dynamic range. Such qualities are keys to deliver a reliable communication, especially in terms of resistance to blocking interferers, or in terms of required carrier over interference ratio which is very low and thus profitable for frequency reuse pattern. Finally GMSK modulation defined for GSM/GSM-R is very robust to system linearity and this allows wide receiver dynamic range.

Some of the bands interesting for GSM-R are listed in table 2.

Table 2: Standardized frequency bands for GSM-R

	Uplink		Downlink		Bandwidth
GSM 450	450,4 MHz	457,6 MHz	460,4 MHz	467,6 MHz	7,2 MHz
GSM 480	478,8 MHz	486 MHz	488,8 MHz	496 MHz	7,2 MHz
GSM 850	824 MHz	849 MHz	869 MHz	894 MHz	25 MHz
ER-GSM	873 MHz	915 MHz	918 MHz	960 MHz	3 MHz
R-GSM	876 MHz	915 MHz	921 MHz	960 MHz	4 MHz are reserved in Europe for Railways
GSM 900	880 MHz	915 MHz	925 MHz	960 MHz	35 MHz
DCS 1800	1 710 MHz	1 785 MHz	1 805 MHz	1 880 MHz	75 MHz
PCS 1900	1 850 MHz	1 910 MHz	1 930 MHz	1 990 MHz	60 MHz

R-GSM band is a dedicated band to railway operators used throughout Europe and some other countries has demonstrated its high quality and very good match for railway needs.

In some countries, urban railway systems are currently deployed in 1 800 MHz band.

GSM 450 MHz and 480 MHz bands are not currently used for GSM systems. However such frequencies are also well matching railways needs, and total RF bandwidth is compatible with high traffic conditions.

All these bands have in common to be well used for wireless telecommunications with mobiles. Propagations characteristics are well know and propagations models have widely been validated at worldwide level in all possible environments: dense urban to rural. Installation in aggressive environment or space limited area such as tunnel is well experienced, and has been proven in the field.

As a summary, GSM used in 900 MHz and 1 800 MHz frequency bands has proven their quality and reliability, and using GSM in 450 MHz or 480 MHz is well matching urban railway systems needs.

5.2.1 Open areas deployment

Inter-site distances for the R-GSM band can be in the 5 km to 10 km range in the railway environment. This results in a very limited and reasonable amount of sites.

Also, RF signals at these frequencies can easily be transported in coaxial cables or radiating cables. This offer very low coupling losses from base station to antenna in free space, this also offer some flexibility for deployment since antenna is not necessarily collocated with the base station.

In particular 450 MHz and 480 MHz band in comparison to 900 MHz band have:

- lower losses in RF cables, which improves link budget or reduce site cost;
- lower propagations losses, usable to either improve range or to deliver a better data rate;
- no dense communications systems in neighbour bands which would increase interferences;
- lower multipath effects, which provides the possibility to have lower margins for network engineering.

5.2.2 Closed areas deployment

Suppliers and engineering teams have gained significant experience about deploying frequencies such as 900 MHz, 1 800 MHz or 400 MHz in tunnels. At these frequencies, impacts of multipath effects resulting from propagation effects are well understood and manageable, fading depth and length are enough moderate to be compensated by system dynamic range:

- 900 MHz is already widely using radiating cables and repeaters, which has been proven as a very reliable coverage method for tunnels or subway stations;
- 450 MHz and 480 MHz would even have lower RF losses in cables which allow better budget link or reduces site cost.

5.3 GSM-R solution for urban rail

GSM-R technology is tailored for railways needs. Services are defined by Railways Operators in EIRENE Standards documents. Dedicated targets for coverage and relevant KPI are defined too, to ensure the right use of these EIRENE services. For a Railway Operator, this complete accurate frame for the GSM-R system definition is a benefit as it leads to a radio system management fully under control.

In suburban environment, for both Commuter and Mass Transit Railway lines, GSM-R proposes a variety of solutions. Main target is the line coverage for security purpose. But as Operators often require coverage for specific spots along lines like stations, shunting yards, or dedicated zones, GSM-R can be organized in different levels.

GSM-R BTS equipment has multiple configurations able to support a range of capacity (from low to heavy traffic – both voice and data) and can propose one to three (or even more) cells on a same BTS. This flexibility brings the accurate solution for one zone. For instance, MTR underground lines coverage can be defined line per line. It obeys to dispatcher zone of responsibilities. For the line itself, both tunnels and platforms can be covered in appropriate common cell size on a long section of the line. To achieve it, GSM-R system uses several radiating solutions like directive antennas or leaky cables. Extension of coverage can be managed by use of repeaters, optical solution is preferred. At connected stations, such proposals limit resurgences from one line to another. In case of extension of coverage inside stations and paths for public access, distributed antenna systems are supported by GSM-R.

Outdoor parts of urban railways networks are managed in similar way of long distance routes. The major tuning comes from the height of towers and selection of the aerials. The focus is the management of the coverage at tunnel entrance/exit into the outdoor part.

GSM-R system answers to reliability and availability Railways Operators requirements. All GSM-R equipment has internal redundancy design with switch-over ability in case of failure of one internal component of the node. For critical data connection, like ATC systems, GSM-R proposes double coverage solution. It means everywhere along the line, 2 radio bearers coming from 2 separated BTS sources deliver coverage of the train. The end-to-end chain between the ATC computer and the train has no single point of failure.

GSM-R system supports inter-working with a large range of railways telecom systems, irrelevant of the transmission network (either TDM (PDH / SDH) or IP (CarrierEthernet/MPLS):

1) Automatic Train Control system.
2) Dispatcher network (including Public Announcements systems).
3) Trackside emergency phone system.
4) Fixed telephony system.
5) SCADA surveillance system.
6) Control Centre.
7) Passenger information and services.
8) CCTV systems.

5.4 Support of data services

Circuit Switched data (CSD) services are available and already used as a bearer for ERTMS signalling system (see clause 6.1).

To improve data throughput and capacity (by multiplexing users on the same radio resource), IP-based technology are already available: Packet Switched Data (PSD) services like GPRS or EGPRS. Trans-European Transport Network Executive Agency is currently funding a testing and validation program to harmonize the usage of PSD services within the scope of Directive 2008/57/EC [i.8]. GPRS and EGPRS services will then be standardized as the bearer for ERTMS signalling system.

Like in CSD, advanced Packet Switched features like "Packet Switched Handover" are available to manage mobility and to reduce the traffic interruption time during handover procedures.

PSD features are already standardized to provide QoS classification of flows, e.g. prioritization of some packets dedicated to high priority data flows. It could indeed be relevant to distinguish between safety and non-safety critical applications and to deliver corresponding and necessary bandwidth and priority.

5.5 Evolutions of GSM-R

Many evolutions targeted for public GSM are also applicable to GSM-R, major ones being very interesting to increase capacity, data throughput or robustness of the system.

5.5.1 Increased capacity

The need to increase capacity while having the same limited quantity of spectrum brings some technical solutions, already widely deployed by public operators. The simplest one is called Half Rate and consists in multiplexing two users on the same radio resource while being totally transparent for the users. This technique might have been criticized in its early deployment for its poor voice quality, but since it was enhanced by the Adaptive Modulation Rate feature, enabling mobile device to select audio codec most suitable for the radio conditions they are experiencing. The Half Rate capability doubles the system capacity. Latest evolutions in GSM are even considering the use of Quarter Rate, multiplexing up to four users by radio resource.

5.5.2 Improved data throughput

As indicated above GPRS or EGPRS are already available to offer data service in a Packet Switch manner. Latest evolutions in the public domain cope with the very high increase in data services request by the users. Many techniques are foreseen, such as the support of EGPRS2 offering increased data rate in comparison to EGPRS, or the Downlink Dual Carrier enabling the support of two carriers at the same time to double data throughput.

5.5.3 Voice and Data combination

Some metros systems are currently relying on a double system to carry voice and data services. The Dual Transfer Mode functionality, already specified for GSM enables the simultaneous communication on both circuit-switched and packet-switched domain to e.g. enable a driver having a voice communication with a dispatching system while Passenger Information Services is conveyed to the driver's cab.

5.5.4 Enhanced robustness

GSM-R system is already a very robust system by nature, equipments achieving very good Reliability Availability and Maintenance figures. In addition, automatic disaster recovery procedures are being standardized to ensure that a backup Core Network Equipment would replace faulty equipment without any human intervention. This feature could also be extended to the Base Station Subsystem.

5.5.5 Access Network sharing

In some emerging countries the need to deploy vast mobile networks led to include in the GSM Standard the possibility to multiplex different core networks onto a single access network. With this functionality, essential function for safety critical applications located in the core network part remain within the operator's hand, while some economies can be realized in the deployment of the radio access network.

5.5.6 IP evolution

For the time being, Network Subsystems are deployed in two different types as MSC functions can be handled by different architecture: legacy MSC equipment or MSC Servers supported by Media Gateways. The later configuration relies on IP evolution of the NSS, and as such enables an IP readiness to interconnect with other IP networks.

Precisely, the interface between the NSS and the controller equipment was standardized in an IP fashion (using Session Initiation Protocol messages), and the interface between the NSS and the Voice Recording System is about to be standardized.

Other IP evolutions will be considered in a near future, for example towards an ERTMS system, or in the BSS of a GSM-R PLMN.

6 GSM-R bearer for signalling systems

6.1 European Rail Traffic Management System

The decision to use GSM for the European Railways has been helped by the fact that this technology was and remains one of the largest technical and commercial successes in the public radiotelephony with more than 3 billions of subscribers. Some additional services such as the ASCI features (VBS, VGCS and eMLPP) were necessary for the specific needs of the railways and have been implemented in the railways version of GSM, that is to say GSM-R.

GSM-R is now a standardized and validated solution for both voice and data requirements of the railway industry, including the transport of ETCS level 2 between ground and trains. GSM-R is deployed and in commercial operation in several countries since 2000, covering now more than 68 000 km of tracks. Not only it is the standard solution for European Railways, but other countries (such as China, India, Turkey, Algeria, etc.) are also using it.

The GSM-R bearer requirements for ERTMS/ETCS transmission in Circuit Switched Data have been issued by the EuroRadio Interface Group of the UIC (see the document "Radio Transmission FFFIS for EuroRadio"). GSM-R and ERTMS constitute the Control Command Subsystem of the Technical Specification for Interoperability standardized to answer EC Directive 2008/57 [i.8].

In brief, as far as the radio services are concerned:

- The data connection for ETCS is mandatorily the Transparent Asynchronous 4,8 Kbps or 9,6 Kbps as defined in the GSM standards, and optionally the Transparent Asynchronous 2,4 Kbps.

NOTE: These connections are characterized by constant throughput, constant transit delay and variable error rate.

- A data call uses a radio Time Slot used in Full Rate (that is to say one end-user by Time Slot at a given time, and dedicated to data).

- Mobile (trainborne) originated and mobile terminated calls are supported.

Other services are required, such as eMLPP in order to set a high priority ERTMS connection, and Location Dependent Addressing in order to route the call to the most appropriate Radio Block Centre.

The Quality of Service requirements of the GSM-R data transmission bearer are summarized in a technical specification (SUBSET-093 GSM-R Interfaces; Class 1 requirements Version 2.3.0 [i.13]) maintained by the European Railway Agency. In the SUBSET-093 [i.13] the connection establishment delay, transfer delay, transmission interference, and GSM-R network registration delay are standardized. As an example, the end-to-end successful transfer delay of a user data block of 30 bytes is $\leq$ 0,5 seconds for 99 % of the blocks.

The GSM-R system complies with these requirements with the appropriate engineering rules for the radio sites. It is essential to notice that, due to the significant effort made in Europe for the emergence of ERTMS as a totally reliable system for high speed lines and also conventional lines, GSM-R is the sole radio layer whose quality criteria has been fully standardized on one hand, and duly implemented by the industry on the other hand. These various criteria guarantee an optimal level of security adapted to the very high constraints required by high speed trains intelligent signalisation (ETCS level 2 and 3).

6.2 Chinese Train Control System

CTCS is a train control system which has very similar features as ETCS since there are a lot of similarities in Chinese Railways and European Railways in terms of operation modes and signalling systems. Both ETCS and CTCS have put moving block systems as its highest level and the final target. Based on reliable and fail-safe communication, train control system (moving block system or train control system based on communication) become a close loop safety control system to ensure train operation safety and efficiency. CTCS has like ETCS two subsystems: onboard and ground subsystem. The onboard subsystem includes onboard devices and onboard wireless module. The ground subsystem includes responder, track circuit, and Radio Block Centre (RBC) which rely on GSM-R for its wireless communication network.

6.3 Incremental Train Control System

ITCS, a proprietary Standard is a system that can increase maximum velocity of all trains on the network, both passenger and freight. With its precise management and shortened blocks, ITCS can effectively double line capacity over traditional control systems. Safety improves through onboard display and enforcement of all speed limits on a given territory.

ITCS is currently deployed in China (Tibet line) over a GSM-R circuit data link. This combination has proven to work well for 6 years. In addition GPRS is used for some non-safety data.

6.4 Other signalling systems

As a data bearer, GSM-R can be used to convey other signalling systems than ERTMS provided that the requirements in terms of data rate and quality of service are compatible. As already mentioned, GSM-R uses a subset of the circuit-switched data services of GSM, and other services (such as packet data) can also be deployed. Tests to use GSM-R packet data capability (GPRS) are already successfully realized in the Chinese GSM-R network for ITCS. With the same infrastructure, the GSM-R also features voice services including group calls that are fitted for any type of railway staff.

In the case of GSM-R used as a bearer to an Automatic Train Control system, this would bring the benefit of having a single network to convey voice and data at the same time.

7 Economical analysis of GSM-R system

7.1 Industrial synergy for GSM-R

As mentioned already above, GSM-R is a widely deployed system and has proven to be successful. This relies vastly on the synergy that was adopted by telecommunication Industry dedicated to railways, later forming the GSM-R Industry Group association. GSM-R IG regroups 9 companies dedicated to promote GSM-R technology as a world platform for railways communications. As such GSM-R products will be supported and evolved in the long term, under the monitoring of ERA, UIC and ETSI TC-RT.

GSM-R technology, initiated in 1997 by the railways, is therefore a solid industrial technology with a full ecosystem of manufacturers and service expertise.

7.2 Economies of scale

GSM-R products are already available on the market for railway operators. Would this market enlarge to Urban Rail systems, an inevitable cost advantage would also benefit to Urban Rail operators on all equipments: network elements, cab radios and operational handheld radio.

Additionally, in some specific cases where for instance the same railway operator manages both conventional or high speed train lines and Urban Rail, direct economies could be achieved by using a common and unique solution in the core architecture (switching, management systems) for both networks, with also a communality of terminals, which would have a direct positive impact not only on initial investment costs, but also on maintenance costs all over the lifetime of the network.

7.3 Converged services under a sole network

Whereas, in some Urban Rail system two separate networks are needed to convey both voice and data communications, a GSM-R network allow the possibility to reduce this number as voice and data communication up to user data rate of 473,6 kbps using EGPRS or 947,2 kbps using EGPRS2 (as defined in tables 4 and 4b of [i.6]) are manageable at the same time. Several combinations are possible to achieve this:

- Implementation of a voice communication equipment and a data communication equipment in the driver's cab or for the passengers, both equipments being able to communicate at the same time towards the networks.

- Implementation of a Dual Transfer Mode equipment in the driver's cab, equipment being capable of communicating with the network in both circuit-switched and packet-switched domains at the same time.

In all the cases, the convergence of voice layer and data layer for signalisation in the same telecom infrastructure is obviously a guarantee of cost savings during the implementation phase, but also during the exploitation period, and all this without any compromise on the quality of service of the network, whose robustness has been proven since more than 10 years in all major European railway networks such as Germany, UK, France, Italy, Spain and many others.

Annex A (informative): Bibliography

In the mandate M/486 EN (see [i.1]) the following research projects are advised to be taken into account:

"LibeRTiN" (FP5).

"MODURBAN" (FP6).

NOTE: Available at http://www.modurban.org/documents.php

"URBAN TRACK" (FP6).

"MODSAFE" (FP7).

History

Document history		
V1.1.1	March 2013	Publication