



GSM-R – ADVANCED, AVAILABLE, APPROVED AND APPLICABLE

PART 1 - ADVANCED

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SUMMARY

GSM-R, the railway extension of GSM telephony, has been designed specifically to satisfy railway radio communication requirements. In this three-part paper we describe the Advanced features of GSM-R that set it apart as a railway system and demonstrate that it is available technology, ready for use today. We explain how GSM-R has been approved by international standards organisations and has a Notified Body process for type and system approval. Finally, we show that GSM-R is applicable to Australia, providing an effective solution to many of the communication problems of Australian railways. Part 1 outlines the advanced and railway specific features of GSM-R.

INTRODUCTION

GSM-R came into existence through consensus by many European railways. European railways experience the same range of conditions as Australian railways, albeit with a different emphasis. The desert sands of Australia may replace the ice and snow but the operational requirements in Finland and Norway are much the same as those in remote areas of Australia. Higher density traffic in urban areas and lower density in the outlying areas are evident in nearly all railway networks.

Some of the key requirements for Australian railways have been identified as:

- a** A nationally interoperable and compatible system.
- b** Based on open, non-proprietary systems and a publicly available architecture.
- c** Supporting electronic and communications based safeworking systems.
- d** Designed for data transmission.
- e** Supporting the safety and business needs of track managers and train operators.
- f** Suitable for local train operations as well as main lines (including shunting).

The same requirements were the basis of the European assessment of technologies for their

digital train radio system. Over thirty railways studied their requirements, assessed a variety of technologies and ultimately specified a system based on GSM telephony. The GSM standard has been enhanced with railway specific features to form GSM-R.

Interoperable and Compatible

In 1992, the UIC (Union Internationale des Chemins de Fer) began work on a new railway radio specification. The specification, which was required to satisfy the communication requirements of all European railways, was called EIRENE (European Integrated Railway Radio Enhanced Network).

Based on Standards

The group developing EIRENE worked with the international standards organisation ETSI (European Telecommunications Standards Institute) and a consortium of operators, suppliers, vendors and manufacturers called MORANE (MOBILE Radio for RAILways Networks in Europe).

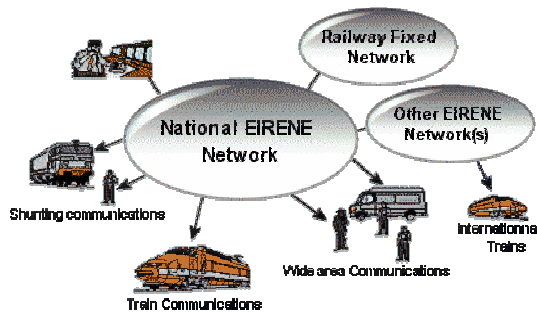
This consortium created a working and appropriate communication system for train drivers, train controllers, security and maintenance teams. Its work was finished with the user approval of the GSM-R prototypes in 1997.

Today, all the GSM-R standards are publicly available and GSM-R is in revenue service.

1. GSM-R – A UNIFIED NETWORK

1.1 Concept

The GSM-R designers wisely based the technology on the enormously successful GSM telephony platform. With many millions of GSM handsets in use today, GSM is a technology that has a future and has a defined development path.



Advanced GSM Features

Some features were added to the rich functionality of GSM to permit the GSM telephone to operate like a mobile radio or walkie-talkie. (These features include call priority levels and the ability to establish group calls and broadcast calls.)

Railway Specific Features

The railways added some railway specific features to GSM – these functions permit users to make calls based on their function in the railway and their location. The GSM-R network interprets the numbers dialled for these calls and sets the call routes appropriately.

Simple concepts; advanced technology. The essence of GSM-R is rigid compliance with standards and creative use of technology.

2 GSM FUNCTIONS

2.1 Concept

GSM has evolved over a number of years with progressive enhancement of its features and functions. The railway requirements drove a new stage of GSM development and standardisation that introduced a set of Advanced Speech Call Items (ASCI). This development, called GSM Phase 2+, was agreed internationally and standardised in the GSM documentation.

The ASCI features added functions to GSM that were previously only available in private mobile radio systems (commonly known as PMR) and some trunked radio systems. The special features provide for:

- call priority assignment – multiple levels of precedence and call pre-emption
- group calls - two or more mobiles can form a group and be “conferenced” into a single call
- broadcast calls – two or more mobiles can receive a call from another mobile or a land line telephone.

2.2 Call Priority Assignment

The call priority assignment features are technically known as “enhanced Multilevel Precedence and Pre-emption” and abbreviated as “eMLPP”.

The call priority assignment means that:

- a Calls in a GSM-R network each have an assigned precedence level
- b Calls having a higher precedence can pre-empt calls and resources having a lower precedence

There are five priority levels. In descending order, the precedence levels are 0, 1, 2, 3 and 4.

The GSM-R network operator can define the maximum precedence available to any mobile and can define a default precedence within the range 1 to 4.

Different mobiles may be assigned different precedence levels within a network.

Railway Emergency Calls have priority 0. Point-to-point emergency calls have priority 2.

The GSM-R switching centre will force a priority of 0 for railway emergency calls, regardless of the priority that the mobile equipment sets.

eMLPP is a very powerful concept and technique. It provides a rigorous method of resource allocation in the GSM-R network so that many different user groups can share the network. Despite the number of groups sharing the network, connection is guaranteed for the high priority users and calls.

Precedence

The originator of a call can set a precedence level in the range between the default level for that user and the maximum level that has been defined. The system will over-ride any attempt to exceed the maximum level of precedence. Calls will normally be set up with the default precedence level for the originator of the call.

The precedence of the call determines that action that the called party's mobile will take when it receives the call. If there is a call in progress, the mobile will act in accordance with the *pre-emption* rules.

Pre-emption

When call pre-emption is active, a call of lower priority will be released if this is necessary for connection of a higher priority call. This pre-emption mechanism applies to all the links connecting the mobile to the network.

2.3 Group Calls and Broadcast Calls

Most calls are made on a one-to-one basis as telephone calls. However, Voice Group Calls and Voice Broadcast Calls can be established readily. Voice Group Calls are open channel calls in which all members of the group can hear the call and can speak in turn during the call. At any point in time, only one group call member can speak. Voice Broadcast Calls are similar, except that only the originator of the call can speak.

The group and broadcast calls can be made to predefined geographic areas or to functional groups. The system is configured in databases to meet the railway operator's requirements.

A part of this configuration is the definition of dispatchers that, if allowed, can take specific roles for the group call. They are able to establish group calls, can speak at any point in time and, if authorised, can terminate group calls.

Groups and Priorities

Mobile radios can be assigned to have different priorities and functional groups. This ensures that urgent and priority calls will always be connected. Further, the users are made aware of priority calls and will be switched to them automatically by a set of precedence and pre-emption functions.

2.4 Voice Group Calls

The Voice Group Call Service (VGCS) is one of the GSM-R features that makes a GSM telephone system behave more like a private mobile radio network. A group of mobile and fixed users can be brought into a group call so that each can participate. The members of the group call can speak in turn, using the press-to-talk button on the GSM-R handset.

Group Membership

The membership data for Voice Group Calls is carried on the mobile terminal's SIM card and authorised in the Home Location Register. This Group ID data is used to determine whether any particular Group Call is applicable to that mobile.

Call Area

When a mobile user starts a Voice Group Call the network uses the Cell ID of the cell where the mobile user is located and retrieves the Group Call Area ID from a database in the mobile switching centre. The call is then set up by the network in all cells that belong to this Group Call Area. The call will be received by all mobiles in the area that have the Group ID that was used to set up the call.

Dispatcher

A *Dispatcher* in GSM-R is a mobile or fixed user that has particular responsibilities and privileges. The dispatcher may be a signaller, train controller, electrical controller, roster clerk etc. Dispatchers are connected to the network by standard links using radio or ISDN.

When a dispatcher (mobile or fixed) starts a group call, the dispatcher has to choose the Group Call Area ID and uses this together with the Group ID as a telephone number. (A Group Call is set up by dialling a particular telephone number). The network then analyses the dial string and sets up the Group Call in all cells that belong to that Group Call Area.

Dispatchers receive all broadcast and group calls to a certain Group Call ID in a group call area for which they are registered in the Group Call Register.

Dispatchers using the GSM network can be located outside the group call area. There can be zero or up to four dispatchers involved in a

particular VBS or VGCS call. The identities of dispatchers are exclusively predefined in the network by the service provider.

2.5 Voice Broadcast Calls

The Voice Broadcast Service is a Point to Multipoint Service. It is very similar in operation and establishment to the Voice Group Call Service (see above). The main difference is that only the originator of the call is allowed to talk. With the exception of the dispatcher, all other parties are only allowed to listen.

Network Initiated Group Calls

A network operator can configure the system so that certain point-to-point calls can be established as network initiated broadcast calls.

Call Area

A broadcast call is connected to

- One or more cells defined for the particular Group Call Area
- All dispatchers listed for the Group Call Area
- All mobiles registered with the Group Call Identity and located within the defined cells.

Making a Broadcast Call

To make a Broadcast Call, a mobile can dial a short code that identifies the Group ID and the fact that it is a broadcast call.

A dispatcher wishing to make a broadcast call dials a number consisting of "<cc> + <ndc> + 5 + 1 + GCRRef". (The meaning of "cc" and "ndc" is explained later in this paper.)

The calling subscriber is sent a notification by the network to indicate the successful establishment of the VBS call so that he can start to speak.

Multiple Calls

A number of broadcast and group calls may exist simultaneously intended for different groups of destination subscribers in the same group call area. Parallel broadcast calls can be made to the same group of destination subscribers in different, possibly overlapping group call areas.

It is possible for a mobile to activate or deactivate the broadcast call reception for different group identities. The selection list is

stored on the SIM corresponding to the subscribed group identities.

Joining and Leaving a Group Call

If a mobile that was involved in a group call leaves the group call area, that mobile will no longer be a part of the group call.

A mobile that enters the group call area during the call will be added to the group call after receiving a notification message from the network.

A dispatcher who dials the group call code for an on-going call is connected to the call, if the dispatcher is entitled to originate a group call.

A service subscriber is denied call originations to an existing VBS call and an appropriate cause value is sent by the network.

A network (application) initiated group call will not be connected to an existing call.

Closing the Call

A mobile initiated broadcast call will be cleared if

- the mobile that initiated the call releases the call, or
- the mobile that initiated the call leaves the group call area, or
- the calling dispatcher or another authorised dispatcher releases the call.

3 GSM-R FEATURES

3.1 Concept

The basic GSM features, together with advanced speech call items constitute a very usable mobile radio system. These features are applicable to many industries and utilities. The GSM-R features bring to GSM some further capabilities that are designed specifically for railway operations.

The GSM-R features accommodate such concepts as associating train consists with the crew of the train. They also permit calls to be made to a railway function (eg signaller or guard), rather than the particular person performing that function.

3.2 Dial by Function

With GSM-R it is not necessary to know the mobile radio telephone number. If the radio is associated with a train or function, the user (or an authorised remote party) can assign the mobile to the train run (trip) number. Any

authorised person in the GSM-R network can then call the train by that number.

For example, if a signaller wants to call the driver of a specific train, it is not necessary to know the phone number of the train equipment. Rather than dialling the phone number of the train driver, the signaller dials the run (trip) number of the train (with a prefix). The network then uses a database to translate the train number into the train driver's telephone number.

This facility, known in the specifications as **Functional Addressing**, is flexible and accessible. Functional numbers can be registered and deregistered to a mobile by the user. The procedures are similar to those used for call forwarding. The network equipment can also register and deregister numbers or groups of numbers.

3.3 Short-Code Dialling

There are many short-code dialling sequences in GSM-R to simplify call set up and handling. The signallers and controllers can operate the system from a standard digital telephone although custom versions of the telephone with display screens and pre-coded buttons are normally used.

3.4 Access Matrix

The Access Matrix for GSM-R is a feature that allows or disallows a call depending on the functions the originator and terminator have within a GSM-R network.

For example, the catering personnel for a passenger train might not be allowed to talk to the train controller. Should such a call be initiated, the mobile switching centre's access matrix feature would analyse the functional numbers of the call parties and would determine that this call is not allowed. The call would not be connected.

3.5 Location Dependent Addressing

Location Dependent Addressing allows the GSM-R network to route a call based on the location of the caller.

For example, if a train driver wants to reach the signaller who is responsible for the area the train is in, the train driver dials the short code "1200". The network will use the short code and Cell identity of the cell the call was

originated from to retrieve the phone number of the responsible signaller from a database. The network will then route the call to this signaller.

The standard Location Dependent Addressing uses a coarse measure of the train's position – the current mobile radio base station. This is adequate in open areas (because the majority of the base stations are very close to the track) but is unsuitable when signaller boundaries change at track junctions.

A modification to the GSM-R specifications is under way to provide enhanced Location Dependent Addressing. This modification provides data fields in the message to accommodate position information collected in latitude/longitude coordinates, in distance measurement from an odometer or in terms of transponders (balises) passed. A software application is then required at the switching centre to decipher the information, compare it with a database and then follow the procedures for standard Location Dependent Addressing.

3.6 Confirmation of High Priority Calls

Confirmation of high priority calls is useful for the analysis that follows any incident. At the end of each high priority call the mobile sends an acknowledgement message to the acknowledgment centre connected to the Mobile Switching Centre. The information is logged at the Mobile Switching Centre and is available for later analysis.

4 GSM-R SUB-SYSTEMS¹

4.1 Overview

There are five sub-systems in GSM-R. These consist of the Mobile Station, the SIM card, the Base Station, the Network and the Operation System.

4.2 Mobile Station

The Mobile Station (MS) consists of the physical equipment used by the subscriber to GSM-R, to gain access to the telecommunications services offered.

4.3 Subscriber Identity Module (SIM Card)

The Subscriber Identity Module card (SIM card) consists of the physical microchip insert in the mobile station terminal equipment.

The SIM plug-in consists of storage (RAM and ROM) and computing capabilities with subscribing information of the final user.

4.4 Base Station Sub-system

The Base Station Sub-system is the physical equipment used to give radio coverage to a determined geographical area consisting of a set of cells, and containing the equipment needed to communicate with mobile stations.

Functionally, a base station sub-system is subdivided into a control function carried out by the Base Station Controller and a radio transceiver function carried out by one or more Base Transceiver Stations.

4.5 Network Sub-system

The Network Sub-system is divided into the following entities.

Mobile Switching Centre

The Mobile Switching Centre is a switching centre that holds all the switching functions needed for mobiles located in an associated geographical area, called the Mobile Switching Centre Area.

A Mobile Switching Centre takes into account the mobile nature of its subscribers and manages the necessary radio resources, especially those procedures required to handle and update the location registration and to carry out the handover.

Gateway Mobile Switching Centre

A Gateway Mobile Switching Centre provides an entry point into the Public Land Mobile Network from another network or service.

A gateway is also an Interrogating Node for incoming public network and GSM-R calls.

Home Location Register

The Home Location Register is a database used for the management of mobile subscribers.

The Home Location Register stores subscriber information and the part of the mobile location information that allows incoming calls to be routed to the mobile switching centre to join the mobile.

Any administrative action by the Network Operator on subscriber data is carried out in the Home Location Register.

The Home Location Register stores many data items, including the three identities that are essential to the system:

- International Mobile Subscriber Identity (IMSI)
- Mobile Station ISDN Number
- Visitor Location Register address.

Visitor Location Register

The Visitor Location Register dynamically stores subscriber information, such as location area and maintains the subscriber information of all mobiles that are in its area.

When a roaming mobile enters a Mobile Switching Centre area, the Mobile Switching Centre warns its associated Visitor Location Register of the situation. The mobile enters a registration procedure during which it is assigned a mobile subscriber roaming number and a visited network address. This serves to route incoming calls to that mobile.

Group Call Register

The Group Call Register is a network function that is used for the registration of group and broadcast call attributes. It is a database function.

The Group Call Register data for specific group and broadcast calls are set at the creation of the call attributes and they can be modified later.

Follow Me Function Node

The Follow Me Function Node is a network function that is used to store the “follow me” data related to the remote party on which *follow me* is applied.

4.6 Operation Sub-System

The Operation Sub-System is the functional sub-system used to manage and maintain the GSM-R network and all the elements within it.

5 NUMBERING PLAN

5.1 Call Types

There are nine different call numbering groups. These are:

- a** Short Code (four digit numbers that can be used by GSM-R service subscribers for abbreviated dialling)
- b** Train Function Number
- c** Engine Function Number
- d** Coach Function Number

- e** Breakout Code (to go from the GSM-R network to another GSM-R network or a national network)
- f** Maintenance and Shunting Function Number
- g** Train Controller
- h** Mobile Subscriber
- i** Public Number (National Network)

5.2 Number Format

The number format for a mobile consists of either the International Mobile Subscriber Identity (IMSI) or the national number (MSISDN).

IMSI: <Mobile Country Code><Mobile Network Code><National Destination Code><Subscriber Number>

MSISDN: <Country Code><National Destination Code><Subscriber Number>

Examples of Number Formats

The abbreviation CC is used to denote the Country Code (eg 61 for Australia) and the National Destination Code specifies the call route within the country.

00+CC+NDC+SN

International public number

0+NDC+SN

National public number

12xx, 13xx, 14xx, 15xx

Short codes

1611, 1622

Short code for emergency call information

2+TN+xx

Train Function Number

3+EN+xx

Engine Function Number

5+TI+GCA+GID

Group call

6+LLLL+xxxx

Maintenance and shunting Function Number

5.3 Numbering Plan Requirements

The relationship between the Engine Number and the mobile(s) supporting engine functions is a semi-permanent relationship. The Engine Functional Number with associated MSISDN number(s) is stored as an entry in the routing

database of the home network of the owner of the engine.

The engine functional number with its associated MSISDN number forms the basic unit of the routing databases. All other functional numbers allocated should be linked to this basic unit.

Shunting Team, Maintenance Team or Train Controller Number

Shunting team members are based on an association of

- Service area identifier
- Shunting team identifier.

Maintenance team member numbers are based on an association of

- Service area identifier
- Type of maintenance team
- Team member identifier.

Train controller numbers are based on an association of:

- Controller location identifier
- Controller function

6 NETWORK COVERAGE AND QUALITY OF SERVICE

The GSM-R specifications detail minimum performance requirements for any GSM-R system.

Much of the work on quality of service for GSM-R has been directed towards its use for electronic train control and signalling on high-speed lines. At present, the high-speed trains in Europe running solely on GSM-R technology are operating at over 300 km/h.

At speeds in excess of 140 km/h the data transmission is affected by the train's movement, even when there is an excellent signal level. This is because the signal amplitude and phase are affected by Doppler shifts and multipath reception.

Degradation of the data transmission results in degraded voice quality and may lead to calls being dropped.

The base stations on high-speed lines are closely spaced to provide high received signal levels and improved transmission performance. This approach, while good in itself, introduces a further complication. As the train moves from base station to base

station, calls that are in progress have to be handed over from one base station to the next. The handover is never instantaneous (although the user is not normally aware of it in voice calls). For voice calls the increase in Bit Error Rate is far from being noticeable to even the most sensitive ear, however for data calls and particularly for data used in signalling systems, the handover can be troublesome.

With the benefit of field experience from trial systems and now from systems in revenue service, the system designers have specified parameters particularly for GSM-R. The handover performance of the GSM-R equipment has been improved, the radio performance is constantly being improved and the cell planning is being refined. The objective is to minimise the number of handovers that are required, while maintaining the required quality of transmission.

The Quality of Service parameters are:

- a** Coverage probability of 95% (measured over 100 metre intervals).
- b** End-to-end connection establishment delay of less than 5 seconds for 95% of calls.
- c** End-to-end connection establishment delay of less than 7.5 seconds for 100% of calls.
- d** End-to-end connection establishment delay of less than 2 seconds for emergency calls.
- e** Maximum end-to-end delay of less than 0.7 seconds.
- f** Bit error rate of less than 10^{-4} for transparent traffic channel data for 90% of the time.
- g** Availability of greater than 99.95%.

7 CONCLUSION

GSM-R is a very advanced communications system for railways. It is based on well-defined standards and a technology that has been proven and developed over many years.

The railway specific components of GSM-R have introduced a new level of flexibility into the GSM technology.

GSM-R operates without compromising the GSM functionality, with full roaming capability for GSM-R mobiles to and from the GSM networks (subject to agreement with the carriers).



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John Aitken has been associated with train radio in Australia over the last twenty years. His largest project was the development of CountryNet in (NSW), pioneering the use of GPS and satellite telephone systems for railways. This was followed by the Pacific National AWARE locomotive system and the Communications Control Centre (CCC) project. Experience with railway radio and passenger security systems in NSW, Queensland, Victoria and Western Australia has reinforced his enthusiasm for systems that are based on international standards. John has a particular interest in human factors and systemic issues in railway communications.





Martin Lehrbaum, MSc.
GSM-R Sales and Marketing
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Martin Lehrbaum has a Senior Management role within Nortel Networks, focused on GSM-R. His primary interests are in developing new markets for GSM-R throughout the world and enhancing the existing Nortel market relationships. Through his extensive customer interaction and knowledge of customer requirements Martin has become involved with the GSM-R product development strategy and architecture.



Over the last year Martin has been leading the customer marketing team for Germany, the biggest GSM-R project awarded worldwide so far. This project has revealed many of the issues (both technical and operational) that are faced by early implementers of a new technology.



Glyn Owen
Marketing Manager GSM-R
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Glyn Owen has spent 25 years working on railway projects for Plessey and Siemens Transportation Systems. Projects have included Transponder Systems for the Advanced Passenger Train, Signal Post Telephone systems and Track to Train Radio systems in the UK and overseas. Glyn was the systems design manager for the Metronet train radio system in Sydney.



Glyn was involved in the initial work on GSM-R by Siemens Transportation.

Glyn represents STS within the GSM-R INDUSTRY GROUP, is deputy speaker of the Technical Group, and is involved from the industry side in the task of updating and controlling the GSM-R specifications.

¹ MORANE SSRS