Reducing The Cost And Improving The Reliability Of The Global Railway Through The Use Of Applications On The Gsm-R Cab Radio

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SUMMARY

GSM-R (Global System for Mobile Communications – Railways) is a technology developed for the railways in Europe, providing the only standard for advanced digital railway communications. GSM-R is not only used today throughout Europe but also globally, for example, in Asia, Africa and Australia as each updates its communications systems. A communication update of this kind, while offering unprecedented interoperability benefits, has meant significant expenditure with customers now wishing to maximise this investment and seeking innovative solutions that will deliver improved operational efficiencies, reduce costs and CO₂ emissions whilst reinforcing a commitment to corporate responsibility. Against this background it has been identified that the Siemens GSM-R cab radio provides an ideal platform that is installed on virtually every single train in Great Britain with references in many other countries. It has plenty of spare processing capacity, additional space within its size envelope for increased functionality whilst operating on a secure high availability network that is dedicated to the railways with maximum coverage. As such it becomes a central processing unit (computer) and communications gateway, available to run additional applications e.g. driver advisory system, remote condition monitoring, passenger information, driver notification and train location ID. In addition software can be easily updated remotely, using the GSM-R network and a remote management terminal, removing the need to perform updates by visiting every single train. These applications can be used either individually or together to reduce the cost and improve the reliability of the global railway.

1 INTRODUCTION

The introduction of GSM-R was mandated across Europe by the European Commission. Many governments have invested significant amounts in installing infrastructure and on-train equipment with Great Britain alone investing around £1.9 billion (Railway Strategies, 2011). The GSM-R network bearer is required for the European Rail Traffic Management System (ERTMS), European Train Control System (ETCS) and GSM-R Voice and provides a single national secure means of driver to signaller communication. The GSM-R Voice system supports a number of railway-specific advanced speech call items (ASCI) features including text messaging, broadcast calls and emergency calls. GSM-R operates across the entire network including tunnels and cuttings which means any problems that could potentially affect the operational railway e.g. safety incidents, line faults or trackside events, can be immediately communicated to the signaller and trains in the area directly. The GSM-R voice cab radio is fitted to virtually every single train on the railway network providing an easily accessible and maintainable on-train computer and communications gateway. In addition to its primary function of voice it is capable of running multiple applications for both operational and passenger benefit, providing additional, unexpected return on the original investment.

This paper addresses how the original investment into GSM-R can be maximised by using existing on board equipment and the GSM-R network, identifying additional applications, and providing the facility to remotely upload and update the GSM-R cab radio from a ground terminal, so reducing the cost, improving reliability and providing additional return on investment for the benefit of the global railway.

2 WHY GSM-R

GSM was chosen as the best technology because it was:

- Widely proven
- Highly interoperable
- A hugely successful global standard.
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GSM-R is built on GSM technology and benefits from the economies of scale of its GSM technology heritage aiming at being the cost efficient digital replacement for existing incompatible in-track cable and analogue railway radio networks. GSM-R has transformed train to ground communication in Europe facilitating the migration from 35 different systems to a unified platform. It has enabled seamless roaming across borders. The European experience has provided a blueprint for global deployment.

![Diagram of GSM-R features](image)

**Figure 1 – GSM-R global railway communication platform**

A complete cab radio installation includes a human machine interface with handset, speaker, drivers control panel and antenna, and the radio itself containing transceiver, processor, input and output ports, antenna connection, power supply and interfaces to existing systems. As the cab radio is fitted to every single cab, depending on the number of drivers cabs in the train formation there is the possibility of up to six cab radios being on-board any given train set; only one of which will be in use by the driver.

![Diagram of GSM-R on train equipment and interfaces](image)

**Figure 2 – GSM-R on train equipment and interfaces**

### 3 MAXIMISING THE BENEFIT OF INVESTMENT INTO GSM-R

Whilst understanding that there is a mandated requirement for GSM-R it should be recognised that additional benefit can be derived to increase the return on the original investment. There is an installed on-train asset operating on a managed infrastructure. This asset provides a communications gateway and has additional processing power and memory available. The GSM-R cab radio fitted in British cabs typically uses around 20% of its available processing power in providing the current radio functionality. The equipment is installed in cabs where space is at a premium and where it is becoming increasingly difficult and highly expensive to fit different human machine interfaces for new devices. An argument exists that greater return should be received from existing assets in order to maximize the original investment. Indeed the Rail Safety and Standards Board (RSSB), Technology Strategy Leadership Group (TSLG) strategy states amongst its objectives that it is seeking maximum benefits from the introduction of ERTMS and operational optimisation of the railway (RSSB, TSLG,
2012). It goes on to state that control, command and communication systems are a key strategic technological capability to deliver the railway requirements over the next 30 years, and that the application of these technologies has the potential to deliver improved capacity, decrease traction energy consumption and carbon emissions, reduce operational costs and provide better onboard communications for passengers. It also states that progressive rollout of GSM-R is a key progress area. It is against this strategic backdrop that the GSM-R Cab radio has been identified as a suitable asset able to provide a platform, using an existing on train asset capable of delivering these objectives. A number of applications have been identified that could address these requirements and at the same time improve the reliability of the railways. A selection of these is described below:

3.1 Driver Advisory System

The driver advisory system is a GSM-R cab radio application providing real time guidance to train drivers about optimum route speed and driving approach. Siemens has developed a specific algorithm for DAS which ensures that the train arrives on time whilst optimising energy efficiency. The DAS algorithm is almost entirely isolated from the GSM-R voice application within the cab radio to ensure that one application only impacts the other when it is useful to do so, for example the voice radio can pass the train’s head code to the DAS application to save the driver having to enter it twice on 2 separate systems.

DAS and the voice radio share the same display so a strict priority scheme is applied where the voice radio displays take priority, and only when the voice radio is in idle mode is DAS advice given to the driver on the display. A GPS receiver is installed alongside the cab radio and a single dual band GSM-R / GPS antenna is used to connect to the GPS and the GSM-R radio with the need for only 1 external antenna.

The DAS algorithm uses both static inputs and dynamic inputs. Static inputs include the timetable database and route data, dynamic inputs include location and time. The algorithm allows for inherent GPS inaccuracy and for areas where the GPS system will be weak or lost.

The advice is displayed to the driver on the existing GSM-R cab radio driver interface (graphical or textual) and takes account of human factors principles in the way that advice is displayed. All DAS advice and information is pre-fixed “DAS:” to differentiate it from radio activity. Prioritisation protocols are observed and immediately anything of higher priority e.g. voice functions occur DAS is immediately removed from the display whilst the driver manages the call. In the event the existing display is located away from the driver’s normal field of vision then audible alerts can be enabled by the driver.

Using the GSM-R cab radio as the hardware and software platform for a DAS system saves space and means that trains do not have to be taken out of service for a prolonged period to enable installation; being able to load the software remotely using the software management tool and storing the data within the Siemens GSM-R cab radio also contributes to ensuring a low total installed cost.

The proven mean time between failure (MTBF) and existing maintenance arrangements provide a low total lifetime cost. The operator uses the existing cab radio and architecture and the driver uses an existing, familiar display reducing the need for, and cost of managing a separate system and additional training. There is the potential for 10 - 20% energy savings through reduced fuel consumption which also reduces the carbon footprint.

Trials of the DAS system have also indicated that trains are more likely to drive to timetable reducing disruption and inconvenience for passengers and reducing the cost to the railways caused by delays and reducing the number of red signals observed by drivers which in turn reduces the probability of signals passed at danger (SPADS).

![Image of DAS advice](image-url)
3.2 Remote Condition Monitoring

The Siemens remote condition monitoring (RCM) application uses existing equipment onboard the train and does not interfere with the operation of the railway system. The equipment monitors the tracks from the trains, with the initial installation being focussed on identifying voids. Train-based void detection is recommended because voids are often not detectable unless the weight of the train is over the void causing the track to deflect.

The RCM concept is to expand the existing on-board GSM-R cab radio through the fitment of an accelerometer processor card. This is able to accurately detect the condition of the track. Software will capture and analyse the data, pre-process on board and transmit the results to the ground over the GSM-R network. The data sent to the ground includes train ID and location (based on GPS data) and severity of the defect and is sent using SMS over GSM-R. Using SMS does not interfere with the current operation of the GSM-R system.

The accelerometers measure vibration and shock in 3 axes. A set of accelerometers fitted to the cab radio on the leading vehicle can detect a rough ride and detect the onset of the condition before it reaches the levels at which a driver would have cause to report. As the accelerometers detect an anomaly the GPS location is recorded and the cab radio reports the precise location to the ground along with the physical train number and route head code. The same GPS receiver and dual band GPS / GSM-R antenna can be used and shared as fitted for DAS.

The ground system PC is in a secure location with LAN/WAN connection to the intelligent infrastructure system. The PC receives potential defect information from all trains on the network and analyses whether multiple reports are coming in from the same location. The ground system is able to reconfigure the sensitivity of the train system by sending a message to the train. Combined with information relating to the severity of the report and whether the severity is changing with time, targeted information is reported via the intelligent infrastructure system to maintenance staff.

The system uses the GSM-R network, not GSM meaning that with the reliability and coverage of the GSM-R network reports can always be reported back immediately to the ground system. A void can change from undetected to a rough ride and become dangerous in as few as just 4 axle passes. Having a rapid alerting system is therefore important.

The Siemens RCM system uses the train network to monitor the track network, using a proven technology enhanced with additional functionality. The equipment is reliable and self powered. Maintenance staff will be accurately directed to the location of a defect, minimising the time spent on tracks and increasing safety. The ground system is able to monitor the changing severity of the defect over time and could provide valuable information on the speed of deterioration providing advance warning and allowing prioritisation and preventative maintenance.

There is a potential to reduce delays and increase safety through having timely reporting of defects across the network all of the time. Enhanced GPS location data reduces the time that maintenance staff are trackside, reducing maintenance costs and disruption from maintenance staff being on the track.

Installation of the system is fast and simple and repeatable across the entire fleet ensuring a low total installed cost. Using proven pre-installed hardware with a low MTBF contributes to low overall whole life costs.

Initial investigation indicates that the network operator can make significant reduction to overall maintenance costs and delay costs through having a reliable monitoring system that is non-invasive yet gives access to 100% of the railway track assets improving rail network reliability.
3.3 Passenger Information

Through the addition of a software application the GSM-R cab radio is able to provide a passenger information function allowing ground staff to send audible announcements over the train’s PA system to provide passenger information during disruption. Many of the train PA systems are already connected to both of the GSM-R radios in both cabs (especially on driver only operated trains).

The GSM-R cab radio can be modified so that the PA call does not distract the driver, with received audio being routed away from the cab radio loudspeaker as the loudspeaker is muted. If the driver receives a controller call then the TOC PA call is terminated and the signaller call is established in preference. Should the driver make an outgoing signaller voice call the ongoing TOC PA call is terminated and the signaller call is established.

Once the train list contains all of the currently running trains for an operator it will be possible to integrate with the real time train tracking systems to support automatic announcements to all trains affected by a delay. There is no need to fit additional hardware and the software changes can be completed remotely using the software management tool. There is no disruption when installing the software as this can be done overnight or during routine maintenance periods. Once again, using existing on train architecture and estate means that there is a low total installed cost with only software updates being required and low whole life costs as proven reliable hardware is being used.

The ability for the TOC to use the GSM-R cab radio as a communications gateway and provide information to passengers without distracting the driver gives operational benefit in times of disruption. Improved customer service and management of the onward journey is enabled without the need for or additional cost of installing or updating existing passenger information systems, improving results in customer satisfaction surveys and increased passenger numbers.

3.4 Driver Cautioning

Delays caused by poor rail adhesion from leaves on the line caused an estimated 4.5 million hours (Network Rail, 2014) of passenger delays in 2013 alone. A software application has been developed which can address this and improve both operational efficiency and passenger satisfaction. Currently as each train enters an area where there is a loss of traction between steel wheels and rails due to leaves on the line, the signaller has to set the signal to red to halt the train and advise the driver that it is entering an affected area – severely disrupting the timetable.

Clearly fallen leaves, particularly wet ones, detrimentally affect both braking and traction, with leaf mulch insulating trains from the rails resulting in signalling systems (which use electric currents in the track to locate trains) becoming less accurate. As a consequence, longer gaps must be left between trains, leading to delays.

With the software application, the signaller is able to pre-record a message warning of poor rail adhesion including precise location details. The message is then delivered directly to the cab radio when a train reaches a specified section of track. The driver can acknowledge receipt by sending a pre-defined text message back; ensuring that the train is kept running and disruption is kept to a minimum.

Operational trials have shown very encouraging results suggesting reduced timetable disruption will be achieved when the software application is implemented across the entire fleet. Once again, using the GSM-R network and...
Reducing the cost and improving the reliability of the global railway through the use of applications on the GSM-R cab radio as a communications gateway brings operational and passenger benefit with reduction in delays and disruption reducing costs and improving reliability.

### 3.5 Remote Update to On-Train Equipment

In order to facilitate the provision of the software applications that are intended to reduce the cost and improve the reliability of the global railway a simple and cost effective method is required to deliver both the application and updates to the GSM-R cab radio.

Currently when providing a software update it is necessary to visit every single cab radio, connect a laptop computer and then perform the upgrade. To simplify this and remove the need to visit the train a remote software management tool can be used.

The cab radio remote management tool provides the facility for cab radio application software and other applications as described above to be remotely managed from a ground system. It allows software; pre-defined text messages and phonebooks to be updated and uploaded as well read back inventory and diagnostic information from the cab radio without the need to visit the train. Direct data communications can be made from anywhere within GSM-R coverage when the cab radio is idle. A scheduler enables one or more operations to be scheduled and performed on a number of cab radios with the results being recorded in order to support fleet-wide updates outside operational hours. Software updates can be loaded into the radio and either activated immediately or later.

Access is only possible with a valid username and password. Access via a circuit switched data call to the cab radios is restricted to authorised users and an allowed list of cab radio serial numbers and their corresponding Mobile Station International Subscriber Directory Number (MSISDN) correlating these before upload.

Having this tool allows applications to be introduced that bring improved reliability and reduced maintenance costs as it is no longer necessary to visit each train when updating software. Flexibility is increased as updates can be made as and when required and activated simultaneously. Proactive inventory management improves reliability as fault logs can be viewed remotely allowing maintenance staff to target faulty units. The remote management tool is easy to use with a standard windows web browser based interface with the potential for updates to take as little as 1 minute to load.

![Figure 5 - Cab Radio Remote Management Tool](image)

### 3.6 Removing Interference

Should the GSM-R cab radio be used as a communications gateway and central processing unit it will need to have a reliable connection the network. It has already been identified that there is network coverage of 99.999%, however it has also been reported that railways are witnessing interference from the public networks (European Rail Infrastructure Managers, 2014).

The GSM (public) network is evolving with public operators seeking to offer first 3G and now 4G networks. Public network operators are also seeking to increase coverage (closer to the tracks) in order to provide the passenger with ‘phone, data and Wi-Fi whilst on the train. As a consequence of these network enhancements emission levels have risen with the potential for emissions from the public base stations interfering with the GSM-R band. In the event that interference leads to connection loss there is a possibility of degraded mode of operation,
resulting in delayed trains and the associated delay costs. Should a situation arise whereby railway emergency calls cannot be made there are safety implications. To address this it is possible to upgrade the GSM-R cab radio through a hardware and software modification to accept a transceiver module that is resistant to interference.

4 BENEFITS TO THE INDUSTRY

Mark Carne, Network Rail Chief Executive has indicated that providing better value for money relies on maximising, improving and extending current systems; accelerating digital enablement of the railway (Infrastructure Intelligence, 2015). It is also stated in the RSSB research programme (RSSB, T964, 2012) that mobile communications are critical to the safe and effective running of Great Britain’s railway, and that there is a positive business case to be made for an integrated approach to mobile communications within the rail environment. It also states that the installation of an on-board gateway is a key enabler in both technical and commercial terms and that this gateway should act as the aggregation point for all train-to shore communications, whilst keeping costs down and benefits up.

The GSM-R cab radio provides such a system; it is a single system of integrated railway communications using off-the-shelf components that is easy to maintain, easily accessible, with software that it is possible to update remotely.

With an innovative approach towards how the GSM-R cab radio’s functionality can be enhanced, demonstrable benefits are provided to the network operator, train operator and passenger reducing the cost and improving the reliability of the global railway.

Each of the examples included in section 3 provides cost benefit through not having to invest in new or additional on train systems. Should a single system be installed to provide individual benefit and capability it would require individual design or architecture and may not deliver multiple system benefit. By extending the GSM-R cab radio with additional applications and additional transceivers supporting IP-based data communications each is able to deliver benefit that improves the operational railway.

The GSM-R cab radio becomes a communications gateway and applications provider. Each application provides single or multiple benefits, for example:

- DAS reduces fuel consumption and therefore cost;
- RCM allows maintenance to be scheduled based on the state of individual items of equipment and fault diagnosis and so improves reliability, reduces cost and increases safety;
- Passenger information provides real time information to the passenger in the event of disruption, enabling onward journey planning and reducing passenger frustration, thus improving perceptions of reliability and potentially reducing cost of delay;
- Driver cautioning reduces delays and the associated cost through the notification of events to the driver. Although other events may be notified initial trials show cautioning of the specific example of “leaves on the line” reduces timetable disruption.

With each of the applications being facilitated using a remote management tool implementation it becomes easier and more cost effective as not only is train down time reduced, as trains are not taken out of service for long periods of time to install new hardware and or provide software updates, but also train down time is reduced as only one system is being maintained as opposed to multiple systems.

To provide a joined-up use of the technology, and to achieve complete system benefit, the train operator, network operator and train owner need to cooperate in terms of access and sharing information. These solutions have been identified and developed based around the experience of the GSM-R rollout in Great Britain. While these are local solutions for global problems there is no reason why this approach should not be extended to the global railway bringing worldwide benefit, reducing cost and improving reliability on a global basis.

5 WHAT THE FUTURE HOLDS

The telecommunications world is dynamic in nature, and as such GSM-R will evolve to an as yet undefined technology. The GSM-R Industry Group roadmap was published in April 2014 and research by UIC and ERA is ongoing into a suitable replacement. GSM-R has its limitations, being in effect a 2G network, however the
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network throughput can be maximised using General Packet Radio Service (GPRS) or Enhanced Data Rates for GSM Evolution (EDGE or EGPRS).

GPRS extends the GSM packet circuit switched data capabilities, sometimes described as 2.5G providing moderate speed data transfer. EDGE is a bolt-on enhancement for 2.5G GSM/GPRS networks and allows improved data transmission rates. Ease of implementation of GPRS or EDGE will depend on the existing GSM-R network infrastructure capabilities.

![Figure 6 - GSM-R Industry Group Cab Radio Evolution](image)

To address this the Siemens GSM-R cab radio can be modified to migrate to new network bearers with the migration path to an LTE (or other system) being developed whilst retaining the same user interface. Any future communications device will have the capability to continue to run the applications using the GSM-R network applicable to that application or migrate to a new “faster” bearer where one exists. With a clear migration path the introduction of the next mandated communications system for the digital railway should maintain the philosophy of reduced cost and improved reliability. As the communications network for the railway and the on-train equipment evolutionary path starts to emulate that of the mobile phone the opportunities for applications increase and the single system approach continues to offer the possibility of reduced cost and improved reliability.

6 CONCLUSION

Europe and other areas have invested significantly in GSM-R, it has been identified that the installed network and on-train asset can be expanded and it can be demonstrated that the rail industry has the opportunity to reduce its costs and improve reliability through taking advantage of this opportunity to expand through the use of additional applications on the GSM-R cab radio. The value to the market is based on the improvement in performance, increased reliability and availability of assets, maximising the use of an existing asset, reducing costs and enhancing safety.

The applications described have the benefit and capability to drive the costs down with Great Britain leading the way in its approach to identifying ways of maximising its investment in GSM-R through the use of operational and passenger applications with the objective of delivering the 30 year vision of the TSLG.

The approach uses proven pre-installed hardware, does not interfere with the operation of the railway system, involves low cost train design and installation which is fast and simple whilst at the same time using existing infrastructure without affecting existing GSM-R voice and data traffic. With the long-term roadmap for GSM-R and migration to future bearers understood, and with a clear upgrade strategy for software and equipment identified, it is clearly demonstrated that an existing on-train asset is not only able to deliver the vision of the digital railway today and into the future, but is able to do this whilst reducing the cost and improving the reliability of the global railway.
GLOSSARY OF TERMS

1. Accelerometers | Sensors fitted on a PCB inside the GSM-R cab radio
2. Algorithm | Software calculation
3. DAS | Driver Advisory System
4. Dual-band | Antenna for both GSM-R and GPS
5. EDGE | Enhanced Data Rates for GSM Evolution
6. ERTMS | European Rail Traffic Management System
7. ETCS | European Train Control System
8. ETSI | European Telecommunications Standard Institute
9. Ground System | PC based in a secure location to/from which data can be sent and received
10. GPS | Global positioning system
11. GPRS | General Packet Radio Service
12. GSM-R | Dedicated GSM frequency for railway
13. LAN / WAN | Local area network / wider area network
14. MSISDN | A number uniquely identifying a subscription in a GSM or a UMTS network
15. PCB | Printed circuit board
16. RCM | Remote Condition Monitoring
17. RSSB | Rail Safety Standards Board
18. TSLG | Technology Strategy Leadership Group

REFERENCES