Survey on operational communications
(Study for the evolution of the railway communication system)

25 February 2014 • David Taylor, Nils Lofmark, Maria McKavanagh

The opinions expressed in this study are those of the authors and do not necessarily reflect the views of the European Railway Agency.
Introduction

Current status
Spectrum evolution
Future trends
Analysis of future scenarios
Terminal evolution
Strategy for system replacement
Summary
Introduction

This document captures the findings of a study into operational communications for railways

- The objective for the study was to identify potential strategies for the evolution of GSM-R over time to a future concept of communications for railways which required
  - an investigation of the current situation and future trends
    - for railways and other users of critical communications
  - the development of potential scenarios for future evolution
  - an assessment of the scenarios to determine the merits of each
This study is part of a programme of activities for future railway communication systems.

Introduction

ERA requirements gathering exercise

Study on models applicable for railway communication (initiated by ERA)
The scope of the study required research into the current situation and an assessment of future trends.

**Phases**

- **Research**
  - Assessing current situation…
    - …in rail and related sectors (e.g. other transport sectors, public safety)

- **Scenario development and analysis**
  - Determining future trends…
    - …in rail and related sectors, covering
      - operating models
      - spectrum
      - bandwidth requirements
    - …as well as assessing potential sharing models (e.g. with public safety)

- **Final reporting**
  - Developing strategies…
    - …for future evolution of
      - terminals
      - network systems
    - …as well as providing overall conclusions and recommendations
Information for the study came from both research and interviews

Primary research inputs and outputs

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<th>Primary inputs</th>
<th>ERA inputs</th>
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<th>Primary outputs</th>
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Interview summary

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<tr>
<td>Railway IMs</td>
<td>UK NRT</td>
<td>Tim Lane</td>
<td>Principal Strategy &amp; Innovation Manager</td>
<td>23 September</td>
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<td>ProRail</td>
<td>Allard Klop</td>
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<td>Trevor Foulkes</td>
<td>Head of Signalling &amp; Telecommunications</td>
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<td>4Tel</td>
<td>Derel Wust</td>
<td>Managing Director</td>
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<td>Railway equipment suppliers</td>
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<td>Norman Frisch</td>
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<td>Pierre Cotelle</td>
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<td>Jean Michel Evangelisio, Rainer Lasch</td>
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<td>Ola Bergman, Michael Koecker, Dirk Lowandowski</td>
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<td>Railway trade associations, regulators and government departments</td>
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<td>Stephen Parry</td>
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<td>Rob Postema</td>
<td>Feasibility Study Manager</td>
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<td>Deutsche Telekom</td>
<td>Wendelin Ruter, Karl-Heinz Lauden</td>
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37760-83 | Commercial in confidence
Introduction

**Current status**

Spectrum evolution
Future trends
Analysis of future scenarios
Terminal evolution
Strategy for system replacement
Summary
Rail sector inside Europe

- Operational communications are carried within main-line services using **GSM-R** which is
  - an adaptation of GSM to provide features for railway operation
  - mandated as the interoperability standard for certain cross border lines within Europe through the CCS-TSI
  - one of the bearers for ETCS, together forming the ERTMS standard

- Ownership of infrastructure (including telecoms) usually lies with the state

- Network capacity is not a concern for voice services, but is for ETCS while circuit-mode data is used

- Voice functionality is regarded as absolutely vital, as is the **Railway Emergency Call (REC)**
Other sectors

- **Public safety**
  - two major technologies, TETRA and TETRAPOL, for voice and low-speed critical data services
  - increasingly relies on commercial networks for data
  - some interoperability, mainly by extending the network

- **Utilities**
  - use radio networks to communicate with an estate of fixed assets for monitoring and control, rather than voice services
  - use PMR, cellular, satellite and DSL

- **Transport**
  - little use of GSM-R, rather a wide range of private and public solutions, often with hybrid solutions for voice and data
Introduction
Current status

**Spectrum evolution**

Future trends
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Strategy for system replacement

Summary
Sub-1GHz spectrum for railways would make the communications system evolution easier

- Due to channel bandwidths it would not be feasible to operate a narrowband system, e.g. GSM-R, and a broadband system; this creates restrictions when considering an on-frequency migration to a new technology solution.

- The availability of sub-1GHz spectrum would simplify the transition as it may allow re-use of sites.
  - however, identifying where the spectrum could come from, and justifying the need for dedicated spectrum would be difficult.

- While the concept of spectrum sharing with a like-minded organisation has merit, and would provide economic benefit, it is unlikely to be achievable on a pan-European basis.
  - since such like-minded organisations operate on a national basis.
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Summary
Future communication trends in the mobile market [1/2]

- The largest wireless telecoms markets in Western Europe are Germany, Italy and the United Kingdom with all markets at over 100% penetration
  - LTE is becoming established with 77 networks in Western Europe, and 64 networks in Central and Eastern Europe
- In **Western Europe**, the total telecoms market is expected to shrink from EUR274 billion in 2012 to EUR239 billion by 2018
  - which explains the interest in other revenue streams, e.g. M2M
- In **Central and Eastern Europe**, telecoms operators are also experiencing market maturity with service revenue expected to peak in 2013
Future communication trends in the mobile market [2/2]

- **LTE** will become the dominant technology for commercial networks in Western Europe of the next five years
  - based on the ten-year cycle which happened with 2G and 3G, a replacement technology (known by some as ‘5G’) should be implemented by 2020–2022

- **Coverage** is defined in terms of percentage of the population covered rather than geographic coverage
  - the degree of coverage will reduce for higher data rate technologies
  - the trend is for MNOs and government to improve coverage by filling in ‘not spots’ where there are users who are not able to access mobile networks
Future communication trends in specific sectors [1/2]

- The primary trend in **rail** operational communications is an increase in data connectivity
  - in parallel to moving to an IP environment for signalling
- In **bus services**, more and more data is being used for passenger information and fare collection
  - with a need to control emissions there is a demand to pass information on about the performance of the bus and engine
- In **civil aviation**, data use is increasing, to provide more accurate data than is possible with voice transmissions
Future communication trends in specific sectors

[2/2]

- **Mobile broadband** is the overriding future trend in **public safety**, however, there is still a recognised need for voice applications, specifically group voice
  - users have a need for a very fast call set-up of less than one second so most of the current mobile networks are unsuitable

- **Utilities** are seeing a need for more radiocommunications
  - smart metering is increasing with a wide range of communication bearers used, e.g. signalling over the power line
  - smart grid is a critical application that requires a fine level of control with a fast response time, otherwise there is a risk of instability
Software-defined radio could bring economic and deployment benefits to the railways

- As each new wireless technology standard is defined, new cab radios have to be procured
  - resulting in migration issues due to some railways using legacy technology

- Implementing radio functions as software modules would allow different standards to co-exist in the same equipment, manually selected or implicitly selected by the network

- The SDR could be coupled with a communications package that it would reconfigure to provide the optimal RF link
  - selecting the frequency and modulation scheme to match the local infrastructure

A minimum set of expandable parameters must be supported by all railways to ensure interoperability
Introduction
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Future trends

**Analysis of future scenarios**
Terminal evolution
Strategy for system replacement
Summary
Identifying the requirements allowed a range of hypotheses to be made

- Four high-level strategic objectives influencing the study have been identified
- The operational requirements are being considered in a parallel study
- Hypotheses have been proposed to consider changes to the current environment that will influence options for the period relevant to the study (15+ years)

These objectives and hypotheses allowed a range of options to be developed
Analysis of future scenarios

For each future option there are example scenarios that could be implemented.
SWOT analysis: strengths

<table>
<thead>
<tr>
<th>Example scenario</th>
<th>Strengths</th>
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<tbody>
<tr>
<td>E1: Continue with GSM-R and retain frequency band</td>
<td>- Functionality proven and no need for high data rates in railway communications&lt;br&gt;- Spectrum available&lt;br&gt;- Narrowband solutions allow increased flexibility in network planning&lt;br&gt;- GSM-R infrastructure built or planned across Europe already&lt;br&gt;- Interoperability straightforward</td>
</tr>
<tr>
<td>E2: New private network technology mandated in existing band</td>
<td>- Better support for IP data&lt;br&gt;- Can encourage separation of bearer and application&lt;br&gt;- Existing frequency band (&lt;1GHz) good for long-range communications&lt;br&gt;- May not need more sites (spectrum characteristics already understood)</td>
</tr>
<tr>
<td>E3: New private network technology and new frequency band mandated</td>
<td>- Better support for IP data&lt;br&gt;- Can encourage separation of bearer and application</td>
</tr>
<tr>
<td>E4: Shared network with similar organisation</td>
<td>- Better support for IP data if the network is IP based&lt;br&gt;- Can encourage separation of bearer and application&lt;br&gt;- Shared cost of infrastructure switch element&lt;br&gt;- May require less spectrum than two separate networks&lt;br&gt;- Both parties will save money relative to independent networks</td>
</tr>
<tr>
<td>E5: Commercial network service</td>
<td>- Better support for IP data&lt;br&gt;- Can encourage separation of bearer and application&lt;br&gt;- Network services evolve with commercial network&lt;br&gt;- Overall cost lower (lower capital cost and maintenance)</td>
</tr>
<tr>
<td>E6: Commercial network service (MVNO)</td>
<td>- Better support for IP data&lt;br&gt;- Can encourage separation of bearer and application&lt;br&gt;- Network services evolve with commercial network&lt;br&gt;- Improvements in availability and resilience, by virtue of using multiple networks&lt;br&gt;- Control over the users (SIM cards)</td>
</tr>
<tr>
<td>E7: Railway works with commercial operator</td>
<td>- Better support for IP data&lt;br&gt;- Can encourage separation of bearer and application&lt;br&gt;- Can specify requirements to operator – solution tailored to railway requirement&lt;br&gt;- If own spectrum held, this provides negotiating power</td>
</tr>
</tbody>
</table>
## SWOT analysis: weaknesses

### Example scenario

**E1: Continue with GSM-R and retain frequency band**
- Obsolescence/GSM platforms may not receive investment
- Tight coupling of bearer and application retained
- As MNOs roll out broadband technologies, interference issues may increase
- Limited supplier market leads to high costs
- Have to build own network
- Inflexible – future migration difficult

**E2: New private network technology mandated in existing band**
- Specialist GSM-R functions may result in proprietary technology (modifications to standards)
- Limited supplier market leads to high costs
- Have to build own network – new infrastructure and terminals
- New technologies tend to work on 5MHz blocks (GSM-R is 4MHz) – may only use part of band, lowering data rate
- New technology yet to be identified
- Will require solution (e.g. dual-mode operation) during migration – difficult to accommodate in existing band
- Inflexible – may be further migration issues in future

**E3: New private network technology and new frequency band mandated**
- Specialist GSM-R functions may result in proprietary technology
- Limited supplier market leads to high costs
- Have to build own network – new infrastructure and terminals
- New frequency likely to be higher, with a need for more sites
- New technology yet to be identified
- Will require solution (e.g. dual-mode of operation) during complete migration due to use of separate bands
- Inflexible – may be further migration issues in future

### Example scenario

**E4: Shared network with similar organisation**
- Specialist GSM-R functions may result in proprietary technology
- Limited supplier market (but larger than E3/E4) leads to medium costs
- Have to build network (with third party) – new infrastructure and terminals
- Bringing organisations and spectrum together is complex
- Have to agree network access priorities
- Third-party requirements may impose additional constraints
- Likely sharing organisations do not have the same pan European coordination directives as the railways; fragmentation at member state level is more likely

**E5: Commercial network service**
- New terminals required in commercial bands
- Devices are more complex
- May have to use commercial voice services rather than rail-specific voice services
- No control on coverage or availability, except by SLA – inflexible and subject to market interests
- Charging model likely to change – e.g. revenue costs for calls and data

**E6: Commercial network service (MVNO)**
- New terminals required
- Devices are more complex
- May have to use commercial voice services rather than rail-specific voice services
- No control on coverage or availability, except by SLA – inflexible
- Overhead in creating the MVNO

**E7: Railway works with commercial operator**
- New terminals required
- Locked in with the chosen commercial operator
## SWOT analysis: opportunities

<table>
<thead>
<tr>
<th>Example scenario</th>
<th>Opportunities</th>
</tr>
</thead>
</table>
| **E1: Continue with GSM-R and retain frequency band** | • GPRS and IP can be used for signalling in future  
• Other non-European vendors may be encouraged to enter the market  
• Achieve interoperability across Europe |
| **E2: New private network technology mandated in existing band** | • New technology likely to be broadband, providing further capacity and reduced latency  
• Could use E-GSM-R for migration, where available, or to provide a 5MHz band for new technology  
• May get more suppliers, increasing competition  
• More flexible solutions possible (e.g. making use of increased bandwidth) |
| **E3: New private network technology and new frequency band mandated** | • New technology likely to be broadband, providing further capacity and reduced latency  
• Could use E-GSM-R for migration or to provide a 5MHz band for new technology  
• May get more suppliers, increasing competition  
• More flexible solutions possible (e.g. making use of increased bandwidth)  
• New spectrum may be cleaner and suffer less interference |
| **E4: Shared network with similar organisation**      | • New technology likely to provide further capacity and reduced latency  
• May get more suppliers, increasing competition – particularly given a larger customer base from combining with a third party  
• More flexible solutions possible (e.g., making use of increased bandwidth)  
• May be able to share some of the base station kit  
• Could also have additional sites covering rail, increasing capacity and ensuring efficient use of spectrum for a single-frequency network  
• May be an advantage for interoperability if the sharer also needs to operate on the railway, or for a rail incident |
| **E5: Commercial network service**                    | • New service likely to be broadband, providing further capacity and reduced latency  
• Mass-market technology increases competition/reduces costs  
• Can ‘future proof’ the communications element  
• Will force separation of application and bearer  
• International roaming could be easier |
| **E6: Commercial network service (MVNO)**             | • New service likely to be broadband, providing further capacity and reduced latency  
• Mass-market technology increases competition/reduces costs  
• Can ‘future proof’ the communications element  
• Will force separation of application and bearer  
• International roaming could be easier  
• MVNO ‘insulates’ railways from MNO disruption and changes, since there is an alternative bearer |
| **E7: Railway works with commercial operator**        | • New service likely to be broadband, providing further capacity and reduced latency  
• Mass-market technology increases competition/reduces costs  
• Can ‘future proof’ the communications element  
• Commercial operator can build the network faster and at less cost  
• Opportunity for sharing the spectrum with the commercial operator, so it can use it in places not needed by rail |
### SWOT analysis: threats

<table>
<thead>
<tr>
<th>Example scenario</th>
<th>Threats</th>
</tr>
</thead>
</table>
| E1: Continue with GSM-R and retain frequency band | • Existing players may see it as too niche, and withdraw  
• Costs may increase, while telecoms costs are generally reducing |
| E2: New private network technology mandated in existing band | • Suppliers may not develop radios in the GSM-R band  
• Technology selected may end up being a dead end  
• Cost and interoperability issues during migration – particularly challenging if existing band used  
• Rail-specific features may cease to be supported.  
• Possible interference issues with neighbouring bands  
• Work required in standards bodies to add GSM-R band to standards |
| E3: New private network technology and new frequency band mandated | • Suppliers may not develop radios in the new band  
• Technology selected may end up being a dead end  
• Cost and interoperability issues during migration  
• Rail-specific features may cease to be supported.  
• New frequency needs to be in 3GPP band plans for a standard technology or work will be required in standard bodies to add the new band to standards  
• New frequency band may need to be added by 3GPP |
| E4: Shared network with similar organisation | • Technology selected may end up being a dead end  
• Cost and interoperability issues during migration  
• Rail-specific features may cease to be supported.  
• Sharers may want their communications to evolve at different rates, putting pressure on each party  
• Railway community may be forced to adopt a non-optimal solution from other parties  
• Voice may have to become another application – will it be standardised? |

<table>
<thead>
<tr>
<th>Example scenario</th>
<th>Threats</th>
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</thead>
</table>
| E5: Commercial network service | • Suppliers may not make environmentally suitable rail-dedicated equipment  
• Commercial networks can change configuration or service levels, which may have a big impact on the service for railways  
• Little recourse if the commercial operator stops service, due to a fault or external action |
| E6: Commercial network service (MVNO) | • Suppliers may not make environmentally suitable rail-dedicated equipment  
• MVNO supplier has to be carefully chosen and may have difficulty working with the commercial MNOs  
• MVNO approach will suit some member states better than others, due to national variations (e.g. multiple RAN versus shared RAN available in the country – where there is consolidation of RANs this will reduce the effectiveness of the MVNO approach) |
| E7: Railway works with commercial operator | • Suppliers may not make environmentally suitable rail-dedicated equipment  
• Competing priorities from other commercial network customers may affect the service for rail  
• Returns for commercial operators may not be realised, and they may withdraw |
### Analysis of future scenarios

#### Options

The options were assessed for their fit against the high-level strategic objectives and operational requirements.

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<th>Strategic objectives</th>
<th>Operational requirements</th>
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<tbody>
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<td>O1</td>
<td>Retain GSM-R</td>
<td>Good – single platform</td>
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<td></td>
<td>Interoperability</td>
<td>Good – single platform</td>
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<tr>
<td></td>
<td>Service continuity</td>
<td>Fair – platform support reduced over time</td>
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<td>Flexibility</td>
<td>Poor – limited scope for variation</td>
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<td>Economic effectiveness</td>
<td>Poor – dedicated platform with high costs</td>
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<td>O2</td>
<td>New technology – same band</td>
<td>Fair – single platform but change disruptive</td>
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<td></td>
<td>Interoperability</td>
<td>Fair – single platform but change disruptive</td>
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<tr>
<td></td>
<td>Service continuity</td>
<td>Fair – transition challenge</td>
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<tr>
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<td>Flexibility</td>
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<td>Economic effectiveness</td>
<td>Poor – single platform, limited market</td>
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<td>O3</td>
<td>New technology – new band</td>
<td>Fair – single platform but change disruptive</td>
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<td>Fair – single platform but change disruptive</td>
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<td>Economic effectiveness</td>
<td>Poor – single platform, limited market</td>
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<td>O4</td>
<td>New technology – with third party</td>
<td>Fair – single platform but change disruptive</td>
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<td>Fair – sharing efficiency benefits</td>
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<td>O5</td>
<td>Multiple prescribed technologies</td>
<td>Fair – controlled use of multiple platforms</td>
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<td>Service continuity</td>
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<td>Poor – multiple platforms</td>
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<td>Flexibility</td>
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<tr>
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<td>Economic effectiveness</td>
<td>Good – allows for most economic solution</td>
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</table>

*The options were assessed for their fit against the high-level strategic objectives and operational requirements.*
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Strategy for system replacement
Summary
In the future, terminals may evolve to have more than one radio module

- The train-borne kit (**cab radio**) currently provides the GSM-R functionality
  - it has a single radio module supporting GSM and GPRS in the GSM 900 band
- The cab radios used in county rail in Australia may indicate what the future will look like
  - they have five transmitter/receivers (GSM-R, Satellite, UHF and two 3G) as well as a GPS receiver
- There is a need to separate the GSM-R voice functionality from the ETCS functionality for flexibility
- Any future communications will only support voice over IP and so the functionality of GSM-R voice services will need to be developed as an application running over the future radio network
Multi-mode terminals could be used as a tool for transition and provide interoperability

- IMs will have difficulty supporting legacy radio units after they transition to the new technology
  - therefore the terminal should be considered as a transition tool, with a ‘legacy mode’

- **Interoperability** in the future can be achieved using multi-mode terminals which may also be multi technology
  - the IM could specify the mode required to operate on its tracks

- GSM-R is predominantly a solution for communications with train-mounted radios, but future networks should be able to support portables
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Summary
Low-latency, high-data-rate technologies will be required with separation from the bearer

- **Moderate levels of data** will be required in the future and GPRS will not be suitable
  - 4G may be better due to its low latency and high data rates
- However, in the 2020–2022 timeframe, other more advanced technologies will develop, so any future solution for rail should be structured to allow continued evolution
- **Bearer independence** should be encouraged, while still providing suitable interoperability
  - rather than optimising the bearer for signalling, a specification should be provided to the bearer with characteristics such as error performance and latency
# Possible scenario for the transition of terminals

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Summary
Summary

- For main-line train services there is good use of GSM-R as an interoperable standard.
- ETCS is being rolled out, however, circuit-mode operation on GSM-R does not give enough capacity and GPRS is required.
- Use of current spectrum for future solutions is possible, and sub-1GHz is ideal for the future, but the transition would be complex.
- Options for the future policy have been identified and considered against the strategic objectives and operational requirements.
- However, it is clear that while evolution is necessary, it is going to be challenging, but brings benefits.

Next steps: this study is part of a larger programme of activities being carried out by ERA; the findings from this report will be used to inform the subsequent activities which will take place in 2014 and will result in a finalised strategy.
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