GSM-R
Asset & Evolution Management
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Session 2: GSM-R - A Success Story

2.2 GSM-R for ETCS

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ERTMS Users Group - President
The technology innovation represents one of the qualifying driver that enables the modernization of the Organization.

One of the most important innovations introduced by RFI, now more than 10 years ago, was the GSM-R mobile radio system, that has been one of the technology that allowed the improving of the processes and the achievement of high level of operating efficiency.

The most important application where the GSM-R system has played a leading role was the “Italian High Speed Project” where the safe communications between the Train and the Ground systems was carried by the GSM-R without any back-up communication system.

Many years passed since the beginning of our “high speed challenge” and now, after tens of thousands of kilometers and hundreds of trains that every day run on our high-speed lines........

.....we can say with a certain peace of mind that...

“The GSM-R is an excellent technology platform, robust, highly reliable and perfectly suitable for the ERTMS / ETCS application.”
GSM-R for ETCS: *where we are* … *and where we want to go*

**High Speed Lines**
- GSM-R is the bearer for the ERTMS/ETCS Signalling System Level 2
- Strong requirements in terms of RAM (Reliability, Availability, Mantenability)
- Redundant radio coverage (double coverage)
- Quality of Service

**Conventional Lines**
- GSM-R is the Train to Ground communication system (Drivers-Controllers)
- Service communication between railway personnel
- The project covers the main (commercial) railway routes ~ 10.000 km
- GSM-R Network + improvements of SDH Transport Network
- Data Transport Network full IP (IP-MPLS Multi Protocol Label Switching)
GSM-R for ETCS: where we are… and where we want to go

**Key figures**
- Total Length of Railway Network: **16,700 km**
- Covered by GSM-R: **10,600 km**
- Start of implementation: **2002**
- BTS installed: ~ **1,800**
- BSC installed: **19 (CL) + 4 (HSL)**
- MSC installed: **4 (CL) + 3 (HSL)**

**GSM-R**
- High Speed Lines (HSL)
  - ERTMS/ETCS L2
- Conventional Lines (CL)

**Services and Functions**
- Automatic Train Control (HSL) ERTMS/ETCS L2
- Train to Ground Communication Services
- Train to Ground Data Communication
- Management of Railway Emergency
- Service Communication for Personnel
- Mobile Office Applications (GPRS)
- Added Value Services for Passengers (GPRS)

- GSM-R is the system adopted by RFI to fulfil efficiently and in a very integrated way the needs of mobile communications related to the whole railway process.
- GSM-R meets all the requirements of Voice and Data Communication related to railway services, including Automatic Train Control System over the High Speed Lines.

ERTMS: European Rail Traffic Management System  
ETCS: European Train Control System  
Level 2  
GPRS: General Packet Radio Service
GSM-R for ETCS: *where we are… and where we want to go*

**Key requirements**

→ **RAM Requirements: ERTMS/ETCS System**
   Reliability, Availability, Maintainability

   RFI Requirements consider the **GSM-R Subsystem** (GSM-R Network + SDH Transport Network) at the same level of ERTMS/ETCS System (Trackside Equipment – Distributed and Centralised)

   Immobilising Failures:
   mean downtime per year due to hardware DTHW,I = 8 minutes tolerable as consequence of IMMOBILISING failures

   Service Failures:
   mean downtime per year due to hardware DTHW,S = 1 hour 9 minutes tolerable as consequence of SERVICE failures.

→ **Radio Frequency Coverage Level**

   Normal Condition and Fault of BTSs non-adjacent : -92dBm coverage probability of 95% in each location interval (length: 100m)

→ **System Redundancy**

   GSM-R Radio Coverage Redundancy

   Single Fault Tolerant Architecture – LRU Level (Line Replaceable Unit) (GSM-R, SDH Transport Net)

   No-Break Power Supply System (both for the centralized and long track installations)
GSM-R for ETCS: where we are... and where we want to go

Key requirements

Double Radio Coverage
Single Fault Tolerant Architecture

-92dBm

~ 20dB (margin)

Fault
GSM-R for ETCS: where we are… and where we want to go

Key requirements

System Redundancy
Single Fault Tolerant Architecture

Core Network ↔
Transport Network ↔

Settimo Torinese
AC/AV Torino Novara (Milano)
Milano GP
Bologna
Napoli
AC/AV Roma Napoli
Roma Tni
AC/AV Milano Bologna Firenze

Transport Network
Core Network

AC/AV Roma Napoli (Milano)
Bologna
Napoli
AC/AV Roma Napoli
Roma Tni
AC/AV Milano Bologna Firenze

GPRS
SMS VMS Billing

HLR
MSC
SGSN
GGSN
IN
Evolution of GSM-R: next steps

- **Technological evolution** (move to a full-IP platform)
  - NSS Core: New platform (upgrade from Rel.99 to R4)
  - BSS Subsystem: Flexible solutions (BSC / BTS)

- **Architecture evolution** (catastrophic event proof)
  - High reliability and full disaster-recovery architecture
  - Flexible, distributed and modular architecture
  - Downsizing the current network taking advantage of the greater capacity of the new generation of equipment

- **Investment protection** (…that are looking to the future)
  - platforms open to the deployment of new applications and to the evolution of the standards
  - platforms open to the future generation of mobile communication for railways

GSM-R for ETCS: *where we are*… and *where we want to go*
GSM-R for ETCS: where we are… and where we want to go

Evolution of ERTMS/ETCS: next steps

- **Technological evolution** (move to a full-IP platform)
  - ETCS over GPRS
    
    GPRS can be used as a stepping stone from current circuit switching based technology towards any future proof mobile transmission technology.

    By enabling future possibilities of managing dense ETCS traffic, ETCS over GPRS can be seen as a missing link that brings added value by maximizing the impact of investments already made in European ERTMS infrastructures.

- **New applications**
  - ERTMS/ETCS L2 (+ National Signalling System) over Conventional Lines (Interoperable Corridors)
  - Upgrading of the existing infrastructure for faster trains (up to 360 km/h)
  - MONITORING GSM-R Interference
  - ERTMS(ETCS +GSM-R) + IXL Log Analyzer: An Integrated platform
  - Satellite application: Localization and Euroradio data

- **Investment protection** (…that are looking to the future)
  - platforms open to the evolution of the standards
Operational Feedback

- **MONITORING GSM-R Interference:**
  - Observation of GSM-R spectrum in proximity of the railway line

- **Check deeply Operational fault: Italian High Speed Competition is by ETCS L2:**
  - Need a ERTMS Automated Analysis by data Log interpretation
<table>
<thead>
<tr>
<th>Total network (km)</th>
<th>16700</th>
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<tbody>
<tr>
<td>Voice ETCS</td>
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<tr>
<td>GSM-R Planned (km)</td>
<td>10600</td>
</tr>
<tr>
<td>(CL and HR)</td>
<td></td>
</tr>
<tr>
<td>Network Constructed (km)</td>
<td>-10100</td>
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<tr>
<td>Network Ready for Service (km)</td>
<td>9540</td>
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<tr>
<td>Network in Operation (km)</td>
<td>9540</td>
</tr>
<tr>
<td>(11 December 2013)</td>
<td></td>
</tr>
<tr>
<td>Planning level (95% probability, dBm)</td>
<td>-85 dBm CL</td>
</tr>
<tr>
<td>(double coverage)</td>
<td>-92 dBm</td>
</tr>
<tr>
<td>Start of Planning</td>
<td>2001</td>
</tr>
<tr>
<td>Start of Implementation</td>
<td>2002</td>
</tr>
<tr>
<td>Network in Operation</td>
<td>2004</td>
</tr>
<tr>
<td>End of Implementation</td>
<td>2012</td>
</tr>
<tr>
<td>End of migration</td>
<td>2009</td>
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</table>
Continuous observation of GSM-R spectrum in proximity of the railway line

Grdes project → Dejammer

2007: GRIDES (GSM-R Detection System): Prototype EU co-financed
2012: Dejammer (Detection of Jamming in Railway System): industrial application

Continuous observation of GSM-R spectrum in proximity of the railway line, in order to:

1. Measure the quality of the signal transmitted by RBC (Radio Block Centre) and trains
2. Detect non-malicious or malicious interferences
3. Keep constantly updated a remote analysis centre on the current status including spectrum analysis
DEJAMM-R system is architected into two main units:

- DEJAMM-R **Sentinel**
- DEJAMM-R **MoC (Monitoring Centre)**
DEJAMM-R Sentinel

To be installed in proximity of an HS railway track
Responsible for scanning of GSM-R frequency bands and report to MoC about the status and the relevant parameters (ALARM + SINR) of all the 38 GSM-R channels in less than 3 minutes (depending on the number of messages sent to the MoC)

Detectable Interferences:

Narrowband interference
- Sinusoidal Oscillations
- FM transmitter
- Narrowband Gaussian Jammer
- Narrowband OFDM (e.g. DAB, DRM, DRM+, DVB-T)
- Broadcast Analogue Television (e.g. PAL)
- UMTS (CDMA 1x)

Wideband interference
- Wideband Gaussian Jammer
- Wideband OFDM (e.g. DAB, DRM, DRM+, DVB-T)
- Broadcast Analogue Television (e.g. PAL)
DEJAMM-R MoC

- Receive data from Sentinels via a TCP/IP network (Fast Ethernet/LAN) or via GSM (GPRS)
- Can support up to 20 sentinel connections
- Highlights all received Alarms from Sentinels (GUI)
- Monitors GSM-R signal levels (SINR) received from Sentinels (GUI)
- Record and store of all received data in a suitable DataBase (MySQL)
- Possibility to make queries about one or more sentinels
- It works like a Remote Spectrum Analyzer
- Configurability through .xml file
- Multilanguage support
GSM-R Signal: FFT
Downlink Band and MCC/MNC Parameters

Country and Provide Codes

<table>
<thead>
<tr>
<th>MCC</th>
<th>MNC</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>222</td>
<td>30</td>
<td>Italy</td>
</tr>
</tbody>
</table>
Interferers situation
**Single channel report**

![Bar chart showing downlink band with 'no alarm' and 'alarm' categories]

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- Catania node - report from 2013-04-07 to 2013-04-18
- Downlink
- This Page

### Downlink

<table>
<thead>
<tr>
<th>Channel</th>
<th>Valid Signal</th>
<th>Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>41</td>
<td>42</td>
</tr>
<tr>
<td>1</td>
<td>46</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>42</td>
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<tr>
<td>4</td>
<td>39</td>
<td>43</td>
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<td>5</td>
<td>35</td>
<td>48</td>
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<td>12</td>
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<td>13</td>
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<td>14</td>
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<td>15</td>
<td>43</td>
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<td>16</td>
<td>39</td>
<td>45</td>
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<tr>
<td>17</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>18</td>
<td>44</td>
<td>40</td>
</tr>
</tbody>
</table>

**Graph**

- **Y-axis**: Count
- **X-axis**: Channel numbers (0-18)
- Two bars for each channel: 'no alarm' (green) and 'alarm' (red)
Automated Analysis

What direction is moving RFI to push the envelope of ERTMS monitoring and troubleshooting?

A new project code-named ERTMS Log Analyzer (named MISTRAL) is in charge of designing an automated processing engine with the following guidelines:

- A Functional Representation of the RBC+ EVC
- A model validated through Model Checking and Formal Methods
- Active Monitoring of Functional Scenarios
- Verify & Validation support in the case of new track scenario
- Comparison between train rides
- Real-Time or Post-Processing detailed Analysis of operating anomalies
Testing Equipements

• Test Trains:
  – 5 Test Trains/Carriages
  – Three equipped with GSM-R Instrumentation
  – One for HSL exclusively (Y1)
  – One for both HSL and Conventional Lines (Archimede)
  – One for Conventional Lines (Talete)
  – One awaiting order for Conventional Lines (Aldebaran)
  – One awaiting order for HSL (Y2)

• Portable Data Collection systems
  – NetProbe Trolleys rel. 1.0 or 2.0
  – Triorail Handsets

• OMC-R
  – Call trace
  – KPI performance monitoring

• Network Monitoring
  – Monitoring Probes at HSL control Centres
  – NetAnalyzer for troubleshooting in regional departments
Data sources are correlated and analyzed to provide a unified view.
## Driving Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregated Train Run</td>
<td>General</td>
</tr>
<tr>
<td>Aggregated Train Stops</td>
<td>General</td>
</tr>
<tr>
<td>Incident Analysis on “Train Trips”</td>
<td>General</td>
</tr>
<tr>
<td>Static vs Dynamic Speed Profile</td>
<td>Speed Analysis</td>
</tr>
<tr>
<td>Speed Profile vs Temporary Speed Restrictions</td>
<td>Speed Analysis</td>
</tr>
<tr>
<td>Average TX/RX Power along the line</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>Average TX/RX Quality along the line</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>Successful Calls</td>
<td>ETCS Call Counters</td>
</tr>
<tr>
<td>Drop Calls</td>
<td>ETCS Call Counters</td>
</tr>
<tr>
<td>Disconnected Calls from Ground System</td>
<td>ETCS Call Counters</td>
</tr>
<tr>
<td>Unknown Reason Disconnected Calls</td>
<td>ETCS Call Counters</td>
</tr>
<tr>
<td>Standard Deviation of Odometry Errors</td>
<td>ETCS</td>
</tr>
<tr>
<td>Number of TNV_CONTACT timeouts</td>
<td>ETCS</td>
</tr>
<tr>
<td>Number of missing information points</td>
<td>ETCS</td>
</tr>
<tr>
<td>RBC Handover with the same MT</td>
<td>ETCS</td>
</tr>
<tr>
<td>Movement Authority Missing Acknowledge</td>
<td>ETCS</td>
</tr>
<tr>
<td>LAPD/LAPB protocol errors</td>
<td>ETCS</td>
</tr>
</tbody>
</table>
The following table provides Train Trips break-down by NID_Engine:
- NID_Engine of faulty train
- NID_Operational of faulty train run
- Number of occurrences
- Timestamp of event

Note: Same NID_Engine can appear on multiple lines.

<table>
<thead>
<tr>
<th>nid_engine</th>
<th>nid_operational</th>
<th>Train Trips</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>9637</td>
<td>1</td>
<td>12/11/10 22:35</td>
</tr>
<tr>
<td>202</td>
<td>9517</td>
<td>1</td>
<td>7/10/10 19:39</td>
</tr>
<tr>
<td>217</td>
<td>9528</td>
<td>1</td>
<td>11/10/10 15:23</td>
</tr>
<tr>
<td>227</td>
<td>9530</td>
<td>1</td>
<td>20/10/10 17:04</td>
</tr>
<tr>
<td>227</td>
<td>9612</td>
<td>1</td>
<td>27/10/10 8:16</td>
</tr>
<tr>
<td>236</td>
<td>9505</td>
<td>1</td>
<td>13/8/10 11:35</td>
</tr>
<tr>
<td>238</td>
<td>9532</td>
<td>1</td>
<td>24/10/10 17:00</td>
</tr>
<tr>
<td>244</td>
<td>9513</td>
<td>1</td>
<td>25/8/10 15:57</td>
</tr>
<tr>
<td>245</td>
<td>9527</td>
<td>1</td>
<td>26/8/10 20:56</td>
</tr>
<tr>
<td>246</td>
<td>9522</td>
<td>1</td>
<td>29/8/10 12:13</td>
</tr>
<tr>
<td>250</td>
<td>9532</td>
<td>1</td>
<td>16/7/10 17:19</td>
</tr>
<tr>
<td>250</td>
<td>9530</td>
<td>1</td>
<td>9/9/10 16:40</td>
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<td>5804</td>
<td>9530</td>
<td>2</td>
<td>18/7/10 16:11</td>
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<td>9626</td>
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<td>29/10/10 14:50</td>
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<td>5825</td>
<td>9510</td>
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<td>17/10/10 8:00</td>
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<td>5831</td>
<td>9603</td>
<td>1</td>
<td>21/7/10 11:24</td>
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<td>5846</td>
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<td>7/10/10 20:19</td>
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<tr>
<td>5964</td>
<td>9374</td>
<td>1</td>
<td>29/8/10 12:29</td>
</tr>
</tbody>
</table>
This chart provides ETCS call closed by NID_Engine:

- Disconnection is evaluated on ETCS channel
- DISCONNECTION_REQUEST X.224 is missing
- One of two endpoints closes the call without DISCONNECTION_REQUEST message or whenever RBC requires the disconnection
This chart provides Worst Odometry errors associated to their NID_Engine:

- Parameter is evaluated as sum of Under Reading and Over Reading Errors
- Over reading and Under reading are taken straight from Train Position Reports
This chart provides average Frame Error Rate associated to its NID_Engine:

- Parameter is evaluated at LAPB level
- FER is more than Zero if LAPB packets are retransmitted
As anyone can spot large part of failures belong to Radio Interface GSM-R Errors

- Radio Interface Message Failures (GSM-R) account for over 71%
- Radio Interface Failure in general (EURORADIO) accounts for 16%
- Another 10% is due to unspecified causes.
New Challenges

• Deeper ETCS investigation
• ETCS Application Layer Analysis at functional level
• Design requirements validation (e.g. vs FFFIS)
• Formal requirements description language
• Extended data collection platform (e.g. EVC Logs)
• Automated incident analysis
• Certified Engine
New Data Sources

Schematic Plan Management
- Main design Data (Name, Revision, Date, Supplier, Initial and Final Km.
- Balise, Track Circuits and all other relevant items along the line
- Altitude and Speed profiles

Network parameter configuration
- Track Circuit Installation Rules
- Balise Telegram Tables
- RBC Message Tables
- RBC Condition Tables

Train-Ground Communication
- Performs the acquisition of RBC-MSC communication
- Aggregates traffic by HSL, NID_Engine, NID_Operational, Direction, Type, involved RBCs

Ground-Ground Communication
- Interlocking Status Update
- RBC to RBC communication
- Interlocking to Interlocking communication

Diagnostic Trains Data
- Track Quality Index
- Electric and Tracion
- Telecommunication
- Balise
Requirements Validation

**Speed Profile**
- Evaluates:
  - Static Speed Profile (through schematic plans)
  - Dynamic Speed Profile (through radio messages)
  - Slowdowns
  - The system also evaluates TSRs events

**Voltage and Phase Condition Change Transmission**
- Verifies that Voltage and Phase Conditions Change are properly sent to the train accordingly to implementation guidelines.
- It also monitors and evaluates hot box measurement systems

**Rendezvous Logic**
- Verifies Balise linking in terms of:
  - First Item
  - Proper Direction
  - Proper Sequence

**RBC radio coverage**
- The system verifies that interval between two messages is less than TNV_Contact timeout.
- In case such an event occurs the system evaluates that EVC complies with such parameter.
Thank you for your attention!

Fabio Senesi
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