The Viability of TETRA for ETCS Railway Signalling System

Nets4trains 2016, San Sebastian, Spain
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   - Why GSM-R in Europe
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Introduction
Signalling systems available in the market

**ETCS**

**European Train Control System**
- Used mainly in high speed lines in Europe
- It is part of the European standard ERTMS, defined by the UIC (International Union of Railways)
- Target: Interoperability of cross-border traffic

**CBTC**

**Communication Based Train Control**
- Used in conventional lines, metros or tramways (mass transit)
- It is not standard, interoperability is not guaranteed.
- Each manufacturer has developed a different solution

**PTC**

**Positive Train Control**
- System similar to ETCS but developed in USA
- Today, not so extended than ETCS in Europe. It is in definition process
Wireless technology for railway operations

Some of history…

The Union Internationale des Chemins de Fer (UIC) in 1997 chose the GSM standard as a basis for its future digital mobile system, at a time when the TETRA standard was just being established.

This led to the specification of the GSM-R standard (GSM for railway), and the introduction of Voice Broadcast Calls, Voice Group Calls and Priority features as new added services in GSM.

GSM-R was the most mature technology at that time, and was elected by 1 vote in competition with TETRA.
ERTMS: European Rail Traffic Management System

ERTMS (European Rail Traffic Management System)

ETCS (European Train Control System)

GSM-R (radio-communication system)
Why ERTMS in Europe?

The election of a radio technology makes easier the interoperability between international rail networks.
What happens in other rail environments? (I)

Is the interoperability a real requirement in all the rail networks?

International networks in Europe

National networks

Regional networks

Urban lines

Outside Europe
What happens in other rail environments? (II)

Why are not possible other alternatives for the communication system?
ETCS Signalling over TETRA
ETCS Signalling over GSM-R

- **ETCS requirements:**
  - Exchange vital data between the on board part (train) and the fixed part (RBC), holding the communications 100% of time.

- **GSM-R requirements**
  - QoS Requirements for GSM-R in ERTMS: EIRENE Specifications, Subset 093 [1]

<table>
<thead>
<tr>
<th>QoS Parameter</th>
<th>Value (see 6.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection establishment delay of mobile originated calls</td>
<td>&lt; 8.5s (95%), ≤10s (100%)</td>
</tr>
<tr>
<td>Connection establishment error ratio</td>
<td>&lt;10^-2</td>
</tr>
<tr>
<td>Maximum end-to-end transfer delay (of 30 byte data block)</td>
<td>≤ 0.5s (99%)</td>
</tr>
<tr>
<td>Connection loss rate</td>
<td>≤ 10^-2 /h</td>
</tr>
<tr>
<td>Transmission interference period</td>
<td>&lt; 0.8s (95%), &lt;1s (99%)</td>
</tr>
<tr>
<td>Error-free period</td>
<td>&gt;20s (95%), &gt;7s(99%)</td>
</tr>
<tr>
<td>Network registration delay</td>
<td>≤30s (95%), ≤35s (99%), ≤40s (100%)</td>
</tr>
</tbody>
</table>

*Subset-093 (GSM-R Interfaces - Class 1 Requirements)*
TETRA solution scheme

WAYSIDE EQUIPMENT  TETRA AIR INTERFACE  ON-BOARD EQUIPMENT

ZCs Network

TETRA NEBULA Infrastructure

ZC Zone controller

TETRA On-board Radio

OBC On-board computer

Signaling System

TETRA Communication System

TETRA data Communication Solution for Rail Signalling = TETRA NEBULA Infrastructure + On-Board Equipment
Circuit Mode Data (CMD)

CMD General Characteristics

Phases

- SET-UP (TCH Assignment)
- DATA TRANSFER
- RELEASE

Notes:
- Once the connection is established ➔ Channel **TCH busy until end call**
- Sent **transparent** between fixed and on-board Applications through TETRA Air Interface.

- Types of CMD calls supported by TETRA standard:
  - CMD Call Types
    - Point-to-point
      - Full-Duplex
      - Half-Duplex
    - Multipoint
      - Half-Duplex

- CMD calls at different speeds with different levels of protection (Speed vs Security):
  - CMD Calls
    - Unprotected TCH 7.2Kbps
    - Protection TCH 4.8Kbps
    - Protection TCH 2.4Kbps
ETCS Signalling over CMD

Scenario Test – Laboratory Environment
ETCS Signalling over CMD

RF Simulate Handover – Laboratory Environment

RX1

RX2

TX1

TX2

Sim CH1

ATT

Duplexor

On-board equipment

Sim CH2

Limit of Dynamic Sensitivity (-99/-102dBm)

Simulating HT100

Test Conditions
**TETRA QoS performance according to EIRENE**

**Connection Establishment**
- **Definition:** Value of elapsed time between the connection establishment request (ATD) and the indication of successful connection establishment (CONNECT).

- **Measurement:** 10,000 calls originated every 6 seconds from on board part to fixed part, by means of the proper AT commands through RS-232 radio interface.

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;8.5 s (95%) and ≤10 s (100%)</td>
<td>&lt; 1s (100%)</td>
</tr>
</tbody>
</table>

**Connection Establishment error ratio**
- **Definition:** Ratio of the number of unsuccessful connection establishment attempts to the total number of connection establishment attempts.

- **Measurement:** Same test as Connection Establishment.

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10^{-2}</td>
<td>0</td>
</tr>
</tbody>
</table>
TETRA QoS performance according to EIRENE

Maximum end-to-end transfer delay

- **Definition**: Time between the request for transfer a user data block of 30 bytes and the indication of successfully transferred end-to-end user data block

- **Measurement**: Packet transmission of 30 bytes every second between fixed and on board part. Packet data transfer is maintained for 1 hour in 4 sessions.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Link</th>
<th>Maximum Delay (s)</th>
<th>Average delay (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Uplink</td>
<td>0.402</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.360</td>
<td>0.194</td>
</tr>
<tr>
<td>2</td>
<td>Uplink</td>
<td>0.377</td>
<td>0.219</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.372</td>
<td>0.195</td>
</tr>
<tr>
<td>3</td>
<td>Uplink</td>
<td>0.449</td>
<td>0.214</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.402</td>
<td>0.196</td>
</tr>
<tr>
<td>4</td>
<td>Uplink</td>
<td>0.433</td>
<td>0.215</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.372</td>
<td>0.194</td>
</tr>
</tbody>
</table>

**TETRA end-to-end delay transfer**

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5 s (99%) *** User data block 30 Bytes</td>
<td>&lt; 0.5 s (100%) ***User data block 30 Bytes</td>
</tr>
</tbody>
</table>
TETRA QoS performance according to EIRENE

Transmission Interference Period (TTI)

- **Definition**: Period of time in which there may be loss of information or information received with errors (mainly handovers, the most critical moment of the communications).

- **Measurement**: Packet transmission of 30 Bytes between fixed and on board part every second with handovers every minute. Packet data transfer is maintained for 1 hour 4 times.

<table>
<thead>
<tr>
<th>HANOVER TYPE</th>
<th>TTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;0,8 s (95%) and &lt;1 s (100%)</td>
</tr>
<tr>
<td>3</td>
<td>&lt;1 s (95%) and &lt;3 s (100%)</td>
</tr>
</tbody>
</table>

**TETRA Transmission Interference Period**

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0,8 s (95%) and &lt;1 s (100%)</td>
<td>HO1: &lt;0,8 (95%) and &lt;1s (100%)</td>
</tr>
</tbody>
</table>
TETRA QoS performance according to EIRENE

Error-Free Period (TRec)

- **Definition**: An error-free period (Trec) shall follow every transmission interference period (TTI) to retransmit user data units or user data units not received along with user data units waiting to be served.

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;20 s (95%) and &gt; 7s (99%)</td>
<td>&gt;20s (100%)* Theoretical calculations</td>
</tr>
</tbody>
</table>

- **Analysis**: 

![Diagram showing TETRA QoS performance with SBS1 and SBS2, 14Km (min) distance, 100Km/h speed, and 500 sec time interval.]

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TETRA QoS performance according to EIRENE

Network registration Delay

- **Definition**: Value of time elapsed from the request of registration of the radio terminal to the indication of successful registration.

- **Measurement**: Elapsed time between turning on the radio and the reception of the register command. Test performed 200 times.

<table>
<thead>
<tr>
<th>EIRENE Requirements</th>
<th>CMD TETRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30 s (95%) and ≤ 35 s (99%)</td>
<td>&lt;15 s (100%)</td>
</tr>
<tr>
<td>&gt;40 s (errors)</td>
<td></td>
</tr>
</tbody>
</table>
Addional TETRA QoS performance

Bit Error Rate (BER)

- **Definition**: Number of erroneously received bits compared to the total number of bits sent in a given time interval.

- **Measurement**: All previous test.

| CMD TETRA | <10^-4 |

Maximum Speed

- **Definition**: A maximum speed of up to 200 km/h must be guaranteed without affecting the QoS parameters.

- **Analysis**: Empirical proof and theoretical calculations performed. Speed conditioned by the dynamic sensitivity and the maximum frequency deviation produced by the Doppler effect.

\[
V \leq \frac{500 \times C}{f - 500}
\]

- \( f = 470\text{MHz} \quad V \leq 1148\text{Km/h} \)
- \( f = 870\text{MHz} \quad V \leq 620.7\text{Km/h} \)

| CMD TETRA | >200km/h* |
TETRA additional features
TETRA: Additional features (I)

- Frequency band

TETRA operates in frequency bands from 300 MHz and higher. GSM-R, operate in the 800-900 MHz bands. It requires many more base station repeaters than TETRA to obtain the same coverage.

→ Savings not only in radio equipment, but also in civil engineering (buildings/shelters, towers, etc…)

- Spectrum efficiency

TETRA is 4 times more efficient using the spectrum than GSM-R. It provides 4 channels in a bandwidth of 25 KHz, while GSM provides 8 channels in 200 KHz

→ The use of the spectrum, which is a very limited resource today, is clearly optimized with TETRA
**TETRA: Additional features (II)**

- **IP technology**

  TETRA manufacturers have tended to 100% IP-based systems providing services to third parties via an IP connection. On the contrary, GSM-R provides a Primary Rate ISDN (PRI) interface.

  \( \Rightarrow \) **TETRA implementation saves money comparing GSM-R due to the high costs of E1 links and the maintenance those require**

- **Technology usage profile**

  GSM-R (based on GSM) was developed for mobile telephony. The infrastructure cost is supported by millions of subscribers.

  TETRA was initially created for low density user private systems, with a usage profile closer to the railway system requirements.

  \( \Rightarrow \) **TETRA technology is much more cost-efficient and it is designed and dimensioned for the customer.**

- **Functionality**

  TETRA offers group calls, emergency calls, priorities management, group dynamically assigned, ambience listening calls, direct mode as well as various data services.

  \( \Rightarrow \) **TETRA includes in the standard native features that fit with railway requirements meanwhile GSM-R adapted the basic technology to meet such functional requirements**
Conclusions
Conclusions

- **ERTMS standard solves railway interoperability problems between high speed and conventional trains crossing European borders** by using ETCS and GSM-R.

- ETCS is considered one of the safest and most efficient protection systems. Implemented beyond Europe, in China, India, Taiwan, Saudi Arabia or South Africa.

- Other scenarios like **national, regional, metropolitan European lines and any kind of system outside Europe can use other technologies like TETRA** as GSM-R is not mandatory.

- TETRA meets naturally EIRENE requirements established for communications as GSM-R does.

- Furthermore, TETRA provides technical advantages that make it a **better alternative to GSM-R**.

- There is a **real reference working on field** of ETCS over TETRA in Kazhastan.
Thank you very much!

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