How 5G technologies could benefit to the railway sector: challenges and opportunities

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Trains and Radio

- Safety-critical train operation: an evolution required
  - GSM-R predicted obsolescence by 2030
  - Next generation needed by 2025 (5 years migration)
  - A COTS solution being operated on a dedicated spectrum is the preferred option by railway operators
- Additionally, a large set of safety-related services identified for railway operations
- Passengers comfort: a revolution expected
  - Poor cellular QoS inside trains so far
  - Dedicated deployment using cellular spectrum along railway tracks in slow progress
  - ... whereas 5G is coming soon around the train

How to make the most of future access network infrastructures?
5G Consumer Scenarios: Coverage & Capacity

Capacity:
Multi-Gbit/s User Throughput

Coverage

Capacity:
Ultra-Dense Network

Capacity:
Group Mobility
5G Key Radio Access Technologies

x10 spectrum efficiency
  – Use very narrow antenna beams for spatial user multiplexing: Massive MIMO

x10 network density
  – Reduce deployment footprint: RF/Baseband functional split (RRH/BBU)
  – Optimize mobility: Control plane/User plane separation

x10 spectrum
  – Aggregate bands including Millimeter wave bands (up to 100 GHz)
  – Reserve low bands for coverage and use millimeter wave bands for capacity

1 ms latency
  – Reduce the minimum slot duration: mini-slot, shorter symbols
  – Distribute network intelligence close to the base stations: Edge computing

Source: 5GPPP
3GPP Evolutions Towards Verticals

From a set of **add-on** in 4G (LTE-A) standard...

- Mainly driven by public safety (adoption in US in 2012)
- LTE-Pro released in Mar.2016 (Rel.13)

... to **native requirements** in 5G

- Mar. 2015: SA study of 5G use cases (FS_SMARTER)
  - Incl. critical communications
  - Follow-up Work Item until Mar.17
- Sept. 2015: 5G RAN workshop
  - Phase 1 (consumer), Phase 2 (professional)
- Dec. 2015: EU Commission liaison with 3GPP to consider uses cases from verticals as drivers of 5G basic requirements (phase 1)
5G Professional Scenarios: Reliability

- Emergency communication
- Large-scale events
- Aeronautical communication
- M2M communication
- Multi-angle real-time communication
- B2B communication
- 4K/8K digital signage
- New train guidance
- Remote control
- High-speed railway communication
- Automated operation
- Car telematics
- Network appliances
- 5G Slave Base Station (RRH)
- 5G Master Base Station (BBU)
Train-Specific Requirements in 5G

• Train-specific service requirements (SA)
  – Study on Future Railway Mobile Communication System (SA1, TR 22.989)
    • Gap analysis between existing 3GPP functions and FRMCS user requirements
    • To be completed probably in Mar. 2017
    • First use cases agreed: Access to the system, Uncontrolled power down, Invitation to a voice communication, Assured Voice Communication (AVC) (for shunting operation), role management and presence, location services, interworking with GSM-R

• Train-specific deployment scenarios (RAN)
  – Study on 5G Scenarios and Requirements (RAN, TR 38.913)
    • Radio parameters: carrier frequency, inter-site distance, user density, max. mobility speed
    • Critical train communications are included in high speed scenario
    • To be completed in Dec. 2016 and sent to ITU-R WP5D
**Tentative Roadmap of 5G Deployments**

<table>
<thead>
<tr>
<th>2016-2020</th>
<th>2021-2025</th>
<th>2026-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rel.14: Standard</td>
<td>Rel.15: 5G basic features (incl. mmw &lt; 40 GHz + URLLC)</td>
<td>Migration from GSM-R to next system</td>
</tr>
<tr>
<td>Product</td>
<td>Trials of next system</td>
<td>Possible end of GSM-R support</td>
</tr>
<tr>
<td>Deployment</td>
<td>First 5G release</td>
<td></td>
</tr>
<tr>
<td>Rel.15: Demo @ PyeongChang Olympics</td>
<td>Rel.16: 5G advanced features (incl. massive MTC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rel.17: Not discussed yet</td>
<td></td>
</tr>
</tbody>
</table>

- **First 5G release** discussed in RAN #70 Plenary (Dec 2015)
- **Demo @ PyeongChang Olympics**
- **First 5G Deployment @ Tokyo Olympics**
Next Train Radio Access Dimensioning

- Many applications with different requirements
  - Throughput, reliability, service areas, train velocity
  - Ex: Platform CCTV (only close to station, at medium/low velocity)

<table>
<thead>
<tr>
<th>Client services</th>
<th>Link</th>
<th>Safety Communications</th>
<th>Application priority</th>
<th>Data rate per link</th>
<th>Number of links per line</th>
<th>Cumulative data rate (in kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>train</td>
<td>ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Control System</td>
<td>Car Controller</td>
<td>Zone controller</td>
<td>Yes</td>
<td>High</td>
<td>10 kbps</td>
<td>40 trains 100 trains 400 1000</td>
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<tr>
<td></td>
<td>Car Controller</td>
<td>Central controller</td>
<td>Yes</td>
<td>High</td>
<td>20 kbps</td>
<td>40 trains 100 trains 800 20000</td>
</tr>
<tr>
<td>Maintenance Management System</td>
<td>Train Information</td>
<td>Central</td>
<td>No</td>
<td>Low</td>
<td>0.5 kbps</td>
<td>40 trains 100 trains 20 50</td>
</tr>
<tr>
<td></td>
<td>Car Controller</td>
<td>Central</td>
<td>No</td>
<td>Low</td>
<td>0.5 kbps</td>
<td>40 trains 100 trains 20 50</td>
</tr>
<tr>
<td>Video Transmission</td>
<td>Train Video</td>
<td>Central Controller</td>
<td>No</td>
<td>Low</td>
<td>2000 kbps</td>
<td>2 video flows 4 video flows 4000 8000</td>
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<tr>
<td>Audio Transmission</td>
<td>Audio in Train</td>
<td>Central Controller</td>
<td>No</td>
<td>Low</td>
<td>64 kbps</td>
<td>20 calls 200 calls 1280 12800</td>
</tr>
<tr>
<td>Passanger Information System</td>
<td>Train Information</td>
<td>Central Controller</td>
<td>No</td>
<td>Low</td>
<td>10 kbps</td>
<td>40 trains 100 trains 400 10000</td>
</tr>
<tr>
<td>Other</td>
<td>Train</td>
<td>Central Controller</td>
<td>No</td>
<td>Low</td>
<td>10 kbps</td>
<td>40 trains 100 trains 400 10000</td>
</tr>
</tbody>
</table>

Exemple of train radio access dimensioning (urban rail requirements, Source ETSI TR 103111)

- UIC dedicated spectrum not enough to handle all FRMCS applications
  - Reserve UIC spectrum for high priority operational applications
  - Use shared/public spectrum for lower priority applications
How 5G may impact next generation train radio infrastructures

• Towards an heterogeneous infrastructure

1. For the basic set of **high-priority applications**: Dedicated macro-cell layer reusing existing GSM-R masts on UIC frequency bands

2. For **new FMRCs applications**: Shared pico-cell layer taking benefit of future passenger-oriented deployment by telcos along railways tracks
   - Additional antennas on millimeter wave bands offering enough capacity
Opportunities and Challenges

• Requirements of vertical sectors considered natively in 5G
  – Insertion of railway scenario and radio requirements under progress
• 5G stable products below and above 6 GHz may be available by the time of migration from GSM-R to the next standard radio system
• 3GPP is fully engaged on 5G ultra-fast development with first deployment planned from 2020
  – E.g., RAN1: ~600 delegates, 9 meetings/year, >2000 contributions/meeting
  – Making sure 5G technologies are validated for railway scenarios requires a significant effort by railway stakeholders
• The limited UIC dedicated spectrum may imply using two radio access network infrastructures with a phased deployment
  1. A soft-migration of the current infrastructure (same sites & spectrum)
  2. The deployment of a capacity-oriented infrastructure after careful validation of brand new 5G high-frequency technologies in railway environments
Thank you for your attention