ETSi Workshop: Developing the Future Radio for Rail Transport

Next Generation TCMS and Adaptable Communication System

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### INNOVATION PROGRAMS

<table>
<thead>
<tr>
<th>IP1</th>
<th>IP2</th>
<th>IP3</th>
<th>IP4</th>
<th>IP5</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost-effective and reliable trains, including high-capacity trains and advanced traffic management and control systems</td>
<td>X2RAIL 1</td>
<td>cost-efficient, sustainable and reliable high-capacity infrastructure</td>
<td>IT solutions for attractive railway services</td>
<td>technologies for sustainable and attractive European freight</td>
</tr>
<tr>
<td>long-term needs and socio-economic research</td>
<td>smart materials and processes</td>
<td>system integration, safety and interoperability</td>
<td>energy and sustainability</td>
<td>human capital</td>
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</table>

**Key objective**
- Doubling railway capacity
- Increasing reliability and punctuality by as much as 30% in the railway sector
- 50% reduction of life-cycle costs
Adaptable Communication System

TCMS

Technology Demonstrator (TDs)
Projects specifying, developing and demonstrating a specific technology resulting in a lab tested and/or simulated prototype

Integrated Technology Demonstrators (ITDs)
Projects integrating/combining TD prototypes at system level (lab and on-site) and testing performance

System Platform Demonstrators (SPDs)
Assessment of the whole systems performance based on the results of TDs and ITDs. SPDs bring S2R innovative solutions to a technology maturity level for a new generation of railway systems

Metro / Urban
Mainline
Highspeed
Regional
Freight
### ADAPTABLE COMMUNICATION SYSTEM IN SHIFT2RAIL IP2

<table>
<thead>
<tr>
<th>TD2.1 Adaptable Communication System</th>
<th>X2RAIL 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD2.2 Automatic Train Operation (ATO)</td>
<td>X2RAIL 1</td>
</tr>
<tr>
<td>TD2.3 Moving Block</td>
<td>X2RAIL 1</td>
</tr>
<tr>
<td>TD2.4 Safe Train Positioning</td>
<td>X2RAIL 2</td>
</tr>
<tr>
<td>TD2.5 Train Integrity</td>
<td>X2RAIL 2</td>
</tr>
<tr>
<td>TD2.6 Zero on-site testing</td>
<td>X2RAIL 1</td>
</tr>
<tr>
<td>TD2.7 Formal methods</td>
<td>X2RAIL 2</td>
</tr>
<tr>
<td>TD2.8 Virtual Coupling</td>
<td>X2RAIL 1</td>
</tr>
<tr>
<td>TD2.9 Traffic Management System</td>
<td>X2RAIL 2</td>
</tr>
<tr>
<td>TD2.10 Smart wayside objects</td>
<td>X2RAIL 1</td>
</tr>
<tr>
<td>TD2.11 Cyber Security</td>
<td>X2RAIL 1</td>
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</table>

Forthcoming project

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**ETSI Workshop: Developing the Future Radio for Rail Transport**
OBJECTIVES OF THE ADAPTABLE COMMUNICATION SYSTEM

Railway Communication
Specification, development and test of prototypes of a train-to-ground radio system to support existing train control systems as well as new innovation and applications introduced by Shift2Rail projects.

Bearer independent
Design a “technology independent” system, avoiding as far as possible any specific railway solution to reduce LCC. Allow future evolutions of the radio bearer without impact to the applications to keep the cost of the system as low as possible. Able to make ‘best possible’ use of available resources.

Support convergence
Address convergence of metro and mainline applications, standardization of function and services with a technology independent approach to share cost and allow interoperability.

New business models
Encompass new business model definitions supporting the shift from "network as an asset" to "network as a service" model vision.

The future communication backbone to enable innovation and digitalization for all railways
ADAPTABLE COMMUNICATION SYSTEM IN X2RAIL-1

- User & System Requirements
- Business Model Analysis
- System Specification
- Choice of Technology
- Prototype Definition and Development
- Test Strategy
- Lab Demonstrators
  - Metro/Urban
  - Mainline/Highspeed
  - Regional/Freight

- Today
- WP3 End: Feb. 2019

Forthcoming project linked to AWP2018

ETSI Workshop: Developing the Future Radio for Rail Transport
BUSINESS MODELS & CHOICE OF TECHNOLOGY

Network Ownership Models
- Dedicated Mobile Network
- Dedicated Network with Supplementary Public Network
- Dedicated Network, Radio Access Network Sharing with Public Network
- Public Network, Infrastructure Manager as Mobile Virtual Network Operator
- Public Network

Evaluation for four market domains in terms of Cost Analysis and SLA:
- High-speed / Mainline
- Urban / Metro
- Regional
- Freight

Selection Criteria:
- System Requirements
- Traffic Model
- Radio Link Characteristics
- Coexistence and Interoperability

Calculation of KPIs to support a quantitative and qualitative comparison

- Frequency Band
- Support of GSM-R Band
- Use of paired / unpaired spectrum
- Channel Bandwidth
- Possibility of Carrier Aggregation
- Maximum Aggregated Bandwidth
- Typical Frequency Re-Use
- Transmission Transfer Interval (TTI)
- TTI Bundling
- Downlink Multiple Access
- Uplink Multiple Access
- Duplex Mode
- Support of Hybrid ARQ
- Support of Incremental Redundancy
- Support of Adaptive Coding & Modulation
- Support of MIMO
- Support of Dynamic Scheduling
- Peak Downlink Data Rate
- Peak Uplink Data Rate
- Peak Downlink Data Rate @ 5MHz
- Peak Uplink Data Rate @ 5MHz
- Peak Downlink Spectral Efficiency
- Peak Uplink Spectral Efficiency
- Average Throughput Cell Center @ 5MHz
- Average Throughput Cell Edge @ 5MHz
- Guaranteed Minimum Throughput Cell Center
- Guaranteed Minimum Throughput Cell Edge
- Average Spectral Efficiency (Railway)
- Maximum Supported Speed
- Measures against Doppler
- Measures against multipath propagation
- Railway-compatible propagation profiles
- Minimum User Plane Latency
- Connection Setup Time
SPECIFICATION - ADAPTABLE COMMUNICATION SYSTEM ATTRIBUTES

- Communication services for all railway applications, fully decoupled and independent from underlying radio technology and network topology
- Multi-access & multi-radio and resilient to radio technology evolution
- Traffic prioritization, flow segregation and service pre-emption
- Link aggregation and logical link reliability
- Superior service availability for critical railway applications
- Radio management, mobility inter-network and inter-technology handover completely transparent to applications
- Support of end-to-end application security
- Enable new operating models including “Network-as-a-Service”
SHIFT2RAIL IP1: FROM TCMS TO WTCMS

- Multiple wired networks.
- Train lines for safety applications.
- Each subsystem its control unit.
- Only mechanical coupling.

- SIL4 ready system. TSN wired network.
- No train lines.
- Wireless Train Backbone (WLTB) for coupled units (allows Virtual Coupling).
- Wireless Consist Network (WLCN).
- Integrated VCU with Functional Distributed Function.
<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>DATA CLASS</th>
<th>DATA SIZE</th>
<th>DATA RATE NEED</th>
<th>CYCLE TIME</th>
<th>LATENCY</th>
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<td>TCMS</td>
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<td>10Mbit/s</td>
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<tr>
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<td>Forbidden</td>
<td>250ms</td>
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<tr>
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<td>Process</td>
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<td>[No need]</td>
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<tr>
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<td>Message</td>
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<tr>
<td></td>
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<td>100 Kbit/s audio channel</td>
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<td>0.1 s for audio, 0.5 s for video</td>
</tr>
</tbody>
</table>

**Notes:**
- TCMS = Train Control and Management System
- 3CycleTime and 7CycleTime refer to specific time intervals considered for train operations.
- The latency should be between 0 and max.
CURRENT EXPERIMENTAL ARCHITECTURE

Based on cellular network (LTE)

Pros

› Scheduled radio resource allocation -> Predictable performance -> Safety.
› Possible with current market technology.

Cons

› Need of eNB and UE in each consist (costs↑↑↑).
› No multicast support in the Uplink (needed for TRDP).
› Not aligned with other industries’ trends (C-V2X: V2V, V2I, V2P…).
› Thoughput limitation in harsh environments.
WLTB: RESULTS OF TESTS

**Depot tests:**
- The PD downlink LTE tests present a FER of 15% which can be derived from the attenuation of the wireless link due to the distance between the antennas and the attenuation of the cables.
- Tests at 3.2 Mbps have been supported with low FER and latency; not at 256 Mbps.

**Field Tests:**
- UL performs significantly worse than DL:
  - The UL uses a single-carrier modulation, which is less robust against multipath and Doppler effects.
  - UL is also based on 1x2 MIMO, while DL is based on 2x2 MIMO and multicarrier modulation.

**General conclusions:**
- Current architecture is complex and expensive: 1 eNB+EPC per consist.
- The network requirements can only be achieved with broader bandwidth: difficulties to obtain such big frequency reservation.
- High effect of environment, need for more directive communications.
WORK TO BE DONE IN CONNECTA-2: EVOLVED WLTB

Future steps to overcome limitations:

› Split C2C communications in 2 networks:
  › TCMS->Cellular-based communications. High reliability, low latency, low throughput needs.
  › OMTS->802.11-based communications. Best effort traffic, high throughput needs.
› Evolve to PC5-based communications: 1UE per consist instead of eNB+EPC+UE.
› Apply Massive MIMO and adaptable beamforming to reduce environment impact on communications.
› Higher transmission power or active antennas.
› Do not start from scratch but from C-V2X.
  › Present the WLTB Use Case in ETSI/3GPP to be adopted by release 16.
  › Start testing the PC5 interface to evaluate its performance (BER) and impact in safety traffic.
UPCOMING EVOLUTION OF WLTB

Pros:
› Costs ↓↓↓
› Direct communication->Low latency.
› Aligned with other industries (bigger market due to C-V2X).
› New possibilities: T2V (Train-to-vehicle), T2P (Train-to-Pedestrian), T2I (Train-to-Infrastructure) for shared platforms (e.g. trams or level crossings).
› Integrated within 3GPP roadmap.
› Possibility to integrate with 3GPP-T2G.

Cons:
› C-V2X only for vehicular industry (possible to use in other frequencies?).
› C-V2X Phase1 (Release 14) max period of 100ms and latency of 20ms.
› Communication range 300m-320m and no relay mechanism for the moment.
› Low data-rate (Possible to overcome by combining with other 802.11-based comms for non-safety traffic).
WLTB & T2G ROADMAP (I)

WLTB
- Tests on real vehicles LTE r11
- Demo: Functional WL TB LTE r11
- WL TB LTE r14-15 interoperability tests

T2G
- Interoperability tests IEC61375-2-6
- Demo: Interoperability
- Exploring integration of safe & non-safe T2G
- Full demo on real vehicles unified T2G
BUILDING THE COMMUNICATION LAYER FOR THE FUTURE RAIL SYSTEM

TCMS
On-Train, Train-to-Train & Train-to-Ground communications
Supports safety and non-safety functions
Enables signalling, control, train integrity, virtual coupling
Ongoing Synchronisation and Alignment with FRMCS

ACS

Next Steps
• Plan to integrate the prototypes for validation in a lab environment and field trials
• Validate key characteristics and benefits to the rail system

TCMS
Train Integrity
Virtual Coupling

TD
Automatic Train Operation (ATO)

Cyber Security
Adaptable Communications System

TD
TCMS
Thank You!

This is the future...