Next Generation of Railways and Metros wireless communication systems

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Alain BERTOUT Alcatel-Lucent
Wireless communication: What’s at stake for Rail?

Some of the key challenges that train/metro operators are facing today:

- Overcoming increasing traffic,
- Ensuring passengers safety and security during their journey,
- Improving travel comfort,
- Providing real time multimedia information and access to social networks in stations or in motion.

Those challenges pertain to the following operational domains:

- Operation of the transportation system
- Safety and security
- Passenger experience
Communication at the core of converged rail operations
Railway application requiring wireless communications

Two main families of applications with very different constraints and specifications can be defined:

**Vital Application** such as signalling and control/command of equipment.
- low bandwidth (some 10 to 100 kbps) but high degree of availability (at least 99.99%),
- robustness and reliability (e.g. packet error rate of 10^{-3} for 200 byte packet).

CBTC (Communication Based Train Control) for metros or ETCS (European Train Control System) for mainline trains.

**Non-vital applications** such as Passenger Information, remote maintenance, on-board video surveillance, CCTV for track or platform monitoring, internet access, etc.
- much higher bandwidth (several 10s of Mbits/s in both direction train-to-ground and ground-to-train),
- lesser robustness constraints (e.g. packet error rate of 10^{-2} for 1Mbyte packet length).
Ground to train requirements
Typical bandwidth per train

<table>
<thead>
<tr>
<th>Applications</th>
<th>G2T</th>
<th>T2G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalling</td>
<td>10 to 100 kbps</td>
<td>10 to 100 kbps</td>
</tr>
<tr>
<td>Voice dispatch</td>
<td>10 to 100 kbps</td>
<td>10 to 100 kbps</td>
</tr>
<tr>
<td>Platform TV</td>
<td>~2 to 4 Mbps</td>
<td>&lt; 50 kbps</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Up to 100 kbps</td>
<td>Up to few 100 kbps</td>
</tr>
<tr>
<td>Emergency Call Point</td>
<td>10 to 100 kbps</td>
<td>10 to 100 kbps</td>
</tr>
<tr>
<td>On-board CCTV</td>
<td>~50 kbps</td>
<td>~2 to 6 Mbps</td>
</tr>
<tr>
<td>PIDS</td>
<td>~100 kbps</td>
<td>~10 kbps</td>
</tr>
<tr>
<td>High Speed Internet</td>
<td>2 to 8 Mbps</td>
<td>500 kbps to 2 Mbps</td>
</tr>
</tbody>
</table>

Need for several Mbps, Real-Time, High availability, Multi-service.
Comparison of wireless technologies for Railways

<table>
<thead>
<tr>
<th>Technology comparison</th>
<th>GSM-R</th>
<th>TETRA</th>
<th>P25</th>
<th>WiFi</th>
<th>LTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational voice support</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>VoIP</td>
<td>VoIP</td>
</tr>
<tr>
<td>Broadband data support</td>
<td>&lt; 10kb/s</td>
<td>&lt; 10kb/s</td>
<td>&lt; 100kb/s</td>
<td>&gt; 10Mb/s</td>
<td>&gt; 10Mb/s</td>
</tr>
<tr>
<td>All IP (native)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Vital traffic support</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2T / call set up time</td>
<td>1 to 5 s</td>
<td>250ms</td>
<td>800ms</td>
<td>100ms</td>
<td>100ms</td>
</tr>
<tr>
<td>Priorities / pre-emption</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3 levels / no</td>
<td>9 levels / yes</td>
</tr>
<tr>
<td>Choice for operating frequency</td>
<td>900MHz UIC</td>
<td>400MHz PMR</td>
<td>700MHz + VHF</td>
<td>2.4 / 5.x GHz</td>
<td>400MHz to 3.5GHz</td>
</tr>
<tr>
<td>Market support (vendors)</td>
<td>3 vendors</td>
<td>+</td>
<td>limited (US specific)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Maturity</td>
<td>End of Life 2025</td>
<td>Mature</td>
<td>Mature</td>
<td>Widely adopted</td>
<td>Emerging</td>
</tr>
</tbody>
</table>

LTE has become the best of breed of wireless technology
Ground to Train Communication converging to 4G LTE

<table>
<thead>
<tr>
<th>Safety</th>
<th>Security maintenance</th>
<th>Passenger Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalling</td>
<td>Voice</td>
<td>Emergency Calls</td>
</tr>
<tr>
<td>Proprietary</td>
<td>TETRA</td>
<td>Maintenance</td>
</tr>
<tr>
<td>WiFi</td>
<td>TETRA</td>
<td>CCTV</td>
</tr>
<tr>
<td>WiFi</td>
<td>WiFi</td>
<td>DRV handling</td>
</tr>
<tr>
<td>WiFi</td>
<td>WiFi</td>
<td>WiFi</td>
</tr>
<tr>
<td>WiFi</td>
<td>WiFi</td>
<td>WiFi</td>
</tr>
<tr>
<td>High Speed</td>
<td>Internet, VoD…</td>
<td></td>
</tr>
</tbody>
</table>

LTE
LTE évolution 3GPP
A convergent standard for all technologies

Commercial radio technologies:
- GSM TDMA
- W-CDMA
- HSPA
- W-CDMA HSPA+
- TD-SCDMA
- CDMA 1X
- EV-DO Rev A
- EV-DO Rev B
- WiMAX 16d
- WiMAX 16e TDD
- WiMAX 16m FDD/TDD

Professional radio technologies:
- P25 (US)
- TETRA
- TETRA 2
- GSM-R

4G ITU:
100 Mb/s in mobility
1 Gb/s static

LTE R8/R9 FDD/TDD
LTE R10 FDD/TDD

Deployed
On-going
Future
Evolution path
Architecture 4G: “All-IP”

New, all-IP mobile core network introduced with LTE

- End-to-end IP
- Clear delineation of control plane and data plane
- Simplified architecture: flat-IP architecture with a single core
- Interfacing with legacy 2G/3G networks
LTE benefits for Railways

- **OFDMA** allows flexible spectrum allocation, augmenting radio coverage and peak traffic up to 300 Mbps with **MIMO** 4x4 antennas and 20MHz channels.

- Radio spectral efficiency can be increased by a 2 to 4 allowing better use of scarce radio spectrum while guaranteeing high availability required for train signaling.

- Many **bandwidth options** (from 1.4 MHz up to 20 MHz), railways operators can benefit from easer access to spectrum.

- **SON** (Self Organized Networks) makes automatic operation, configuration and optimization, avoiding Rail operator to manage complex configuration of radio, frequencies & performance parameters.
LTE – A fast adoption from March 2011 to May 2012*

March 2011
196 operators in 75 countries
17 commercial networks,... ...
73 planned by GSA by end 2012
*Source: GSA, 24th March 2011

May 8th 2012
319 operators in 97 countries
72 commercial networks
134 planned by GSA by end 2012
*Source: GSA, 8th May 2012

NAR: 2 to 16
Note: 5.7 m subs in US (03/2012)
Also +4 LTE n/w for Public Safety

EE: 4 to 12

WE: 9 to 22

CALA: 0 to 2

APAC: 2 to 13
Note: 4 m subs in SK (04/2012)

MEA: 0 to 7

APAC: 2 to 13
Note: 4 m subs in SK (04/2012)
LTE for next generation railway systems

Several elements driving the demand for the next generation of communication system for Rail, namely:

- New services demanding more bandwidth
- Life duration and anticipated obsolescence of existing systems
- Cost of rail specific systems, both in terms of CAPEX but also in OPEX with high level of maintenance

In this context LTE can be considered as a good candidate for this next generation given the very stringent specificities of rail constraints:

- Network High availability and robustness demanded by signalization and control
- A Quality Of Service being able to carry and prioritize both vital and non-vital services
- A bandwidth able to carry very “greedy” application such as video surveillance
- Fast handover between cells compatible with High Speed
- Communication robustness in urban environment

LTE standard offers all needed features of a radio access system to match transport specific needs without specific adaptation.
LTE – Use case for transmort
Lower Cost of ownership

- Optimisation of wireless communications for Rail
  - Single and standardised wireless system
  - Avoid costly operation & maintenance of several aging technologies
  - Can be shared for several transport modes (e.g.: Metro – Tram – Bus)
Ground to Train communication: LTE: a simpler architecture

On-Board Units

Non Vital Applications

Vital Applications

NodeB

RRH

CPRI

RRH

CPRI

Core Network

S-GW / P-GW (7750SR-12)

RADIUS

8950 AAA

8650 SDM (HSS)

9471 MME

Control

User

Servers at OCC

Non Vital Applications

Vital Applications
Innovations Alcatel-Lucent in wireless

lightRadio™

Innovative radio access network architecture

« Green », lower costs, multi-standard

Smaller, simpler, more flexible

lightRadio™ Cube (antenna + RF)

Digital processing on chip

Virtualisation cloud topology

Source: Bell Labs analysis

Macro-cells

Small Cells

Light Radio Product family
Legacy
Single RAN

Site Rental 66% 60% 51%
Civil Works
Power Consumption
Conclusions

• The need for supporting new services, the demand for much higher bandwidth, the technology obsolescence of existing radios, and Operation and Maintenance cost containment leads to look at new wireless solutions.

• The emergence of LTE, the 4th generation of wireless communication, is areal an opportunity for Public transportation: only radio access technology that combines high bandwidth, hierarchical Quality of Service and low latency, therefore capable to carry both vital and non-vital traffics.

• The selection and the allocation of frequency band are now one of the key questions to be tackled as already train operators require to go for this technology.

The all IP architecture should avoid developing any specific “LTE for Rail” system and benefit from the huge mass-market effect of commercial LTE.
ALCATEL-LUCENT 4G LTE CUSTOMERS

Trials split per region
- Europe: 25%
- APAC: 4%
- Middle East: 17%
- North America: 12%
- South America: 42%

Small cells
- 700MHz & 2.6GHz

800MHz/rural/Wholesale

TD-LTE trials or contracts

World's Largest CDMA + LTE Network
World's largest GSM/HSPA + LTE Network

UNMATCHED IN SIZE, SCALE AND SCOPE OF 4G LTE DEPLOYMENTS