Session IV “Mobile on the move

Requirements of Wireless Communications for Control and Operation of Railway Systems

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Agenda:

1. Communications Services for Railways
2. Digital Communications Systems Used in Railways
3. Networks Architectures
4. Conclusion

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
1. Communications Services for Railways

Voice and data service demanded by railways networks

**VOICE:**
- Operation, maintenance and security.
- Private communications
- High quality of service
- Proprietary network operation and maintenance

**DATA:**
- Train signaling: basic to increase network efficiency
- Supplementary data services: maintenance/operation/Location
- Video services:
  - Surveillance
  - Automatic driving

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
1. Communications Services for Railways

TYPE OF RAILWAYS NETWORKS

• National networks:
  • Conventional: voice GSM-R
  • High speed: voice and data (ERTMS system/ GSM-R Communications)

• Regional networks:
  • Voice and supplementary data service: GSM-R/ TETRA /Others

• Metropolitan networks:
  • Voice operation and maintenance: TETRA
  • Data: Communications Based Train Control Systems (CBTC) Proprietary
  • Supplementary video and data service: WLAN

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
1. Communications Services for Railways

VOICE SERVICES

• Fast call establishment <2s
• Location dependent addressing
• Functional addressing
• Group call
• Emergency call
• Priority call schema
• Ambient listening
• Direct mode
• High speed operation (350Km/h)
1. Communications Services for Railways

TRAIN SIGNALLING

• High speed trains: ERTMS (standard)
• Metropolitan railways: CBTC

Bidirectional continuous data transmission, Location information
Objective speed and movement authorization

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
1. Communications Services for Railways

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF SIGNALLING SYSTEMS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF TRAINS (ZONE)</td>
<td>10-40</td>
</tr>
<tr>
<td>POLLING TIME</td>
<td>100ms..500ms</td>
</tr>
<tr>
<td>DATA PACKET LENGTH</td>
<td>1Kbit</td>
</tr>
<tr>
<td>DATA SPEED</td>
<td>2,4..250 kbit</td>
</tr>
<tr>
<td>MAXIMUM COMMUNICATIONS DELAY</td>
<td>&lt; 0,5s</td>
</tr>
<tr>
<td>TRACK SIDE EQUIPMENTS REACTION DELAY</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>CALL ESTABLISMENT TIME</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>CALL LOST DETECTION</td>
<td>&lt;2s</td>
</tr>
</tbody>
</table>

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
2. Digital Communications Systems in Railways:

**SYSTEMS**
- ANALOG
- DIGITAL
  - 2G
    - TETRA
    - GSM-R (ERTMS)
  - 3G
    - Wlan
    - Proprietary (CBTC)

**REQUIREMENTS**
- Voice and data service
- Data rate: 2-250 Kb/s
- Switched or packet data transmission
- Fast connection establishment
- Reduced number of users
- Soft handover

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
## 2. Digital Communications Systems in Railways

<table>
<thead>
<tr>
<th>Feature</th>
<th>TETRA</th>
<th>GSM-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band/ bandwidth</td>
<td>360-400 MHz</td>
<td>900 MHz</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>25 kHz</td>
<td>200 kHz</td>
</tr>
<tr>
<td>Logical channels per radio channel</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Signaling channels</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Link bandwidth</td>
<td>6.25 kHz</td>
<td>25 kHz</td>
</tr>
<tr>
<td>Channel assignment</td>
<td>Trunking</td>
<td>On demand</td>
</tr>
<tr>
<td>Propagation diversity</td>
<td>Triple</td>
<td>Double</td>
</tr>
<tr>
<td>Channel equalization</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Group, diffusion and emergency call</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Call establishment time</td>
<td>&lt;1 s (100ms)</td>
<td>&lt; 2 s</td>
</tr>
<tr>
<td>Direct call: terminal to terminal</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Repeater function</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Data transmission speed. Circuit mode</td>
<td>7200 bps</td>
<td>9600 bps</td>
</tr>
<tr>
<td>Data transmission speed. Packed mode</td>
<td>28800 bps</td>
<td>38.400 bps(GPRS)</td>
</tr>
<tr>
<td>Network size</td>
<td>Fully scalable</td>
<td>minimum 10,000 users</td>
</tr>
<tr>
<td>Terminals cost</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

**Subject:** Requirements of Wireless Communications for Control and Operation of Railway Systems
2. Digital Communications Systems in Railways:

### Wlan radios

<table>
<thead>
<tr>
<th>Standard</th>
<th>802.11</th>
<th>802.11b</th>
<th>802.11a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>2.4 GHz</td>
<td>2.4 GHz</td>
<td>5 GHz</td>
</tr>
<tr>
<td><strong>Maximum regiment</strong></td>
<td>2 Mbit/s</td>
<td>11 Mbit/s</td>
<td>54 Mbit/s</td>
</tr>
<tr>
<td><strong>Carrier</strong></td>
<td>FHSS/DSSS</td>
<td>DSSS</td>
<td>OFDM</td>
</tr>
<tr>
<td><strong>Carriers per channel</strong></td>
<td>79(FHSS)1(DSSS)</td>
<td>1</td>
<td>48 datos y 4 pilotos</td>
</tr>
<tr>
<td><strong>Maximum output power</strong></td>
<td>20 dBm</td>
<td>20 dBm.</td>
<td>35 dBm (PIRE)</td>
</tr>
</tbody>
</table>

### Non standard CBTC radio

<table>
<thead>
<tr>
<th></th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital transmission ISM band</td>
<td>2.4GHz/ TDMA</td>
</tr>
<tr>
<td>Transmission mode</td>
<td>Duplex/ FDD</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5,5 MHz</td>
</tr>
<tr>
<td>Transmission speed</td>
<td>250-2750kbps</td>
</tr>
<tr>
<td>Modulation</td>
<td>DSS</td>
</tr>
<tr>
<td>Transmission power / RX sensibility</td>
<td>0-23dBm / -92 dBm</td>
</tr>
<tr>
<td>MAC layer</td>
<td>proprietary</td>
</tr>
</tbody>
</table>

**Subject:** Requirements of Wireless Communications for Control and Operation of Railway Systems
2. Digital Communications Systems in Railways:

RADIO COVERAGE:

• Linear coverage
• Low traffic
• Open areas: antennas and base stations
• Tunnels: Leaky feeder.
• Reliability and quality of service

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
2. Digital Communications Systems in Railways:

RADO COVERAGE:

Leaky feeder: High cost / high reliability

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
3. Radio Networks in Railway Environments:

**REQUIREMENTS**
- High quality of service
- High reliability
- Complex environment:
  - Tunnels
  - Linear coverage
  - High speed (350Km/h)

**PROBLEMS**
- Handovers
  - GSM-R: 500ms lost
  - High speed (350km/h) operation: equalization
- Bit error rate $<10^{-3}$
- Low Interference (ISM band)
- Availability, reliability $>98$
- Call lost probability $<1$

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
3. Radio Networks in Railway Environments:

HIGH RELIABILITY AND AVAILABILITY NETWORKS

Single layer architecture: One network double number of base stations

- +Lower cost, simple operation
- -Higher number of handovers

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
3. Radio Networks in Railway Environments:

HIGH RELIABILITY AND AVAILABILITY NETWORKS

Dual layer architecture: Two completely independent networks

- High reliability, low handovers number
- High cost, complex operation

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
3. Radio Networks in Railway Environments:

Dual layer architecture:

Signal power level measured in a high speed trains GSM-R network
3. Radio Networks in Railway Environments:

HIGH RELIABILITY AND AVAILABILITY NETWORKS

Dual Frequency: CDMA radios

- Soft handover
- Data redundancy

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3. Radio Networks in Railway Environments:

HIGH RELIABILITY AND AVAILABILITY NETWORKS

Single cell: 1 Base station and radio over fiber repeaters
- Isofrequency network
- No handover

Low number of users
Metropolitan railways

Subject: Requirements of Wireless Communications for Control and Operation of Railway Systems
3. Radio Networks in Railway Environments:

Single Cell, repeaters measurements

Signal power level measured in a train Isofrequency network
4. Conclusion

- Railway systems demand high reliability and QoS communication systems
- Voice communications are resolved with TETRA and GSM-R standards
- Data communications use GSM-R data services or proprietary radios mainly in the 2.4 GHz ISM band
- Data are basic for trains operation and are require in high speed trains and metropolitan railways
- Railways environment is quite complex and different to commercial networks
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Thanks for your attention