Outline

A Brief Overview of HSR Development

Scenarios & Services of Future HSR

5G/B5G Technologies for Future HSR
China: CRH
Germany: ICE
Japan: Shinkansen
France: TGV
Spain: AVE
A Brief Overview of HSR Development

- 2018, HSR operation in China: 27,000 km, 7.3 billion

- Beijing-Zhangjiakou Intelligent HSR: 2022 Beijing Winter Olympic Games

- The daily average traffic of city subway will exceed 200 million MB (2x10^{14}).

- The annual average traffic of railway will exceed 2 trillion MB (2x10^{18}).

- Rail passenger flow → Data flow → Cash flow

"Fuxing" (rejuvenation) Bullet Trains

The percentage of HSR operation mileages

- China: 67%
- The Others: 33%
A Brief Overview of HSR Development

Distance: 800 km
Average Speed: 260 km/h
Travel time: 3 hours

Estimated Costs:
- HST: $55.00
- Air: $120.00
- Car: $86.00
破冰之锤：—— 中国高铁踏上美国路

Icebreaker: China's high-speed railway contributes to USA prosperity

By: Lian Liu in San Francisco

2015-08-25 02:44:37

A Brief Overview of HSR Development

破冰之锤：—— 中国高铁踏上美国路

习近平在波音看见了什么？

习近平访美首站：当北京遇上西雅图

破冰之锤：—— 中国高铁踏上美国路

波音落子中国挑战空客天津工厂

未来十年市场份额不容错过

From: 21st Century Business Herald
Outline

A Brief Overview of HSR Development

Scenarios & Services of Future HSR

5G/B5G Technologies for Future HSR
In 2009, Smart Railway

In 2012, Future Railway Development

EU--Shift2Rail: “Smart Railway”

Shift2Rail and rail research within Horizon 2020

Shift2Rail Information Day for non-JU members (Open calls)

In 2016, EU: Shift2Rail

IEEE: Smart Rail Series
Scenarios & Services of Future HSR

Outside environment
- normal atmospheric pressure

Inside tube
- low air pressure
Scenarios & Services of Future HSR

Passengers

Virtual reality

Multi-media entertainment

Webcast

Videos
Scenarios & Services of Future HSR

Onboard and trackside HD video surveillance

Train multimedia scheduling information flow

Fully Automatic Operation

IoT for Trains
## Scenarios & Services of Future HSR

<table>
<thead>
<tr>
<th>Services Categories</th>
<th>Services Attribution</th>
<th>Use Case Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway Safety-Critical Services</td>
<td>Train Control and Operation Services</td>
<td>Intelligent Transportation and Control System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Onboard and Wayside HD Video Surveillance</td>
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<tr>
<td></td>
<td></td>
<td>Distributed Emergency Communication</td>
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<tr>
<td></td>
<td></td>
<td>Remote Monitoring and Diagnosis System</td>
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<tr>
<td>Railway Non-Safety Services</td>
<td>Train Comprehensive Services</td>
<td>Train Information Distribution System</td>
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<tr>
<td></td>
<td></td>
<td>Customized Passenger Supplementary Business</td>
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<tr>
<td></td>
<td></td>
<td>Train Multimedia Entertainment System</td>
</tr>
<tr>
<td>Passenger-Oriented Services</td>
<td>Onboard Broadband Communication</td>
<td>Onboard Cloud Office</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Onboard HD Multimedia Entertainment System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Onboard Instant Messaging</td>
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<tr>
<td></td>
<td></td>
<td>Onboard Online Game</td>
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<tr>
<td></td>
<td></td>
<td>Social Network Services for Passengers</td>
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<tr>
<td></td>
<td></td>
<td>Remote Medical Assistance System</td>
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<tr>
<td>Internet of Things for Railways</td>
<td>Internet of Things for Railways</td>
<td>Intelligent Train Marshalling System</td>
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<tr>
<td></td>
<td></td>
<td>Dynamic Crew Scheduling System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Railway Mobile Ticketing Dynamic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Luggage Safeguarding System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freight Management Information System</td>
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<tr>
<td></td>
<td></td>
<td>Intermodal Container Management System</td>
</tr>
</tbody>
</table>

Scenarios & Services of Future HSR

Data Collection and Fusion
Data Mining

More In-depth
Intelligent Processing Capacity

More Wider Interoperability

More Thorough Perception

Intelligent Ground Infrastructure + Intelligent Trains

IoT

Act
Intelligent Management and Decision-making

Plan

Study

Do

Outline

A Brief Overview of HSR Development

Scenarios & Services of Future HSR

5G/B5G Technologies for Future HSR
Multi-scenario, multi-indicator, multi-technology system: important feature of 5G distinguishing from the previous generations!
5G/B5G Technologies for Future HSR

High-speed Train

Mobile and wireless communications Enablers for the Twenty-twenty Information Society-II

Table 2: System performance requirements

<table>
<thead>
<tr>
<th>Use case category</th>
<th>Connection Density</th>
<th>Traffic Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadband access in dense areas</td>
<td>200-250 Mbps/m²</td>
<td>DL: 750 Mbps/m² Ul: 150 Mbps/m²</td>
</tr>
<tr>
<td>Indoor ultra-high broadband access</td>
<td>75 Mbps/km² (7/1000 m² office)</td>
<td>DL: 15 Mbps/km² Ul: 3 Mbps/km²</td>
</tr>
<tr>
<td>Broadband access in a crowd</td>
<td>10 Mbps/km² (90,000 in stadium)</td>
<td>DL: 3.75 Mbps/km² Ul: 1.5 Mbps/km²</td>
</tr>
<tr>
<td>50+ Mbps everywhere</td>
<td>10 Mbps/km² (15,000 in urban)</td>
<td>DL: 2 Mbps/km² Ul: 1 Mbps/km²</td>
</tr>
<tr>
<td>Ultra-low cost broadband access for low APU users</td>
<td>10 Mbps/km² (200km)</td>
<td>DL: 100 Mbps/km² Ul: 20 Mbps/km²</td>
</tr>
<tr>
<td>Mobile broadband in vehicles (cars, trucks)</td>
<td>10 Mbps</td>
<td>DL: 100 Mbps per car Ul: 20 Mbps per car</td>
</tr>
</tbody>
</table>

A Deliverable by the NGMN Alliance

NGMN 5G WHITE PAPER
5G/B5G Technologies for Future HSR

Internet of Things for HSR
- Monitoring of equipment, foreign objects, natural environment, etc.

Millimeter wave communication
- High transmission rate

Massive MIMO & beam management
- Reliable transmission of information

Ultra-reliable low-latency communication
- Fully automatic operation (FA0)

D2D/M2M communication
- Reliable communication with large data size

Moving network
- Wireless resource management

Precise positioning
- Wifi coverage, navigation in station
5G/B5G Technologies for Future HSR

HSR communication environment characteristics

1. High mobility (above 350 km/h)
2. Diverse propagation environments
3. Frequency resources are severely constrained and interference
4. Always-online reliable transmission

Bo Ai et al. “Challenges Toward Wireless Communications for High-Speed Railway,” IEEE Transactions on Intelligent Transportation Systems, 15.5(2014):2143-2158. (Analytical paper on high-speed rail complex scenarios and technical challenges was selected for ESI hot cited paper (Top 0.1%))


KPI: Mission Critical, Safety Critical, Dependability, RAMS
Wind level, rainfall and snow depth

Earthquake early warning and automatic emergency disposal

Automatic alarm and prevention of illegal intrusion

IoT for Railway—mMTC(1/2)
Challenges: Special requirements for mass access, high energy efficiency, low latency, and high reliability in HSR environments.

1. The coupling mechanism between environment and information is not clear.
2. The performance of autonomous mechanisms and heterogeneous fusion technologies is not clear.
3. Information Fusion and Decision Face Challenges.

- Interference
- Dynamic channel
- Energy limit
- Equipment heterogeneity
- Self-organization
- Quality of service
- Security
Mm-Wave Communication — emBB (1/3)

- mmWave Radar
- mmWave Backhaul
- mmWave Positioning
- mmWave M-MIMO
- mmWave D2D
- mmWave V2V
- mmWave UAV
- mmWave Beamforming
- mmWave Fault Detection
Sensitive to Blocking

- The sensitivity of mmWave links to blockage is due to their weak diffraction characteristics.
  - Blockage by a human may increase the link loss by 20-30 dB.
  - Human movement can cause intermittent transmission of mmWave links, resulting in a time-varying network topology.

Mm-Wave Commu.—emBB(3/3)

Massive MIMO @ Mm-Wave for HSR—aMBB (1/2)

According to IEC62279, the rail transit automation system is divided into 4 levels according to the degree of automation: GoA 1 to GoA 4.

GoA 1: Grades of Automation

GoA 2: Grades of Automation

GoA 3: Grades of Automation

GoA 4: Grades of Automation

GoA4: The highest level

- Fully automatic operation (FAO)
- Automated high-speed rail system

GoA: Grades of Automation
Precise Positioning (1/2)

- GNSS
- mmWave Location
- A-GPS
- D2D
- VLC
- NFC

Outdoor

Fare gate

Indoor
Beijing-Zhangjiakou high-speed railway has 10 stations

**Zhangjiakou South**
The total construction area of the station is about 96,000 square meters.

**Badaling Great Wall Station**
The Badaling Great Wall Station is located in the tunnel. It is located 102 meters underground and covers an area of 36,000 square meters. It is the deepest underground high-speed railway station in the world.
Edge Computing

1. Core network (Internet)
2. Cloud computing node
3. Wayside fog computing node
4. Train fog computing node
5. Wayside service (e.g., Wayside HD video surveillance, wayside IoT for railways)
6. Onboard service (e.g., onboard HD video surveillance, realtime service)
Information Security

On-Board Computer
Rail Circuit
Man-machine Interface
GSM-R Antenna
Rx

Automatic Train Protection
Speed Sensor
Balise Antenna
Rail Circuit Antenna
Radar Sensor
## Channel Modeling in HSR Scenarios (1/5)

<table>
<thead>
<tr>
<th>CTCS Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTCS-4</td>
<td>GSM-R</td>
</tr>
<tr>
<td>CTCS-3</td>
<td>GSM-R &amp; Balise and Rail circuit</td>
</tr>
<tr>
<td>CTCS-2</td>
<td>Balise &amp; Rail circuit</td>
</tr>
<tr>
<td>CTCS-1</td>
<td>Main locomotive signal &amp; Safe operation monitoring and recording device</td>
</tr>
<tr>
<td>CTCS-0</td>
<td>Universal cab signal &amp; Operation monitoring and recording device</td>
</tr>
</tbody>
</table>

Channel Modeling in HSR Scenarios (2/5)

**Hata Model**

\[
PL_{\text{Aircom}} (\text{dB}) = K_1 + K_2 \log_{10}(d) + K_3 h_m + K_4 \log_{10}(h_m) + K_5 \log_{10}(h_b) \\
+ K_6 \log_{10}(h_b) \log_{10}(d) + K_7 + C_{\text{Loss}}
\]

Da-Xi HSR Line

Aircom

Our Model

Network Planning
Channel Modeling in HSR Scenarios (3/5)

Urban, 20 dB

Suburban, 15 dB

Viaduct, 15-20 dB

Cutting, 10 dB
Channel Modeling in HSR Scenarios (5/5)

Link level software demo of 5G communications for high-speed railway.
5G/B5G Technologies for Future HSR

- **Intelligent HSR, Smart HSR**
  - Intelligent & dependable communication network
  - Radio propagation mechanisms and channel characteristics
  - Always-online reliable transmission with high data rate at high moving speeds
  - Massive random access
  - Radio resource management
  - Cooperative integration of communication, computing and storage resources
  - Vertical industry applications
5G/B5G Key Technologies-Enabled High-Speed Railway Communications

Thanks!

Q & A