Increase of capacity on the Shinkansen high-speed line using virtual coupling

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Overview

- Next Generation Train project
- Virtual coupling
- Simulation tool
- Shinkansen scenarios
Next Generation Train project
Since 2007, 11 DLR Institutes, current phase until 2018

- Ultra-high-speed train (400 km/h, 202m, 800 seats, double-deck, 16 MW)
  NGT HST

- High-speed regional train (230 km/h, 120m, 480 seats, double deck)
  NGT LINK

- Ultra-high-speed Cargo train (400 km/h, currently in design process)
  NGT CARGO
Introduction to virtual coupling

- General idea is the coupling and uncoupling of trains on the move, not only during the stop at the station
- Coupling on the move → every train part needs its own propulsion and energy supply
- Virtual coupling has benefits compared to mechanical coupling:
  - No mechanical couplers needed
  - Avoidance of problems with mechanical couplers
- Switch problem:
  - Switches can fail
  - The train has to able to stop in front of a switch
  - Coupling and dividing train parts have to keep the absolute braking distance ahead of switches
  - The operational benefit of coupling on the move gets lost
- Two general scenarios:
  - Use of conventional switches
  - Use of (not invented) “passive” switches, which can always be passed safely
Scenario summary I
Conventional switches

**Slip Coaching**  train is split up – the last wagons stop at platform

**Doubling Scenario** – Coupling the train after departure

**Double overtake Scenario** - Being overtaken by two trains
Scenario summary II
(Not invented) Passive switches

Coupling and splitting at junctions

Freeway Scenario – Dynamic overtaking on two tracks in each direction
Simulation environment

- Available simulation tools are not able to handle virtual coupling
- New tool called “DFSimu”
- Implemented in Python
- 500 kB source code
**„Shinkansen“ scenario**  
**Tokaido line Tokyo - Osaka**

- Tokaido line is one of the most heavily used high-speed lines of the world
- Dense and punctual train traffic
- Need for more capacity
- Simulation with Shinkansen 700 type train (405m, 708t, 270 km/h, 1323 seats)
Graphical timetable of the afternoon outbound traffic from Tokio to Osaka

Nozomi (few stops)
Hikari (more stops)
Kodama (all stops)
Shinkansen scenario 1: Doubling the Nozomi trains

- Doubling of the fast Nozomi trains
- Leading train starts, following train is waiting until first common switch is cleared
- At the next station the following train keeps the braking distance to the dividing switch
- Using the fact, that the speed near stops is slower
→ Effect: Higher capacity (400 meters twice)
Shinkansen scenario 1: Doubling the Nozomi trains
Shinkansen scenario 1: Doubling the Nozomi trains
Distance between train pairs

- Developing running distance depends on distance between stopping place and switch (Nagoya > Yokohama / Kyoto)
- Distance decreases during run → second is a little bit faster (simulation detects little departure delay)
Stations Nagoya and Tokio

- Shinkansen stations have confined space conditions
- Only 2 tracks per direction in Nagoya, of which only one can be used for terminating trains
Tokio Station Track Occupation

- 6 tracks in Tokio station for Tokaido line
- Currently 12 minutes turn-around-time in average
- Accessing platform track / Door opening / Disembarking / Cleaning / Turning chairs / Boarding / Door closing / Departure / Leaving platform track
- With virtual coupling either a new platform is needed or the turn-around-time has to be shortened
Shinkansen scenario 1 – Nagoya Bottleneck
Results of the Shinkansen scenario 1

- Benefit: increase of line capacity from 15,000 to 23,000 per hour and direction
- New platforms needed in Nagoya and probably Tokio and Osaka needed

<table>
<thead>
<tr>
<th>Timetable: departures at Tokio (16.00 – 19.00)</th>
<th>Original 2015 timetable</th>
<th>Shinkansen scenario 1: Doubling of Nozomi trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozomi trains / h</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Hikari trains / h</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Kodama trains / h</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Train count / h</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td><strong>Seat capacity / hour / direction</strong></td>
<td>15,000</td>
<td>23,000</td>
</tr>
<tr>
<td>Train-kilometer (all)</td>
<td>15,494</td>
<td>24,780</td>
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<tr>
<td>Energy consumption (all)</td>
<td>271.1 MWh</td>
<td>426.1 MWh</td>
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<tr>
<td>Specific energy consumption (all)</td>
<td>17.5 kWh / train-km</td>
<td>17.2 kWh / train-km</td>
</tr>
<tr>
<td>Delay sum arrival (all)</td>
<td>0 min</td>
<td>242 min</td>
</tr>
<tr>
<td>Obstructions (all)</td>
<td>11</td>
<td>104</td>
</tr>
</tbody>
</table>

Nagoya needs new platform
Shinkansen scenario 2: Being overtaken by 2 trains

- Kodama trains are passed by other trains at every stop
- Sometimes even by two trains
- Virtual coupling of these two trains could lead to shorter stop times and thus to shorter travel times
Shinkansen scenario 2: Timetable compression
Shinkansen scenario 2: Timetable compression

• Constraints:
  • Reduction of stopping time from 3 to 2 minutes (1 min at small stations)
  • Reduction of time allowance to 3% for Kodama and Hikari trains
• Results do not meet the expectations
• Reasons:
  • Many stops of Hikari trains prevent benefits for the capacity of the line
  • Station Atami has platforms directly at the fast track
  • Getting Kodama trains one station further for overtaking is only possible by violating the minimal stopping and allowance times
  • Nagoya Bottleneck prevents increase of train numbers
• Benefit:
  • Travel time reduction of 1/3 of the trains at around 20 minutes between Tokio and Osaka
Conclusion and outlook

• Benefit of virtual coupling is limited because of the necessary **absolute braking distance to switches**
• Virtual coupling in operation looks more or less like running in relative braking distance
• Increase of line capacity is possible by doubling fast trains
  • Two platform tracks necessary at every stop
  • Additional track capacity at main stations
• Increase of capacity of Tokaido line from **15 000 to 23 000 pax / h / direction**

Outlook:
• Analysis of a **slip coaching scenario** on high-speed lines (e.g. German North-South-Line with fewer stops at Göttingen, Kassel and Fulda)
• Analysis of **freeway scenario** with the assumption not to have a switch problem
Thank you