

Railway Use Cases for NGV

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Abstract

Railway use cases also relevant to NGV besides road vehicle use cases:

- **Use Case 1: Onboard Train**
 - Wireless train control and monitoring system (TCMS), operator oriented services, customer services
- **Use Case 2: Train-to-Train**
 - Autonomous trains & collision avoidance; remote control of automatic coupling and train integrity; virtual coupling (platooning)
- **Use Case 3: Train-to-Trackside**
 - Signaling, operator oriented services, customer services
- **Use Case 4: Vehicle-to-Train**
 - Shared space in level crossings & shared spectrum

Why Railways?

Definition of vehicle [1]:

A vehicle is a machine that transports people or cargo. Vehicles include

- **wagons, bicycles, motor vehicles (motorcycles, cars, trucks, buses),**
- **railed vehicles (trains, trams),**
- **watercraft (ships, boats),**
- **amphibious vehicles (screw-propelled vehicle, hovercraft),**
- **aircraft (airplanes, helicopters) and spacecraft.**

Why Railways?

Current situation in road traffic:



- **Very efficient use of roads**
- **EU: 75% of freight, 82% of passengers**
- **Many accidents, traffic jams, less energy efficient**

Current situation in railways:



- **Very safe and energy efficient**
- **EU: 18% of freight, 8% of passengers**
- **Inefficient use of railways due to old safety system**

Why Railways?

Current situation in road traffic:



- **Large Market: 1.3 billion motor vehicles, 1.35 trillion \$ trade (2015)**

Current situation in railways:



- **Small Market: 6.2 million rail vehicles, without freight cars only 0.7 million, 167 billion \$ (2015)**

Society and politics: Shift traffic from road to rail

➔ Need for highly efficient and safe railway operation with little additional infrastructure

➔ Reliable low-latency communications and ranging essential

Railway terms

- **Rail vehicle:** Wagon, railcar, locomotive, ...
- **Consist:** a single vehicle or a group of vehicles that cannot be uncoupled



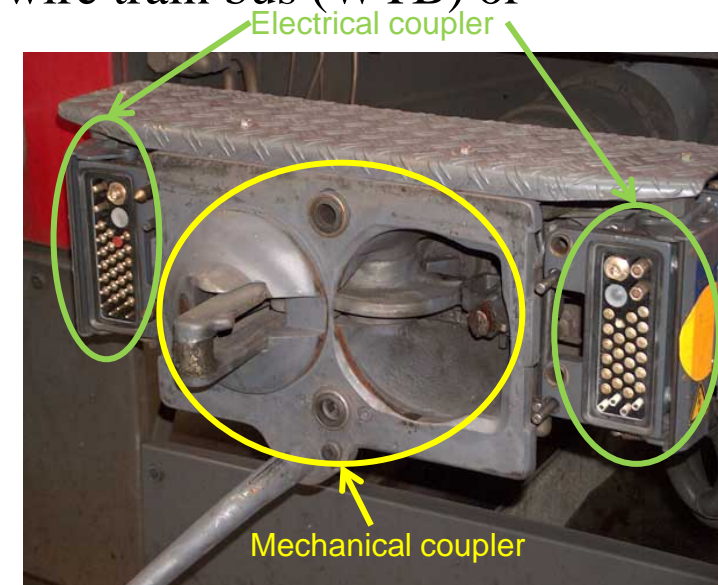
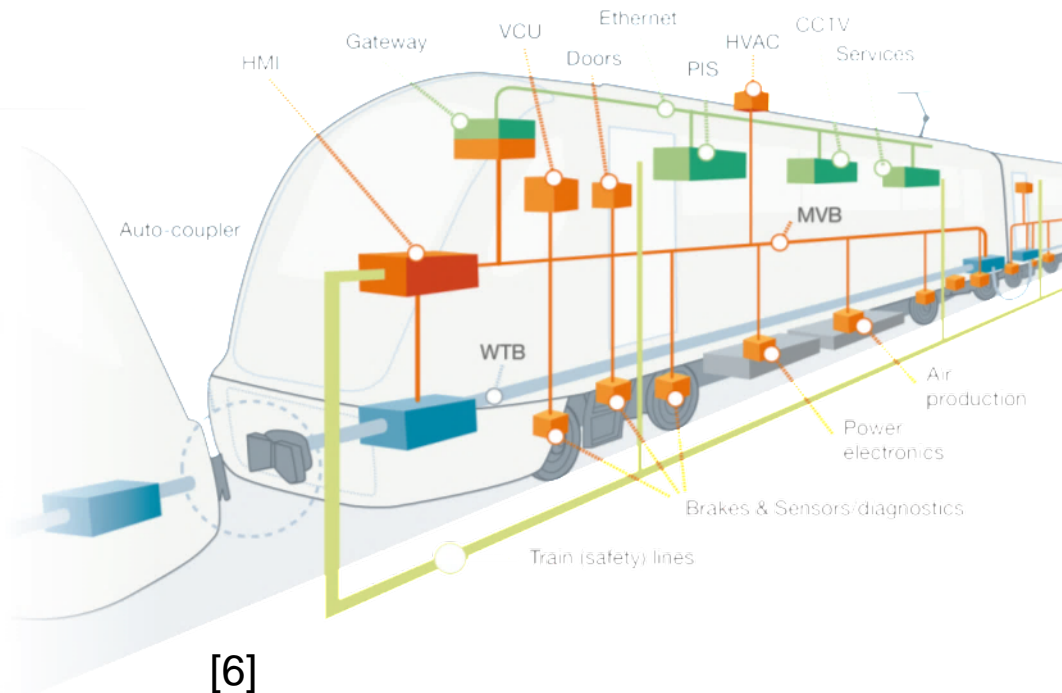
- **Train:** composition of one or a set of consists or rail vehicles that can be operated as an autonomous unit



Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) state-of-the-art [4][5]**

- Inside rail vehicle or consist: Multifunction vehicle bus (MVB) or ethernet consist network (ECN)
- Connecting multiple vehicles: wire train bus (WTB) or ethernet train backbone (ETB)
- Between consists or wagons mechanical and electrical couplers

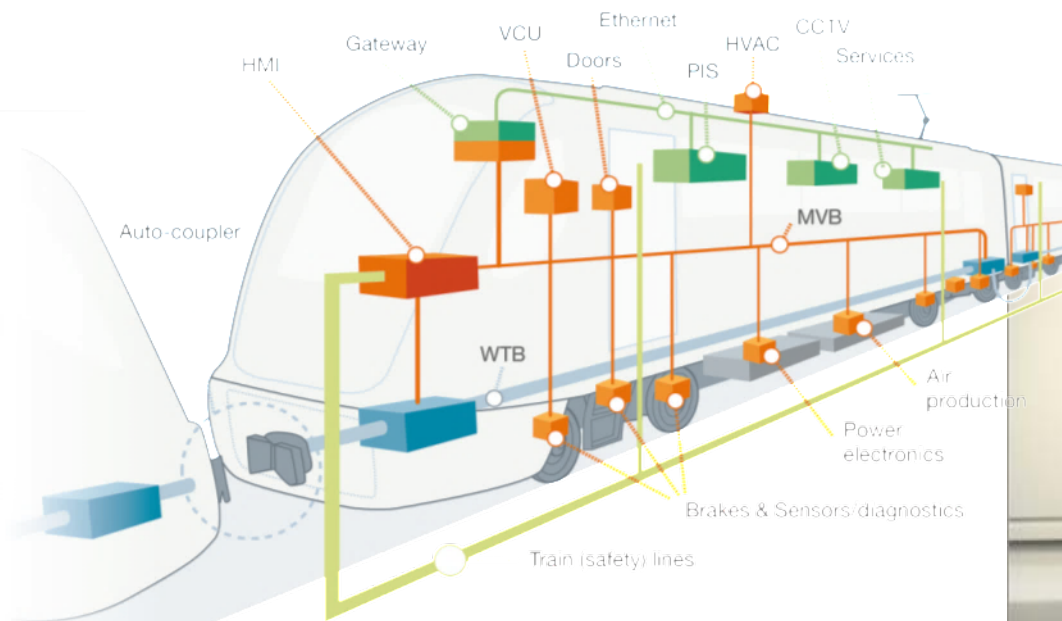


[6]

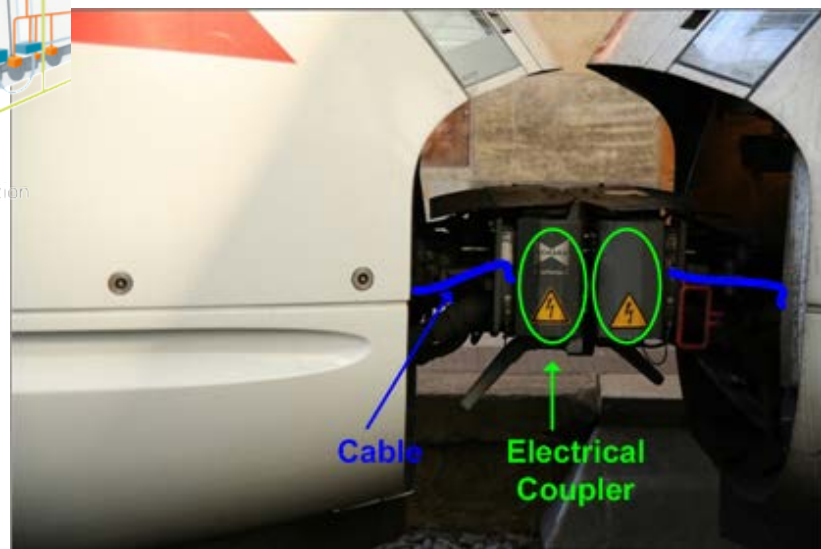
Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) state-of-the-art [4][5]**

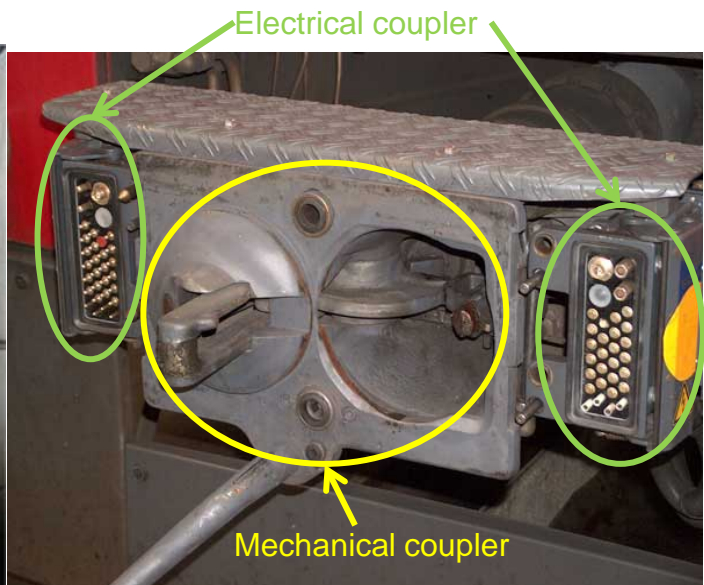
Mechanical stress at coupler leads to many connection failures!



[6]



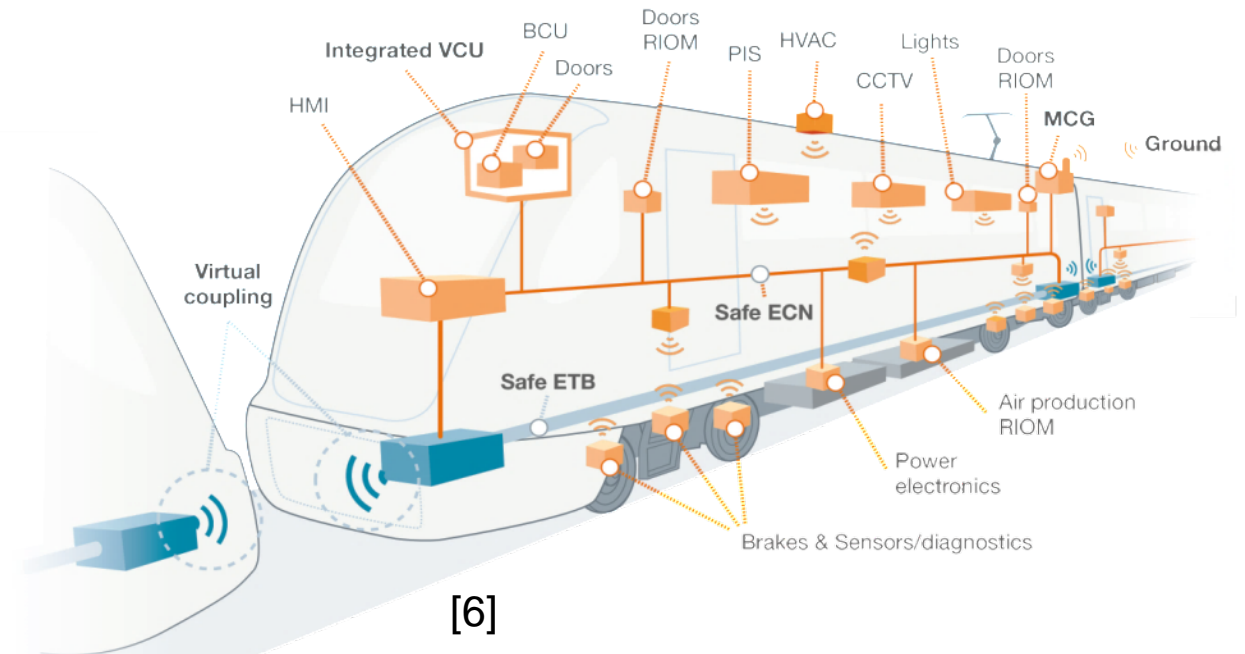
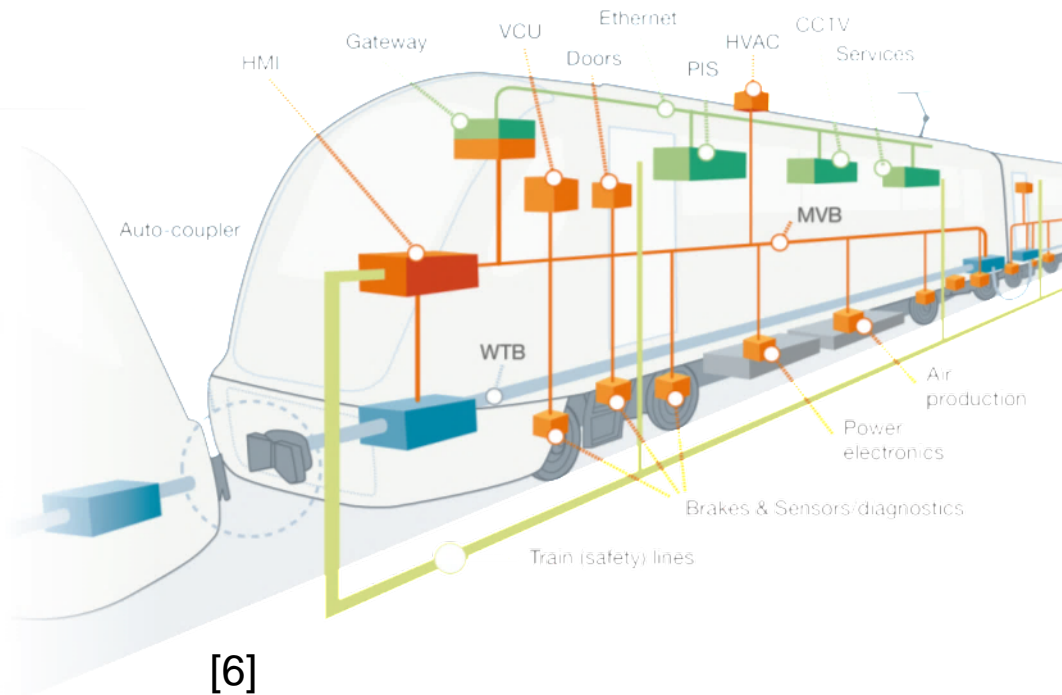
Cable
Electrical Coupler



Electrical coupler
Mechanical coupler

Use Case 1: Onboard Train

- **Wireless Train Control and Monitoring System (TCMS) [4][5]**



Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) Data classes [5]:**
 - Process data= small dimension data (byte or bit) that are sent periodically [7]
 - Message data= differ from process data for bigger size and not sent periodically [7]
 - Supervisory data= as message data, not periodically, used for supervision and inauguration process [7]
 - Stream data= big amount of data sent continuously
 - Best Effort data= data rate and delivery time depend on traffic load

Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) [5]: Key performance attributes: Inside consist**

DOMAIN	DATA CLASS	DATA SIZE	DATA RATE NEED	CYCLE TIME	LATENCY [The latency should be between 0 and max]
		max	max	min	max
TCMS	Process	1432 [acc. IEC61375-2-3]	10Mbit/s	16ms	80ms [5 x Cycle Time min]
	Message	65388 [acc. IEC61375-2-3]	10Mbit/s	Not relevant [Message is not a periodic communication]	250ms
	Superv [Not relevant – slow PD]	Not relevant	10Mbit/s	50ms	250ms
	BestEffort e.g. for data upload/download relevant	Not relevant	10Mbit/s	N/A	N/A
	Streaming [Not applicable]	N/A	N/A	N/A	N/A

Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) [5]: Key performance attributes: Inside train**

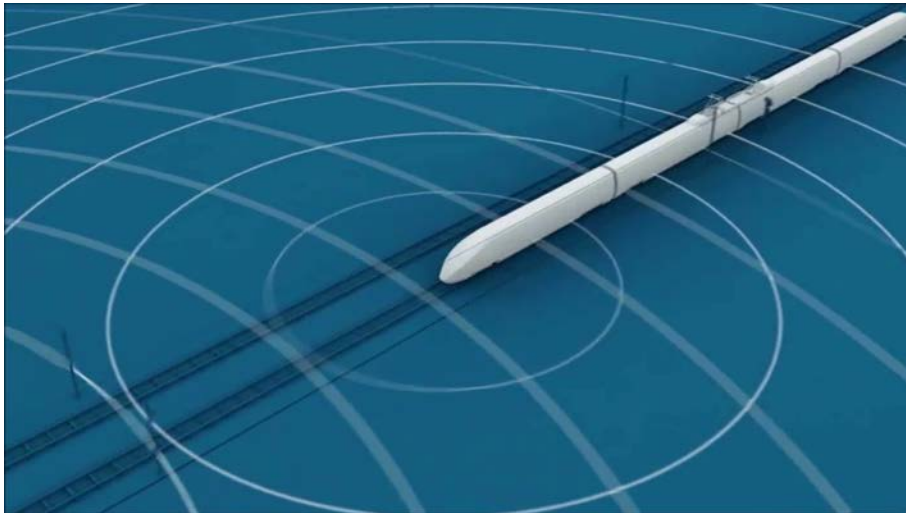
DOMAIN	DATA CLASS	DATA SIZE	DATA RATE NEED	CYCLE TIME	LATENCY [The latency should be between 0 and max]
		max	max	min	max
TCMS	Process	1432 [acc. IEC61375-2-3]	10Mbit/s	40ms [from knowledge of expertise]	Between 3CycleTime and 7CycleTime [from knowledge of expertise]
	Message	65388 [acc. IEC61375-2-3]	10Mb/s	Not relevant [Message is not a periodic communication]	250ms
	Superv [Not relevant – slow PD]	Not relevant	10Mb/s	Not relevant	250ms
	BestEffort	Forbidden	Forbidden	Forbidden	Forbidden
	Streaming [Not applicable]	N/A	N/A	N/A	N/A

Use Case 1: Onboard Train

- **Train Control and Monitoring System (TCMS) [5]:**
 - Required bandwidth ~ 100 Mb/s in one train
 - 30 years innovation cycle
- **Operator oriented services**
 - Improve operational parameters of train, e.g. maintenance costs, vehicle availability, closed circuit television (CCTV)
 - Required bandwidth ~ 1-10 Gb/s in one train
 - 10 years innovation cycle
- **Customer services**
 - Passenger comfort, e.g. public internet, passenger info portal; customer's own devices, WiFi
 - Required bandwidth ~ 1-10 Gb/s in one train
 - 5 years innovation cycle

Use Case 2: Train-to-Train

Enabling Future Applications



Remote control: Automatic coupling and train integrity [9]

Virtual coupling: Platooning [10]

Autonomous trains:
Collision avoidance [8]

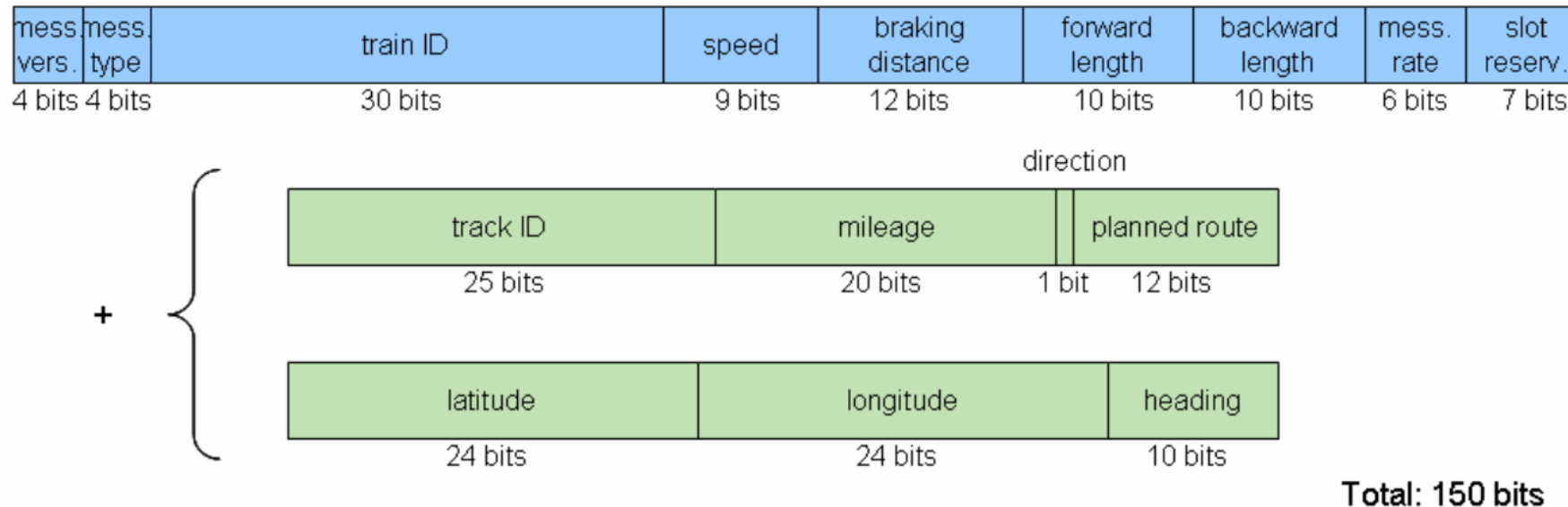


Use Case 2: Train-to-Train

Enabling Future Applications

Autonomous trains: Collision avoidance [8]

- 150 bit message



Use Case 2: Train-to-Train

Enabling Future Applications

Autonomous trains: Collision avoidance [8]

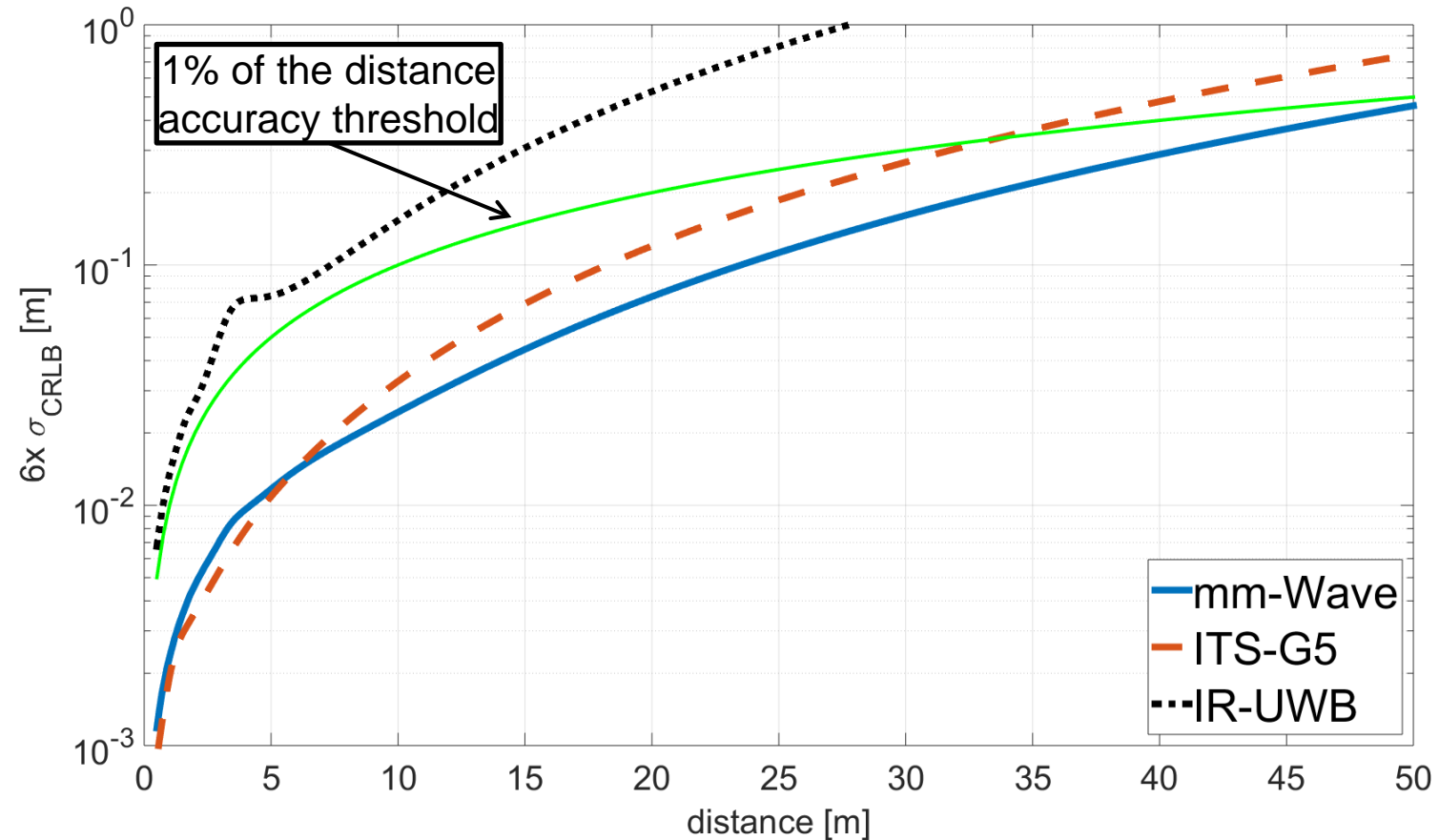
- **150 bit message (excl. authentication and encryption)**
- **Dense train station /shunting yard: 200 static & 25 moving trains, update rates 0.2 Hz static & 1 Hz moving train**
 - ➔ **Minimum message rate = $200 \cdot 0.2 \text{ Hz} + 25 \cdot 1 \text{ Hz} = 65 \text{ Hz}$**
- **System data rate = $150 \text{ bit} \cdot 65 \text{ Hz} = 9.75 \text{ kbit/s}$**
- **Communication range 5 km for 2 km breaking distance of train @ 200 km/h (~125 mph)**
- **Sufficient for informing train driver as safety-overlay in addition to other safety measures**
- ➔ **Higher rates needed to include authentication and encryption also for stand alone system or autonomous operations**

Use Case 2: Train-to-Train

Enabling Future Applications

Remote control: Automatic coupling and train integrity [9]

- Communication and ranging for control
- Ranging accuracy 1% of actual distance
- 6-sigma of Cramér–Rao lower bound (CRLB)
- ITS-G5 (802.11p, 10 MHz),
IR-UWB and mm-Wave
(both 500 MHz bandwidth)



Use Case 2: Train-to-Train

Enabling Future Applications

Virtual coupling: Platooning [10]

- Demonstration at Innotrans 2018 by Siemens, Bombardier, CAF



Use Case 2: Train-to-Train

Enabling Future Applications

Virtual coupling: Platooning [10]

- **Trains per platoon: 3/6/18 in rural/suburban/urban**
- **Message rate 10 Hz**

Update-Delay Δt ($a_{max} = 1 \text{ m/s}^2$)	0.01 s	0.1 s	1 s	10 s
Position uncertainty $ \Delta x _{max}$	0.5e-5 m	0.5e-2 m	0.5 m	50 m
Velocity uncertainty $ \Delta v _{max}$	0.01 m/s = 0.036 km/h	0.1 m/s = 0.36 km/h	1 m/s = 3,6 km/h	10 m/s = 36 km/h

- **Message size 167 bytes**
- ➔ **13.36 kb/s for one train broadcasting to platoon**
- ➔ **40.08/80.16/240.48 kb/s for 3/6/18 trains per platoon in rural/suburban/urban**

Use Case 3: Train-to-Trackside

- **Signaling: Safe operation of trains**
 - European Train Control System (ETCS)
 - GSM-R, future railway mobile communication system (FRMCS) using LTE/5G or WLAN
 - Positive Train Control (PTC)
 - Communication Based Train Control (CBTC) [12]
 - Application standard
 - 802.11b/g or LTE @ 1.8 GHz as well as proprietary solutions @ 5.9 GHz, e.g. based on 802.11a with 5MHz channels
- **Issues:**
 - In urban areas capacity problems
 - Dedicated links (link setup, link loss) to access points/base stations
 - ➔ Broadcast to multiple access points for redundancy, lower latency

Use Case 4: Vehicle-to-Train

- **Shared space: Level crossings**

- Basic safety message/ CAM
- Long breaking distance of trains compared to cars, e.g. 250m @ 100 km/h (62 mph) compared to 50m
- ➔ Need for increased communication range

- **Shared spectrum**

- EC Mandate for regulation:
 - Shared spectrum use of 5.9 GHz ITS band between V2X and urban rail communications
 - Spectrum segregation not an option



Summary

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References

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Straw Poll

Question: Do you consider the presented use cases relevant for NGV?

- **Y/N/Need more information:**
27/0/18