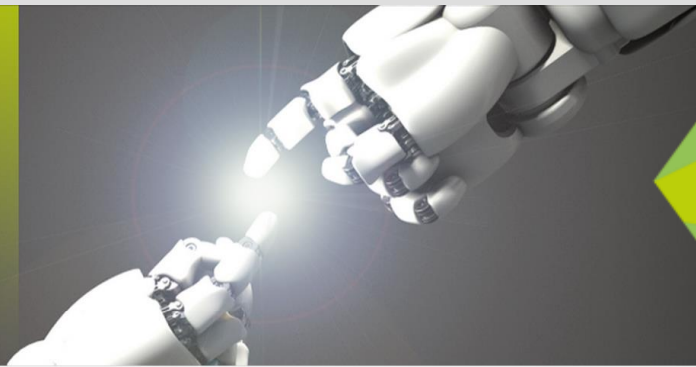




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5G LAB
GERMANY

5G – Impact and Challenges for the Future of Transportation

Dr. Meryem Simsek, Research Group Leader at TU Dresden, Germany
Senior Research Scientist at ICSI Berkeley, USA

 **vodafone chair**

 INTERNATIONAL
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INSTITUTE

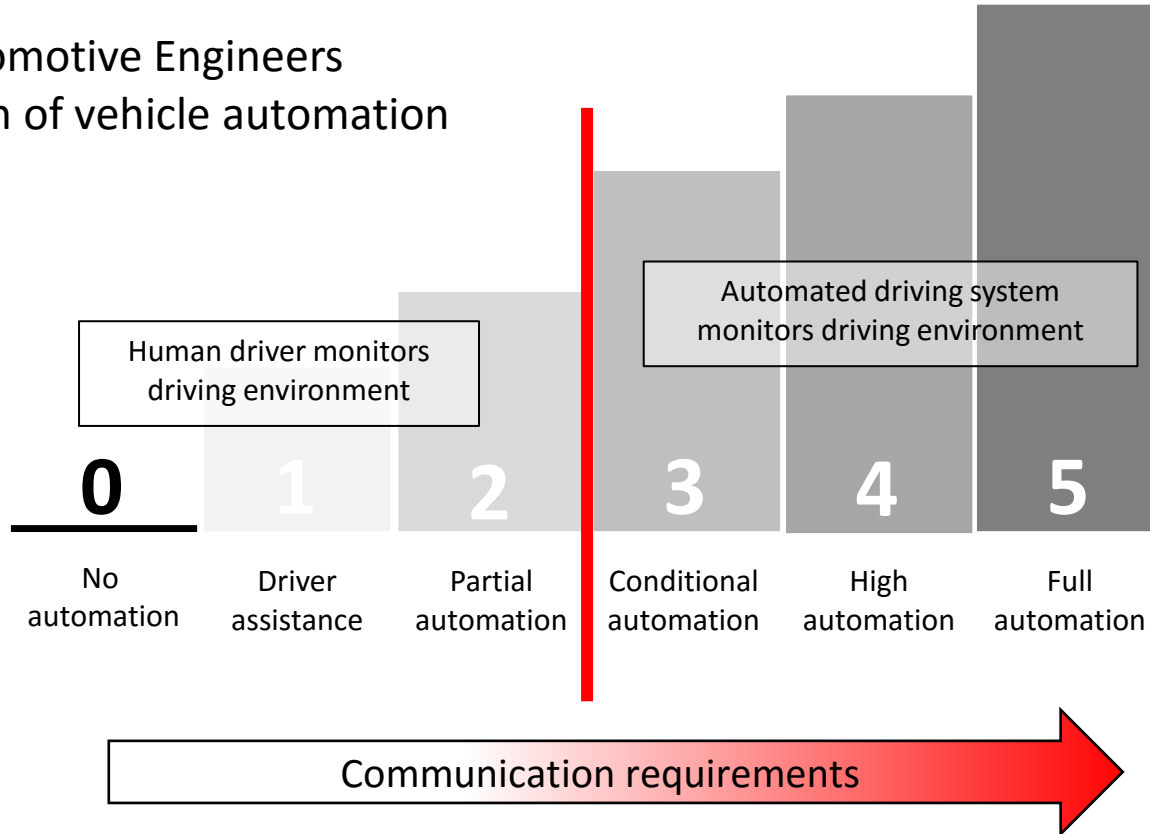
Contributors: Gerhard Fettweis and Andreas Festag

The Future of Transportation



Evolution of Vehicle Automation

Society of Automotive Engineers
(SAE) definition of vehicle automation



Connectivity and Communication is Key

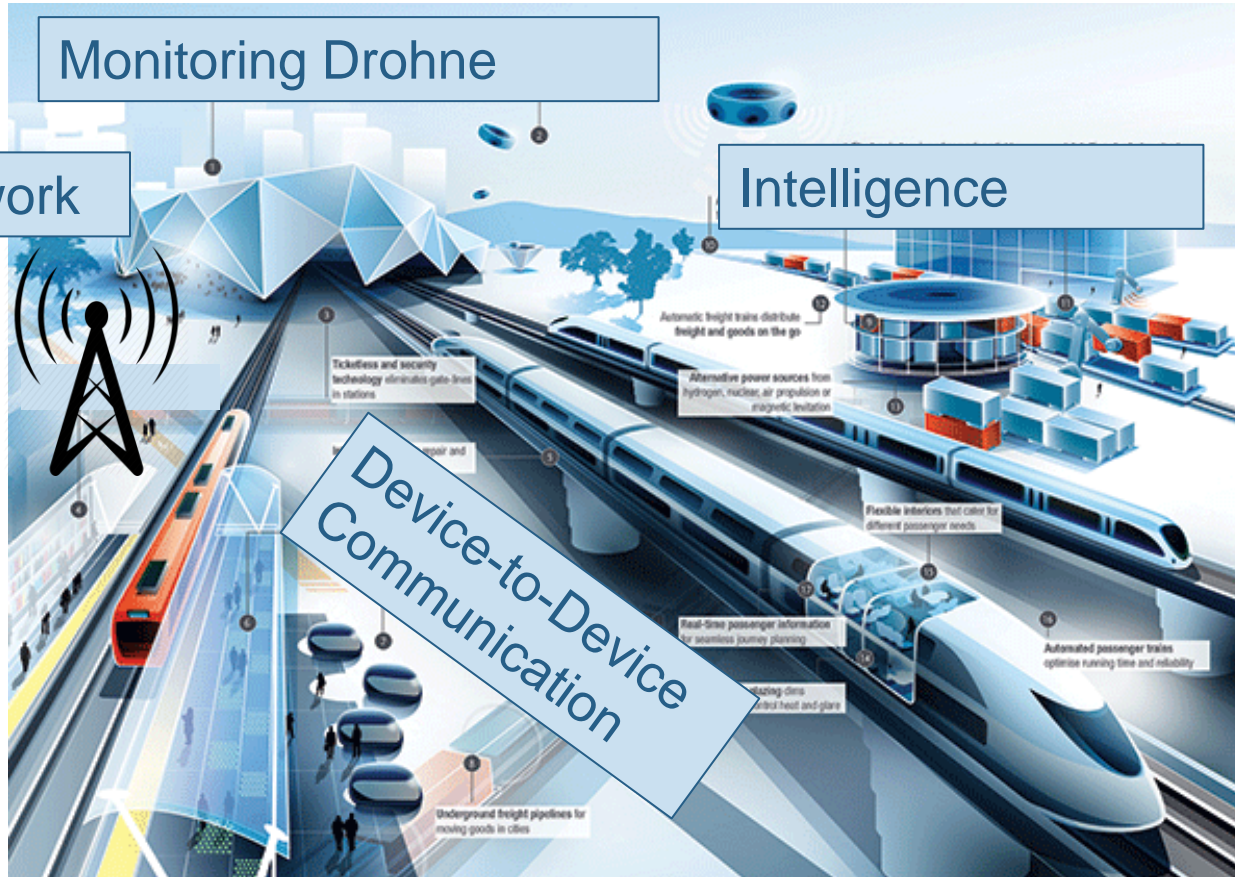
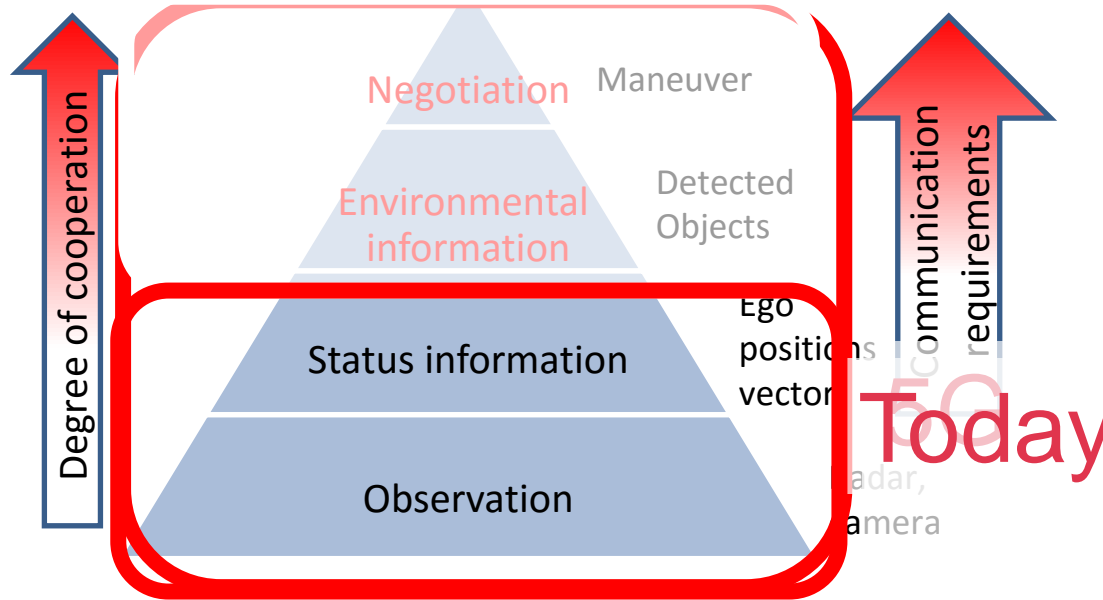


Photo: Arup |
The Future of Rail 2050

New Communication Requirements for Vehicle Automation



- New V2X use cases, such as
- cooperative advanced cruise control (C-ACC)
 - Platooning
 - See-through
 - Bird's eye

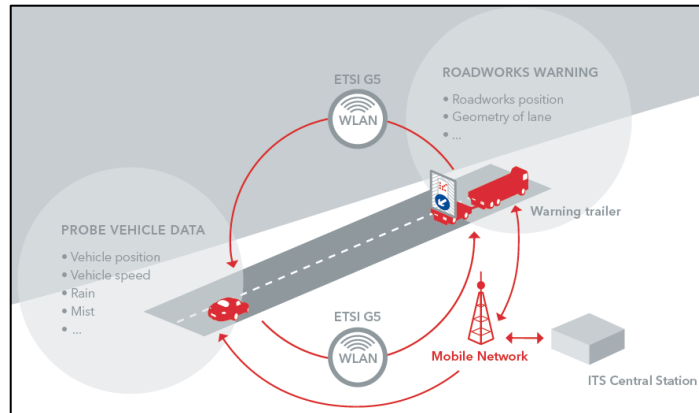
Cooperative sensing and cooperative maneuvering
→ Lower latency and higher reliability required

State-of-the-Art WiFi (IEEE 802.11p)

Basic system

- Research
- Standardization
- Field trials

Pilot: Cooperative ITS Corridor



Source: Cooperative ITS Corridor - Joint deployment, BMVI

Initial applications

- Emergency vehicle warning
- Electronic break light
- Intersection assistance
- Stationary vehicle
- Warning (traffic jam, construction)
- Weather warning
- In-vehicle signage

BUT:

- ➔ No service guarantee
- ➔ Limited Capacity
- ➔ No guaranteed latency

Performance of Release 1 V2X IEEE 802.11p/ITS-G5 (1)

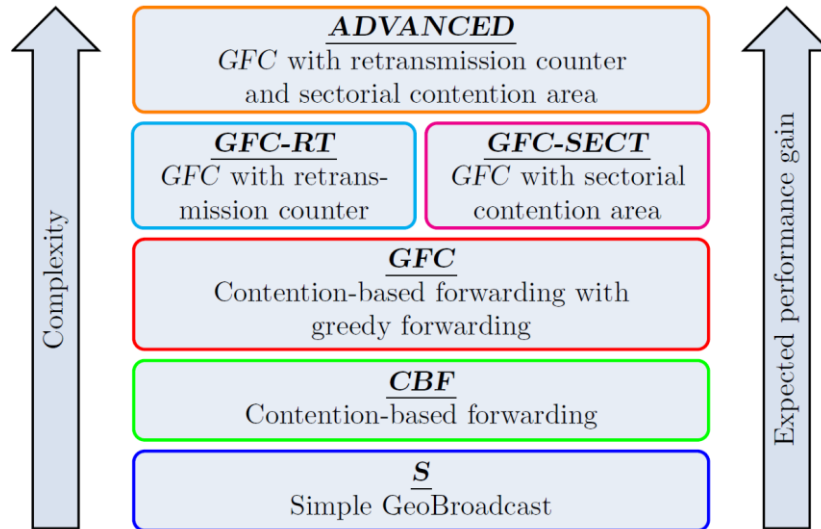
Multi-hop in ad hoc networks

- IEEE 802.11p
- GeoNetworking

Smart forwarding schemes

Metrics

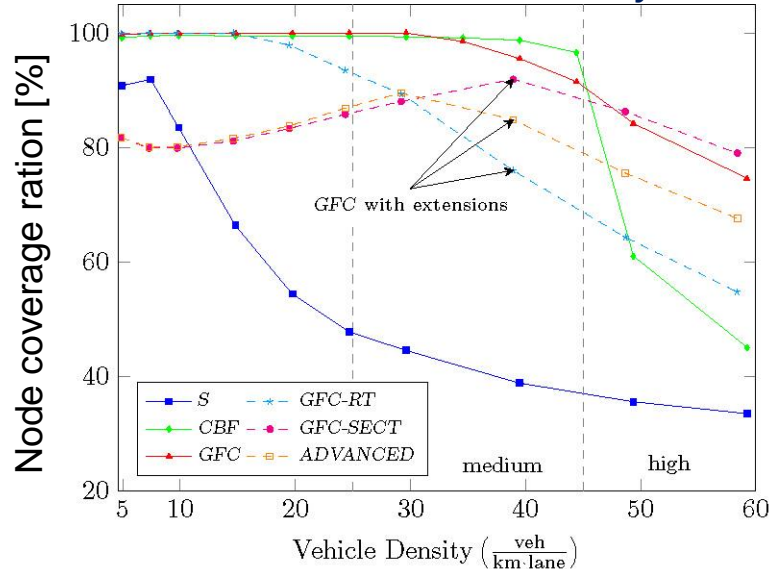
- Node coverage ratio
- End-to-end delay
- Data traffic overhead



Performance of Release 1 V2X IEEE 802.11p/ITS-G5 (2)

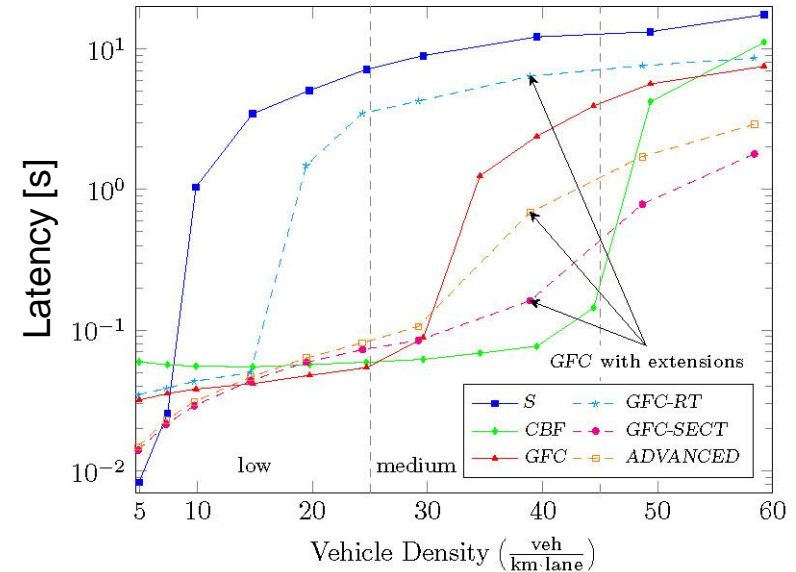
Node coverage ratio: Reliability

$$\text{NCR} = \frac{\# \text{ Rx vehicles in the convoy}}{\# \text{ vehicles in the convoy}}$$



Communication delay: Latency

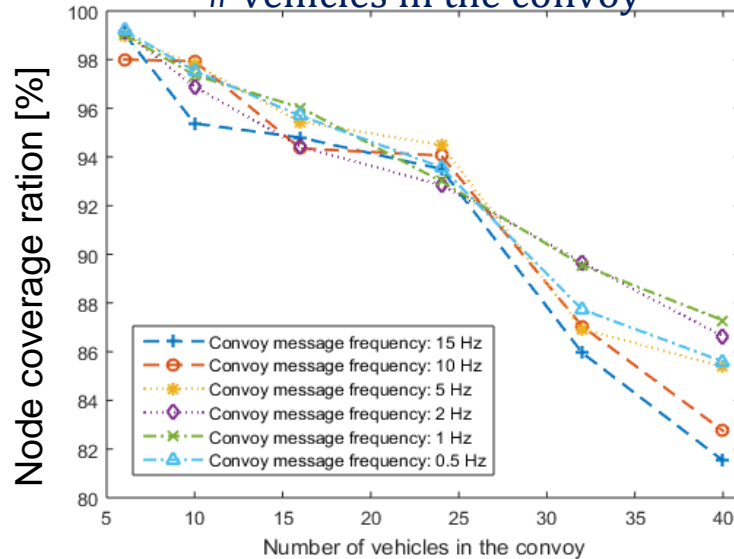
$$\text{Delay} = t_{\text{RX}} - t_{\text{TX}}$$



Convoy Communication for Automated Driving (IEEE 802.11p)

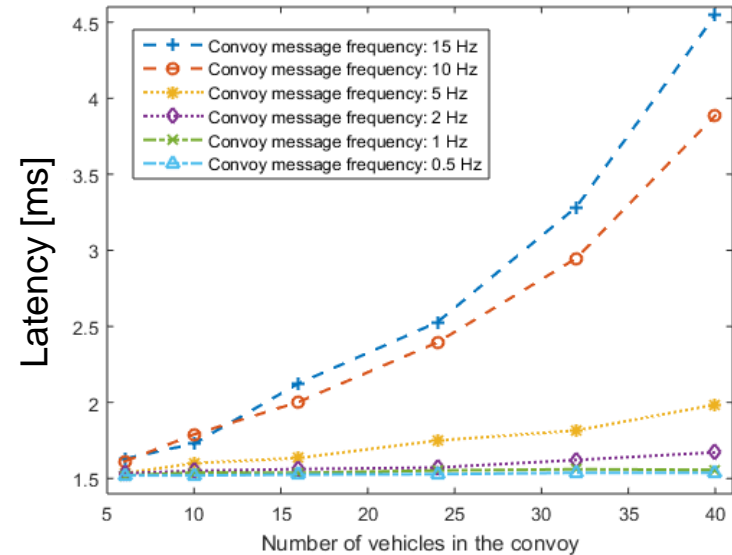
Node coverage ratio: Reliability

$$\text{NCR} = \frac{\# \text{ Rx vehicles in the convoy}}{\# \text{ vehicles in the convoy}}$$



Communication delay: Latency

$$\text{Delay} = t_{\text{RX}} - t_{\text{TX}}$$



I. Llatser, A. Festag, G. Fettweis: "Vehicular communication performance in convoys of automated vehicles", IEEE ICC 2016

Platooning

1-2 ms examples of today's cars: ESC, ABS

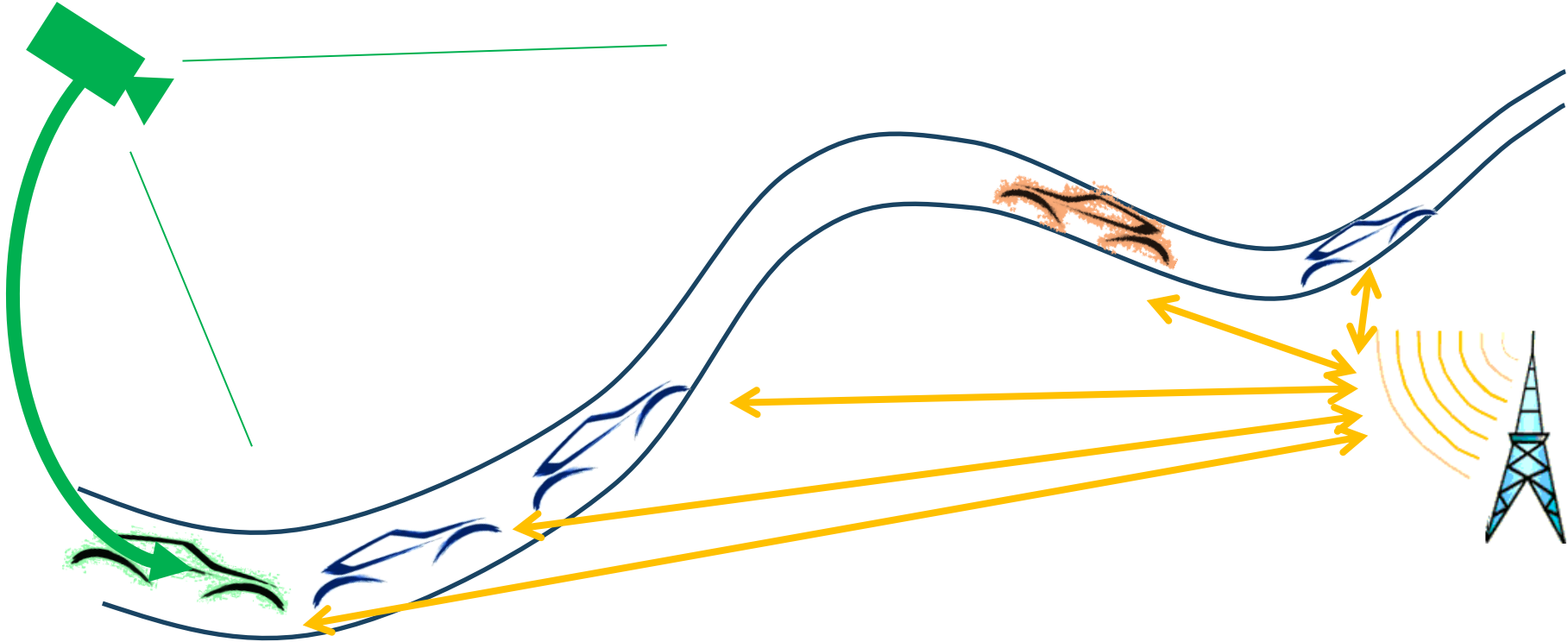


Tomorrow: platooned/convoyed ESC & ABS





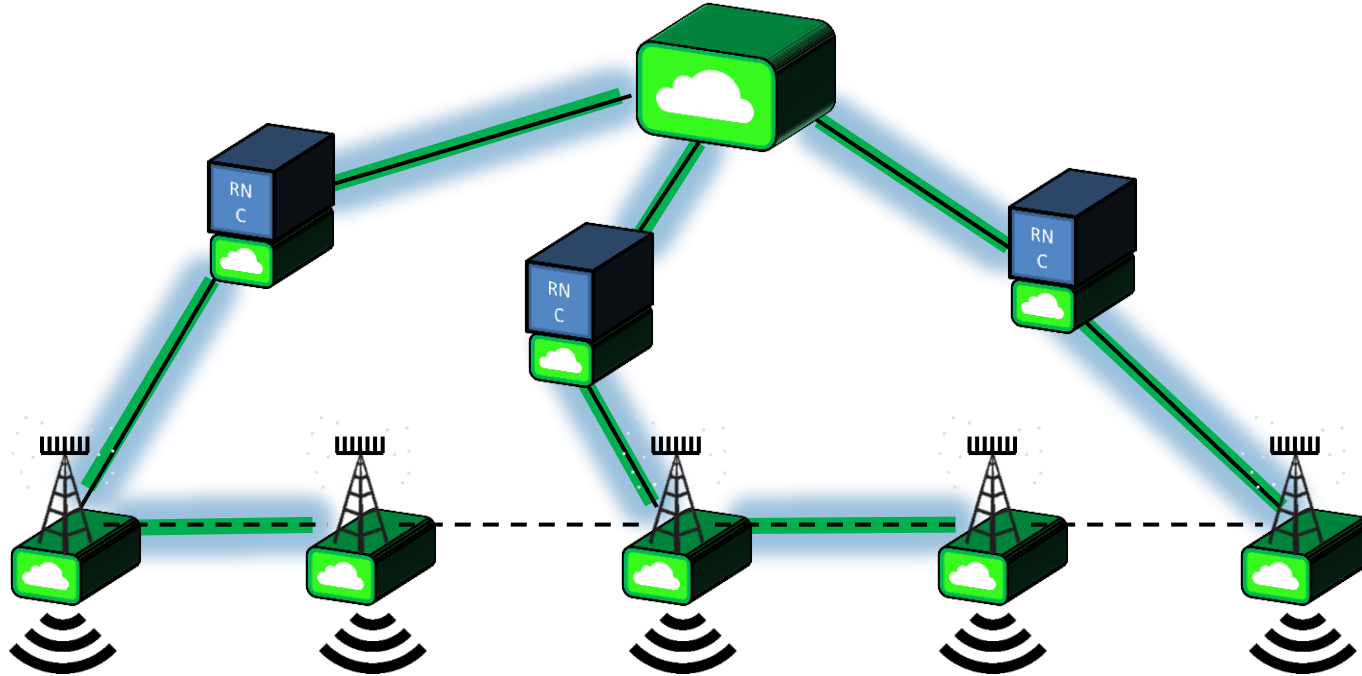
Heads-Up With Rendered Bird's Eye Look-Ahead



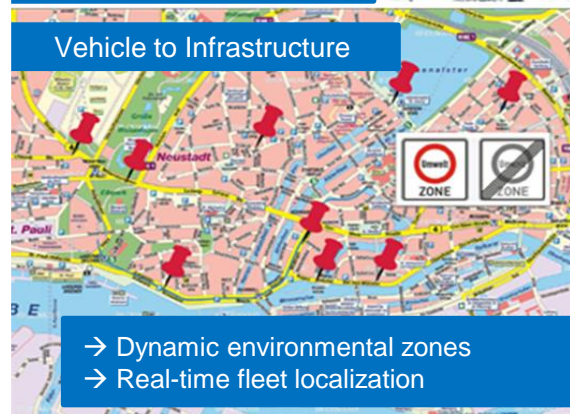
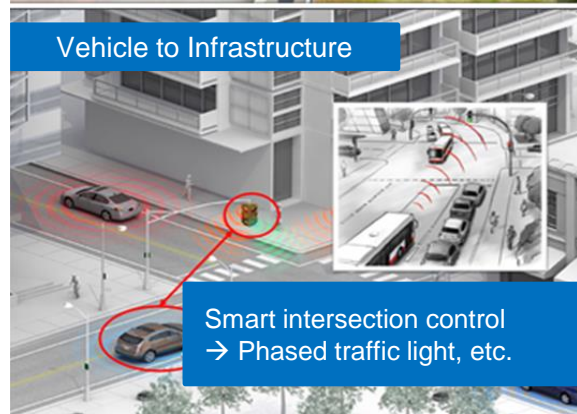


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Mobile Edge Cloud / Micro Cloud / Cloud



Use Cases for Vehicle to 'X' Communication (V2X)




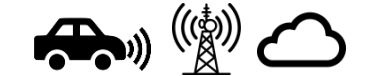

High expectations for

- improvement of road safety
- traffic efficiency
- driving comfort

Includes

- Vehicles
- roadside infrastructure
- vulnerable road users (pedestrians, etc.)

Today's Communication Technologies are Complementary

	Communication type	Technologies	Application formats
	Ad hoc	WLAN: IEEE 802.11p, ITS-G5	C-ITS Msg
	Cellular	UMTS, LTE, LTE-A LTE-V	C-ITS Msg, TPEG, Proprietary protocols
	Broadcast	DAB+ DMB	TPEG

Convergence?

Today

Ad hoc



WLAN
C-ITS Msg

Cellular



Cellular
C-ITS Msg,
TPEG,
Proprietary

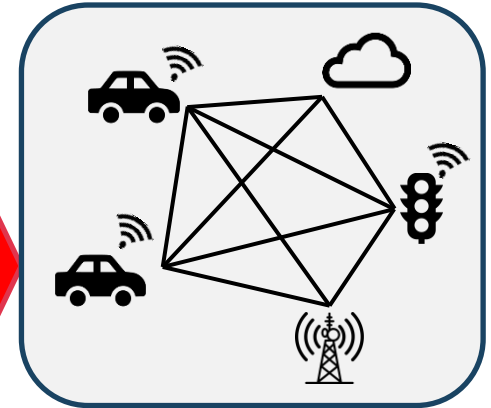
Broadcast



DAB+,
TPEG

Broadband
+ Tactile Internet
+ NB-IoT

2025

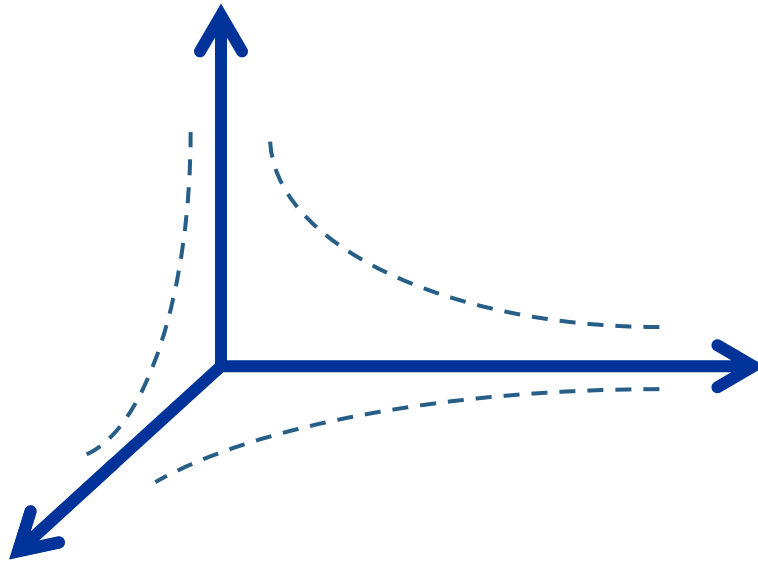


5G

5G Hyperplane

Speed: $>10 \text{ Gb/s} \rightarrow \text{Tb/s}$

Massive Content: Gb/s Services



Massive Sensing: IoT

1b/s over 10 years
off an AAA battery

Massive Control: Tactile Internet

Response: 1 ms

The Tactile Internet: Standardization Map

