Continental
The Future in Motion

Connected and Automated Driving
Requirements for digital telecom infrastructure

4th SIP-adus Workshop on Connected and Automated Driving Systems 2017

Dr. Frank Foersterling

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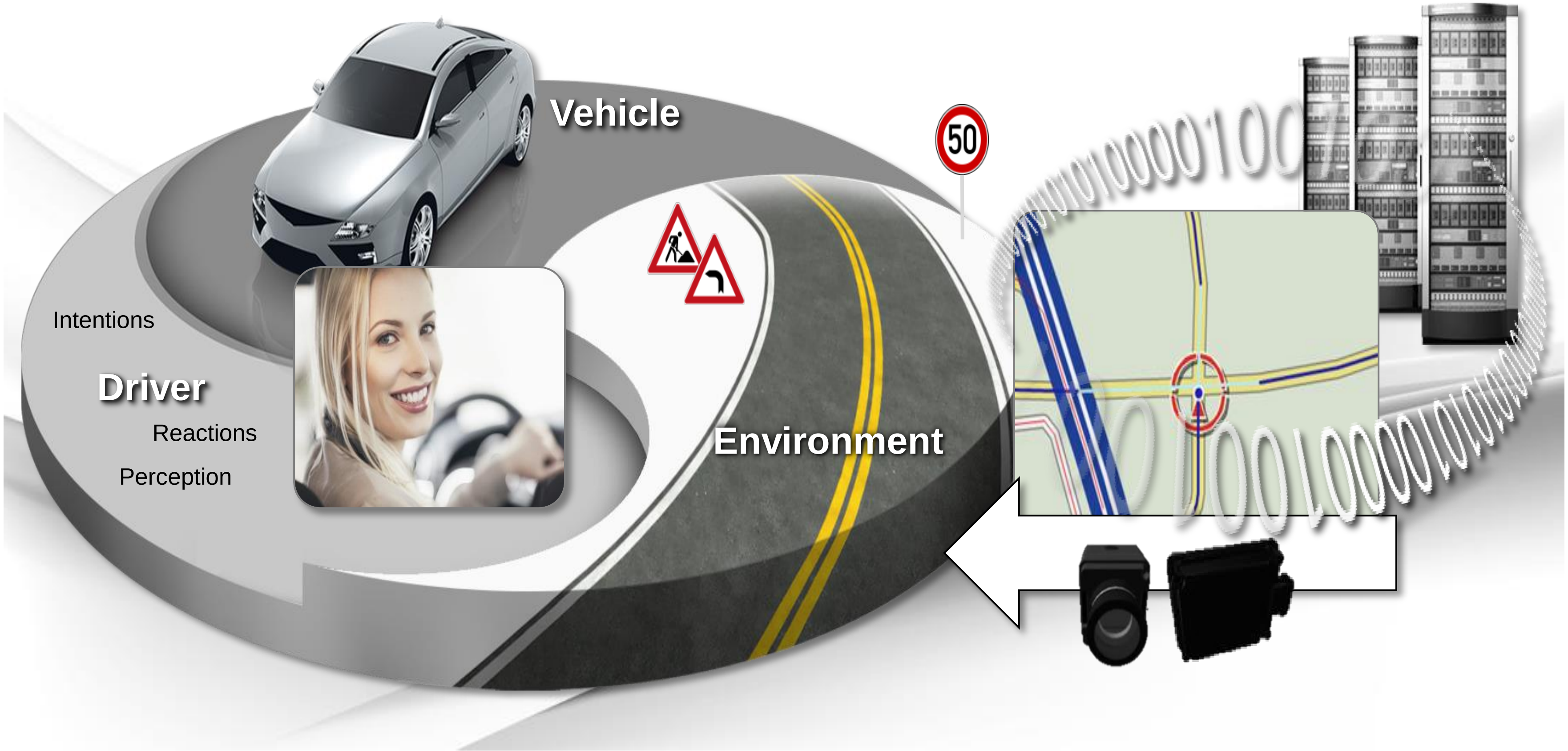
Automated Driving
Close the Loop Between Driver, Vehicle & Environment

Connected and Automated Driving - CAD

Integration of Map and RT Cloud Data into Environmental Analysis

Dynamc electronic Horizon (eH)

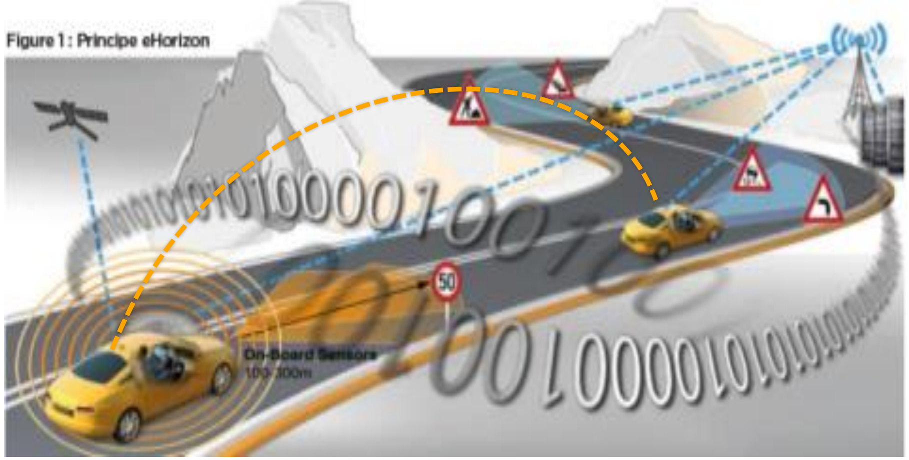


CAD and eHorizon

for smooth driving – at Highway and in urban regions

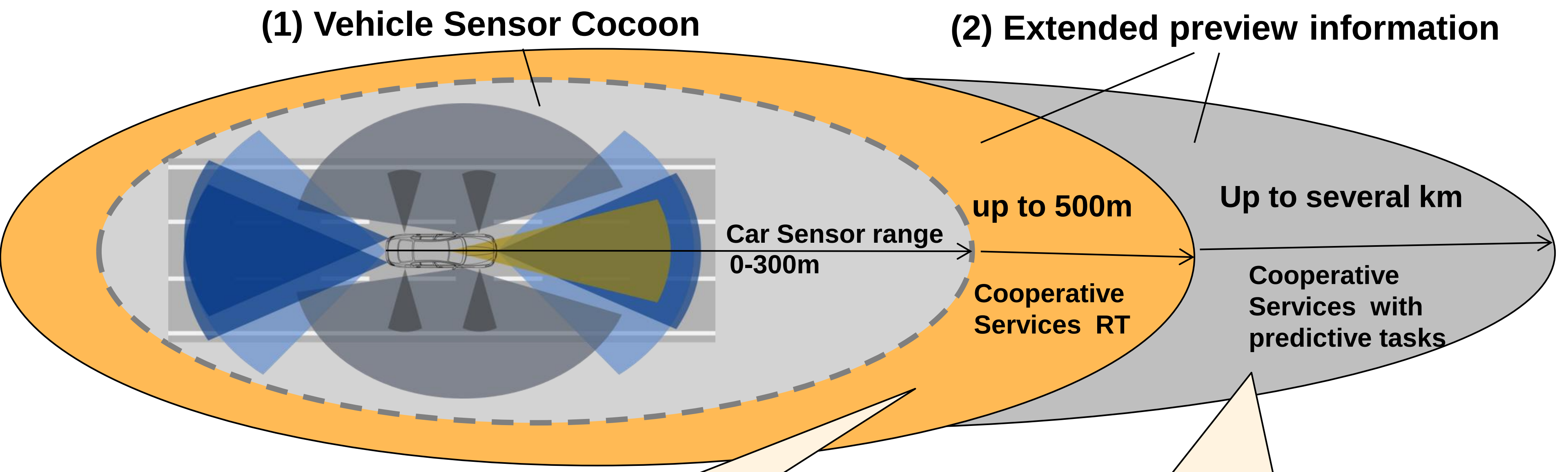
Maps as part of eHorizon

- Predictive view
- Highly precise
- Always up-to.date
- Integration of real-time data
- Crowd sourced intelligence



Sensor setup for CAD

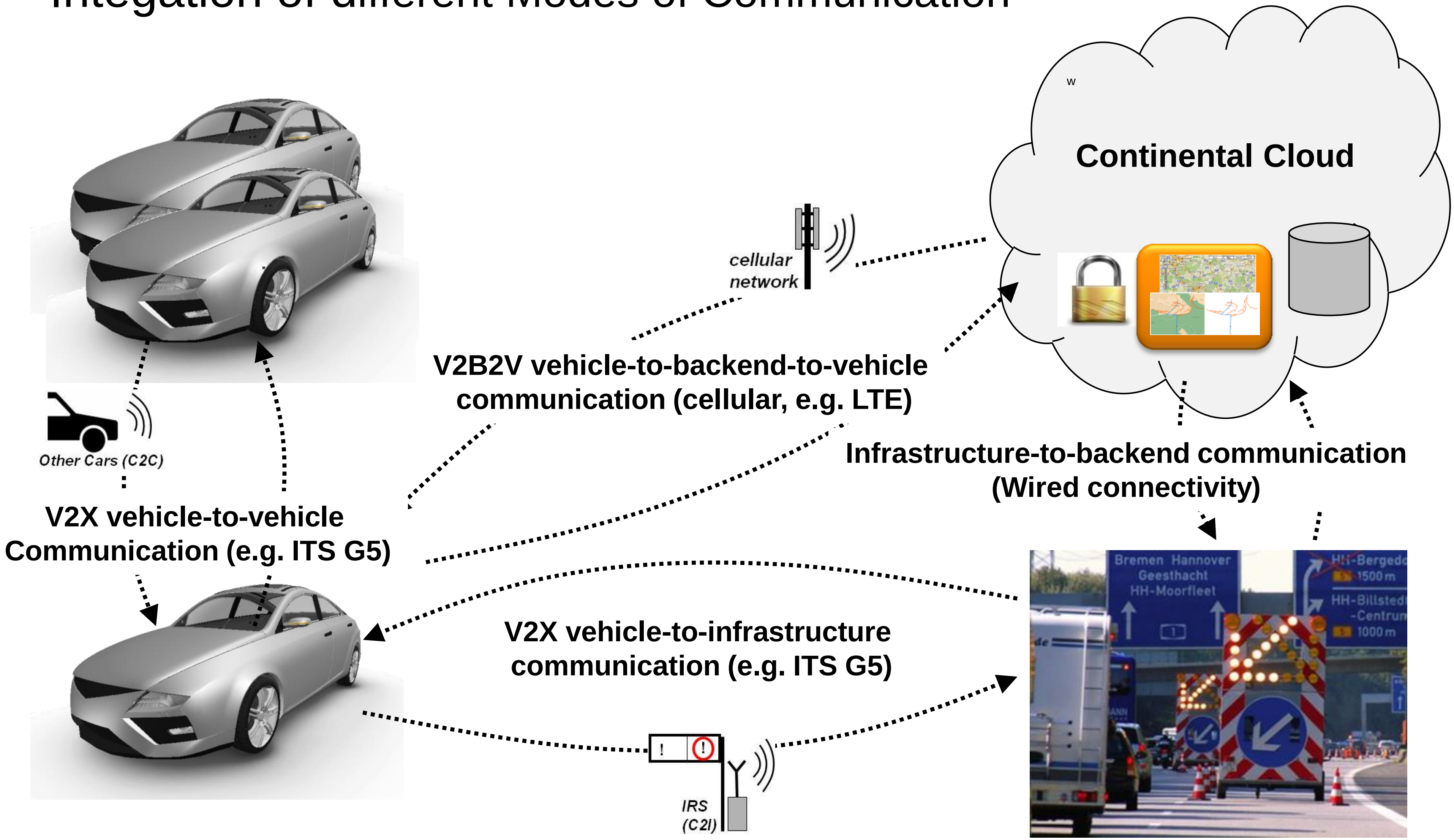
Extension of the Safety Cocoon for the vehicle by means of communication



Real Time Safety
(e.g. based on ITS G5 –now,
e.g. based LTE V, 5G -- soon)

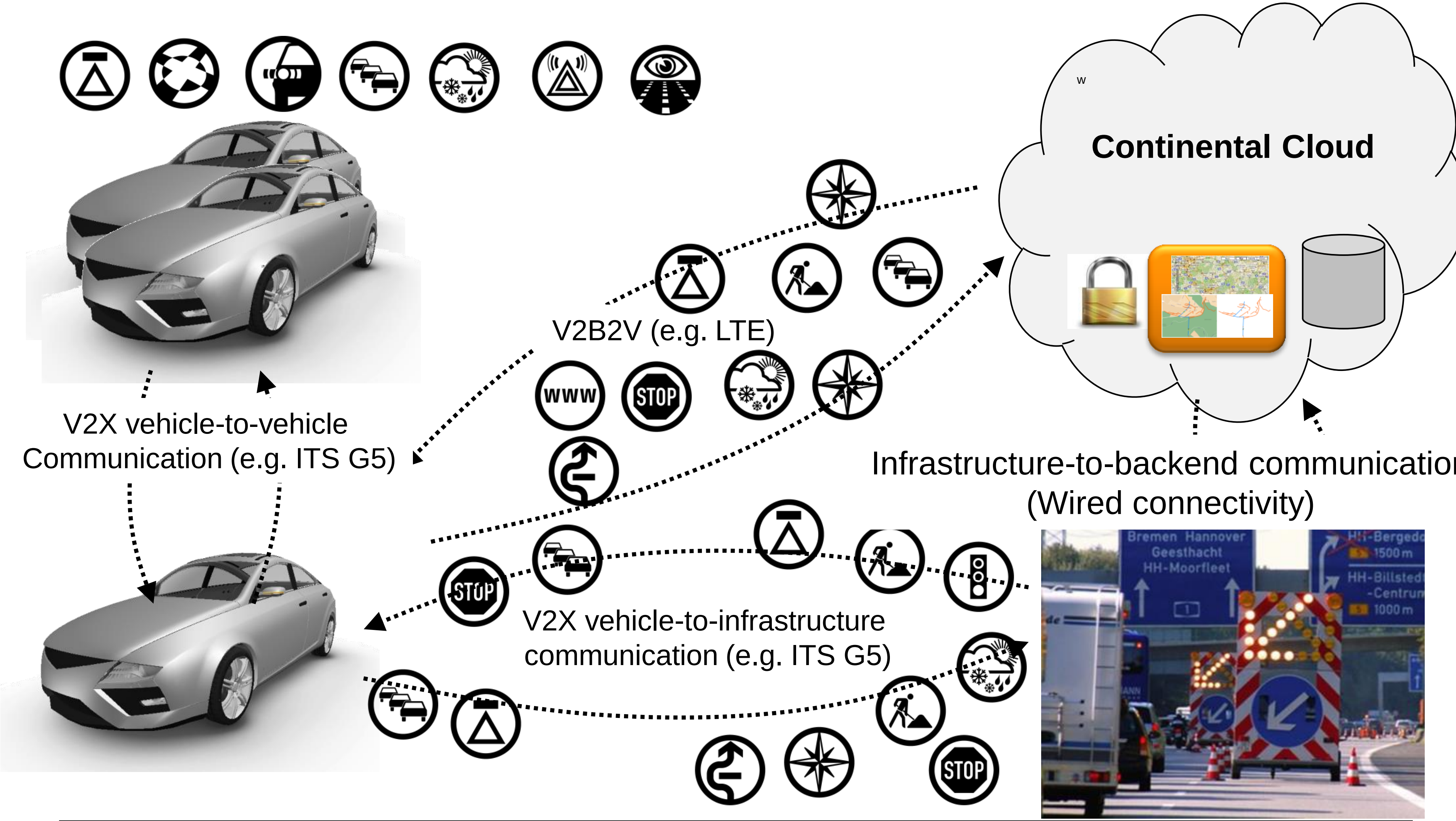
Electronic Horizon, cloud based
(e.g. based on 2G / 3G / 4G – now
e.g. based on LTE MEC, 5G -- soon)

CAD with dynamic eHorizon
Integation of different Modes of Communication



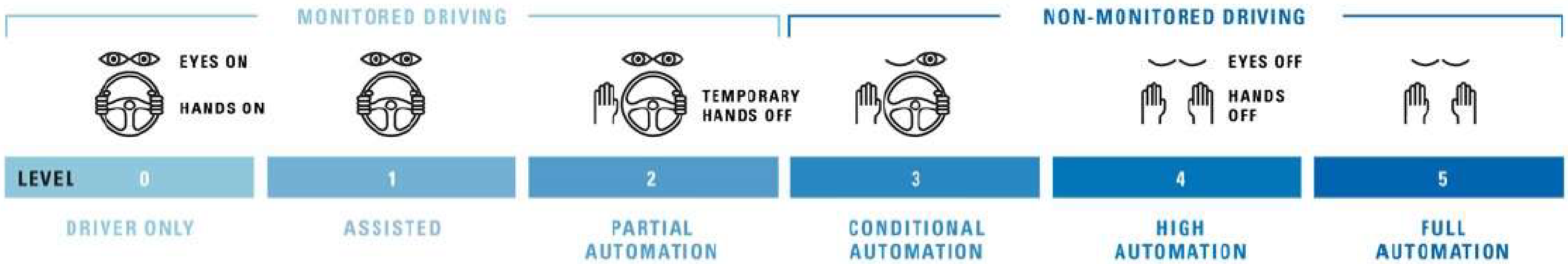
CAD with dynamic eHorizon

Use Case driven approach – via multiple modes of communication



Connected and Automated Driving

Evolution towards AD and 5G communication



2016 — 2017 — 2018 — 2019 — 2020+

Rel 10/11/12

- DL Carrier Agg.
- UL Carrier Agg.
- 4x4 MIMO
- DL 256QAM
- UL 64QAM
- DRAN – CoMP
- Dual Connectivity
- VoLTE

Rel 13, 14 and beyond

- Enhanced Carrier Agg.
- 3D Beamforming
- Low Latency / MEC
- V2X
- NB IoT/CAT-M1
- eMBMS
- Massive MIMO
- LAA & LWA

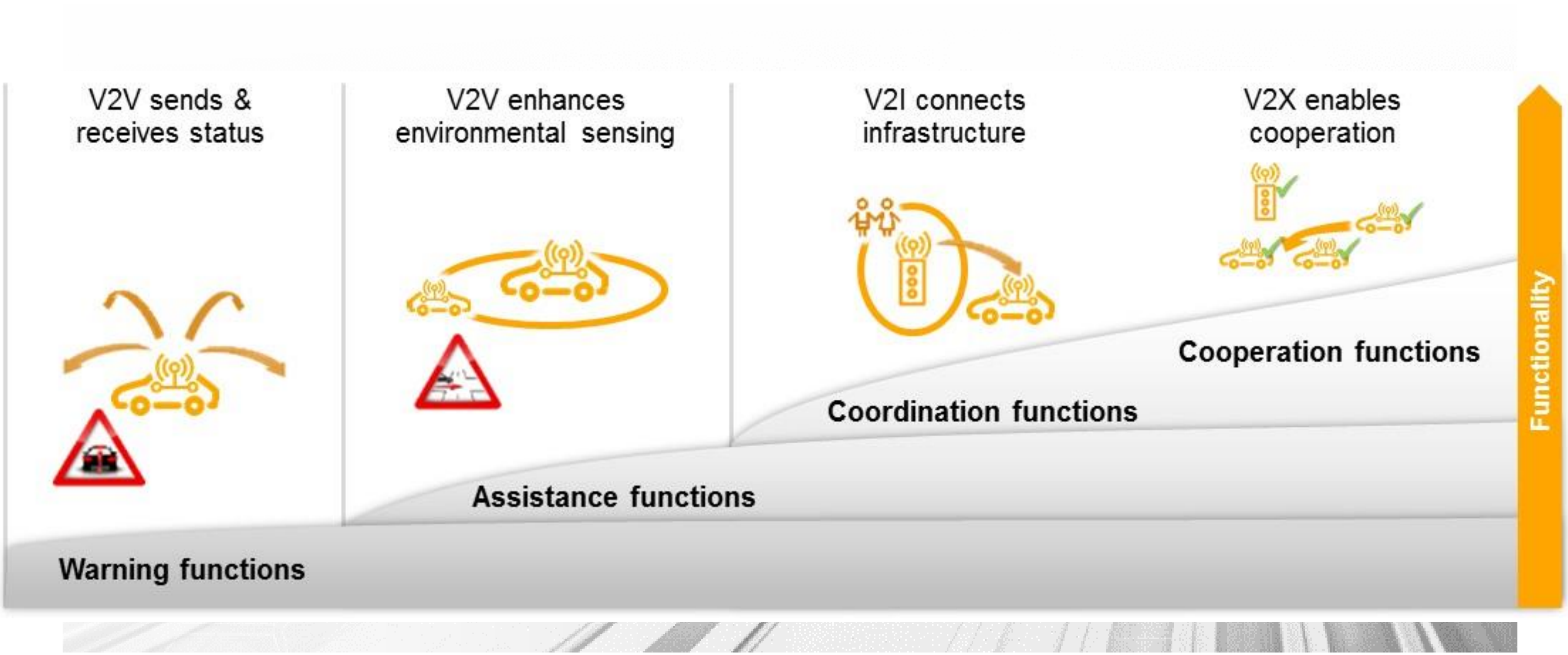
Rel-15

Source: Vodafone

Connected and Automated Driving

Vehicle-to-X enables new safety functions (ITS G5, DSRC)

Technology ready for deployment



5G as Game Changer in Cellular Communication and Connected Functions

- High bandwidth, up to 10 Gigabits per second
- Low latency, almost real-time
- Higher network capacity
- Potential for lower power consumption
- Always up-to-date in-vehicle systems
- Improved safety and comfort on the roads

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The Future in Motion

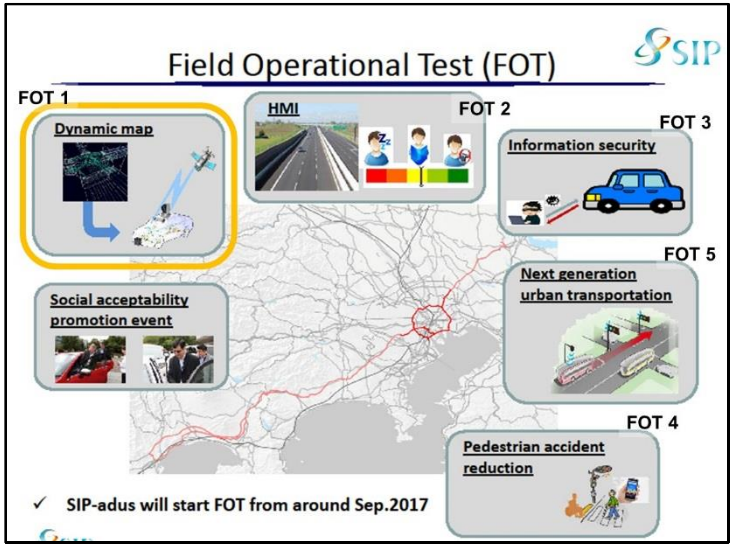
Japan: SIP FOT Project Connected&Automated Driving 2017/2018

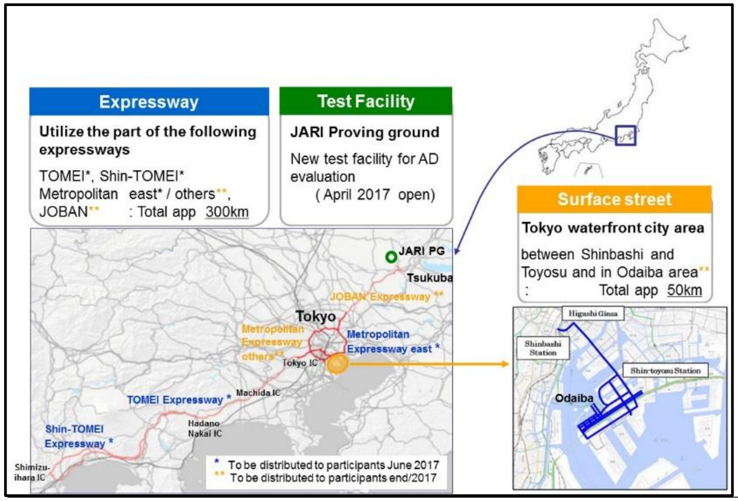
Continental participates

CabinetOffice

SIP

Japan: SIP FOT Project CAD 2017/2018
Continental participates





SIP FOT Press event in Cabinet Office October 3

Minister announced

" SIP FOT start from Oct 3 "

Parking area of Cabinet Office building

5 cars exhibited incl. Continental HAD Passat

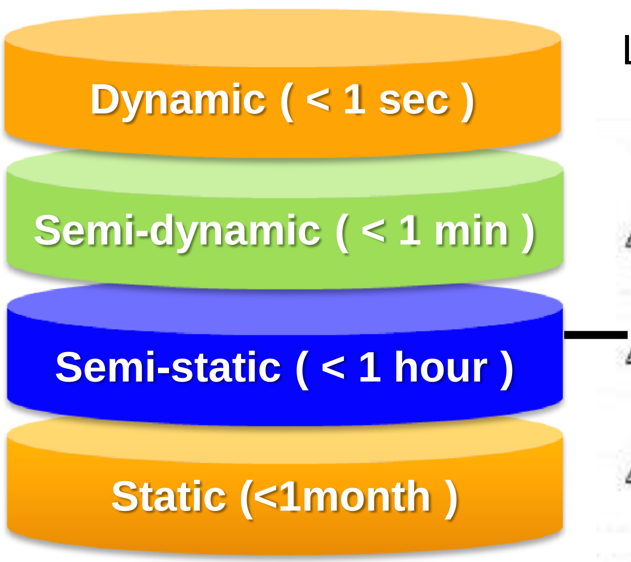
SIP FOT 1 (Dynamic Map)

Deployment Approach: cloud based & in-vehicle based

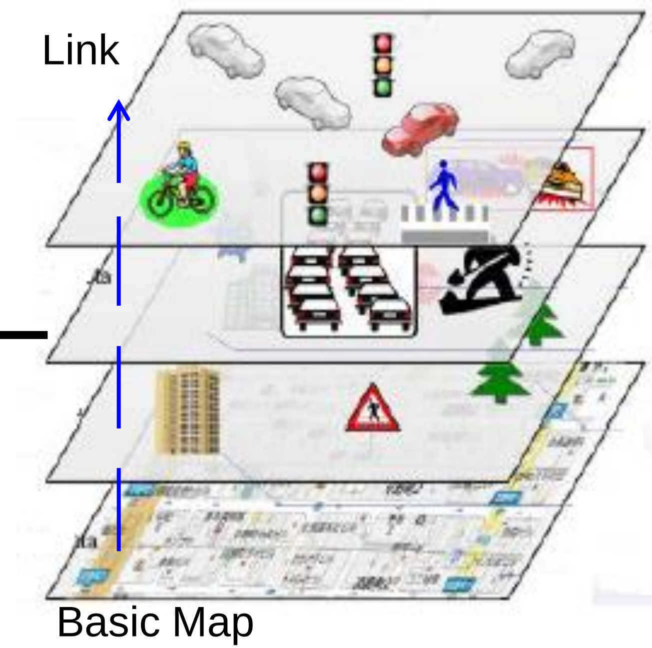
Dynamic Map

Hierarchical structure of digital 'Map' layered by time frame

Update Time frame



Linked layers



Information through V to X

- surrounding vehicles
- pedestrians
- timing of traffic signals

Traffic Information

- accidents
- congestion
- local weather

Planned and forecast

- traffic regulations
- road works
- weather forecast

Basic Map Database

- Digital cartographic data
- Topological data with unique
- Road Facilities

Digital Infrastructure Requirements for CAD

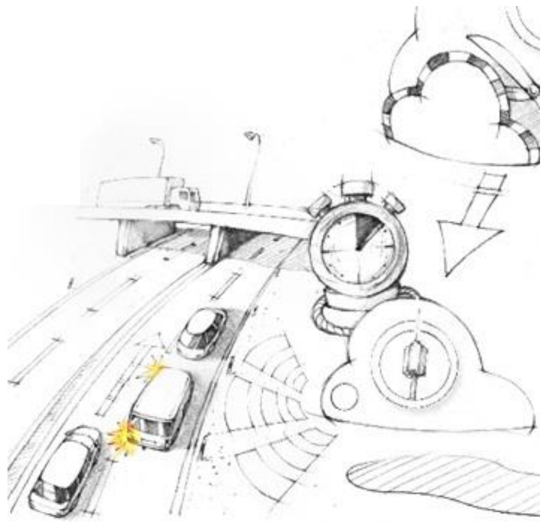
Reliable hybrid telecom infrastructure – validate LTE MEC

ITS G5 Communication
Direct vehicle to vehicle

Vehicle-to-vehicle is about proximity, path prediction and collision anticipation/warning:

- Intersection & Lane Change
- Rear end

ITS G5 Communication
Short Range



Vehicle-to-infrastructure is about broader road conditions:

- Incidents
- Alerts

LTE / 5G Communication
Incl. LTE V2X / LTE MEC

V2X via location-cast is about Electronic Horizon far ahead of the vehicle:

- Weather/road/traffic conditions
- Incidents

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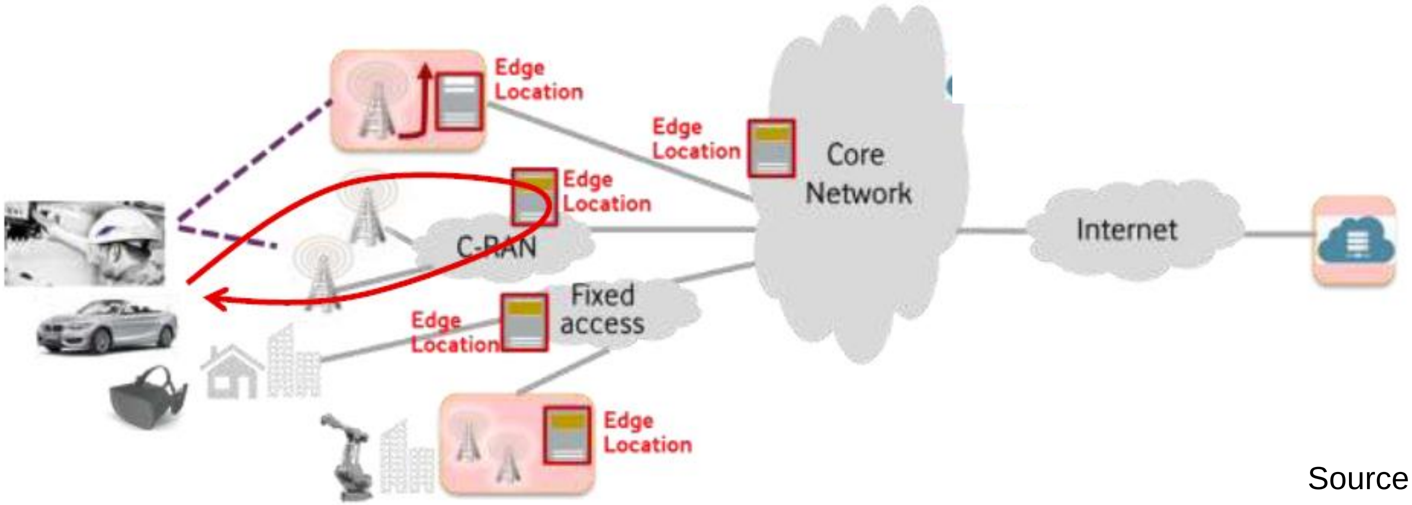
Digital Infrastructure Requirements for CAD
The essence of LTE MEC

Capabilities
1. Distributed cloud at the edge
2. Shortest-path routing to edge cloud
3. Special platform services at edge
4. Services exposure via APIs
5. Workload migration over WAN

Benefits
1. Keeps application traffic local to devices
2. Low latency / RT communication
3. Limited latency under device mobility
4. Computational offload from devices
5. Data aggregation and control for many devices in a geographical region



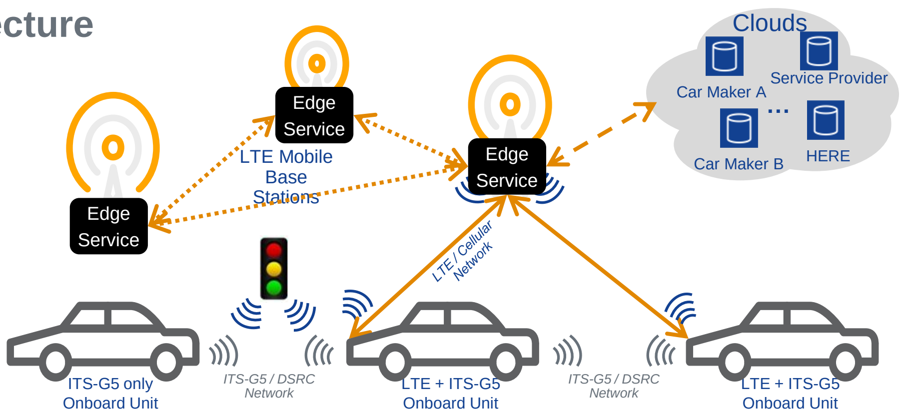
Source: Vodafone

Digital Infrastructure Requirements for CAD
LTE MEC POC (Germany): Project Objectives

Analyse the capabilities of Mobile Edge Computing in the context of V2X communications and connected cars using use cases defined by the car industry:

- Propose e2e network and distributed cloud architectures
- Verify concepts at the German motorway A9 test area in the field
- Propose evolution toward 5G

Architecture



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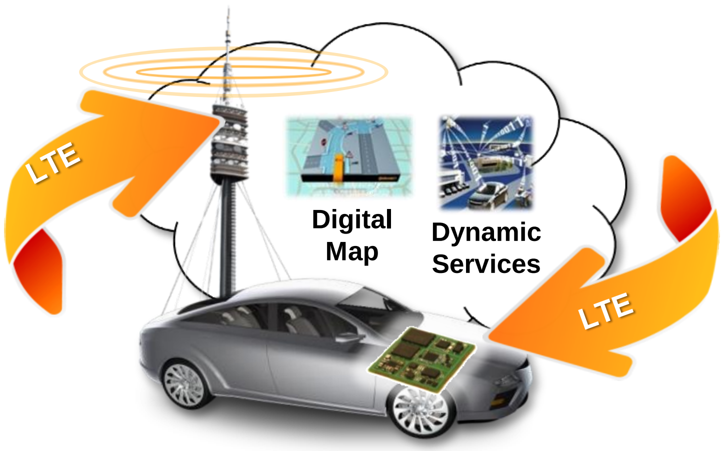
→ Prove LTE as complementary & efficient technology for low-latency V2X communications

Digital Infrastructure Requirements for CAD
LTE MEC POC (Germany): considered Use Cases

Target:

- **Definition and elaboration of the Use Cases, interactions and flow concepts**

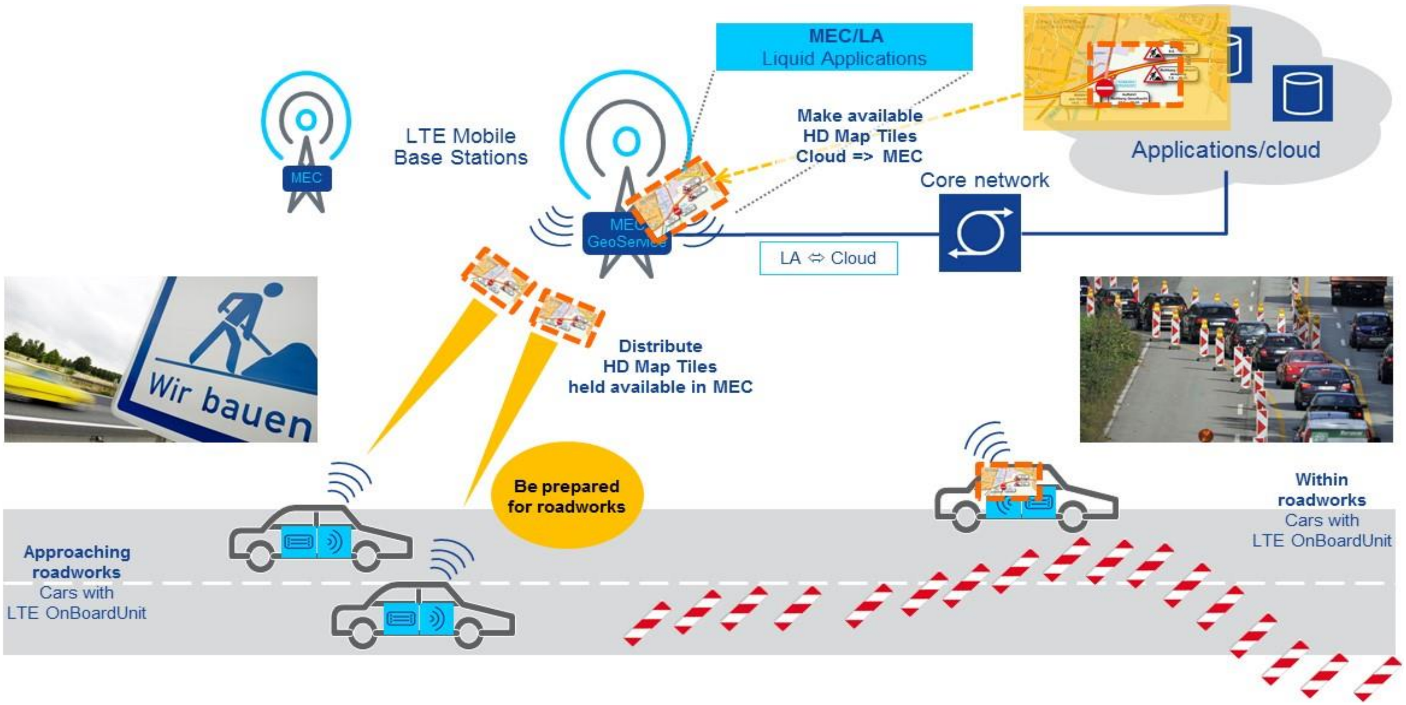


Use Cases:

- **Emergency Warning**
- **End-of-Jam Warning**
- **Variable-Speed-Limit Assistant**
- **Data Collection**
- **HD Map Distribution**

Traffic Jam ahead

LTE MEC POC (Germany):
UC Map Distribution



- Uni-directional interaction between Car2X-connected vehicles via LTE and MEC to the backend.
- Transfer of high-definition (HD) map tiles or map updates from MEC to the vehicle.
- Here the map sections are held available and distributed to the vehicles by the MEC, according to the network coverage of the LTE basestation. The respective map section in the MEC will be synchronized with the backend.
- A broadcast-based (e.g. eMBMS) distribution of map tiles or map updates will be investigated.

LTE MEC POC (Germany):

UC Map Distribution Performance figures (Highway, Rd Class 1-2)

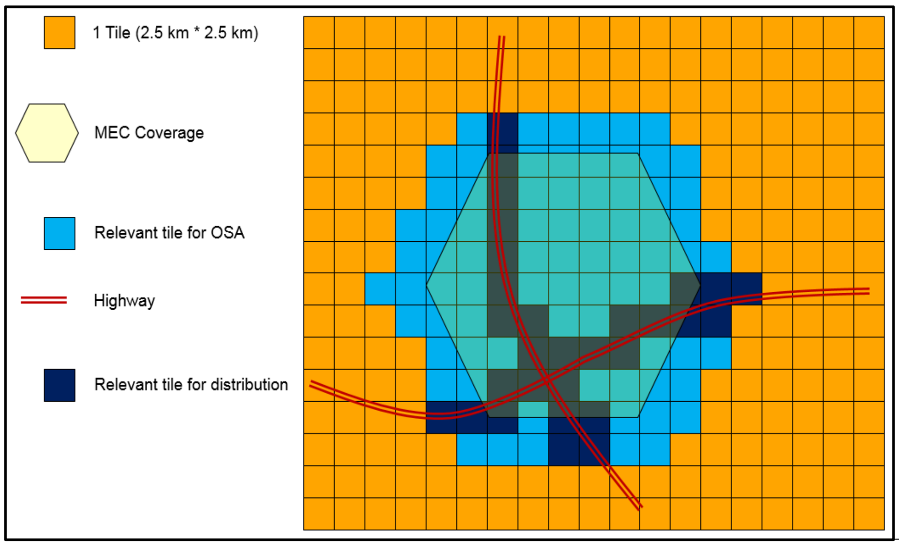
Key MEC figures

- MEC coverage (Radius): 30 km
- Tile coverage: 2,5 x 2,5 km
- Tiles considered (incl. border)
  → own service area (OSA): 484
- Tiles of relevance (Rd class 1-2): 24
- Average tile size (Rd class 1-2): 20Kbyte

Radius	Map Tiles (2.5 x 2.5)		
	Inside	Border	Sum
2.0	0	4	4
6.0	9	16	25
10.0	32	28	60
14.0	75	44	119
18.0	135	56	191
22.0	206	68	274
26.0	295	80	375
30.0	392	92	484

Layer	Size (GB) per Functional Road Class			
	1	1-2	1-3	1-4
ADAS[2)]	0.05 GB	0.15 GB	0.3 GB	0.7 GB
Lane[1)]	1.5 GB	4 GB	7 GB	18 GB
Localization[2)]	0.5 GB	1 GB	2 GB	4 GB
Sum	2 GB	5 GB	10 GB	23 GB

Key data	
HD map tile size	2.5 km x 2.5 km
Average size of a complete tile (1-5)	200 Kbyte [3)]
Average size of a tile with road class 1-2 only	20 Kbyte
Highway kilometers in Germany	13,000 km
Receiving vehicles (according to estimations)	2018: <10,000 2020: 400,000 2025: 2,000,000



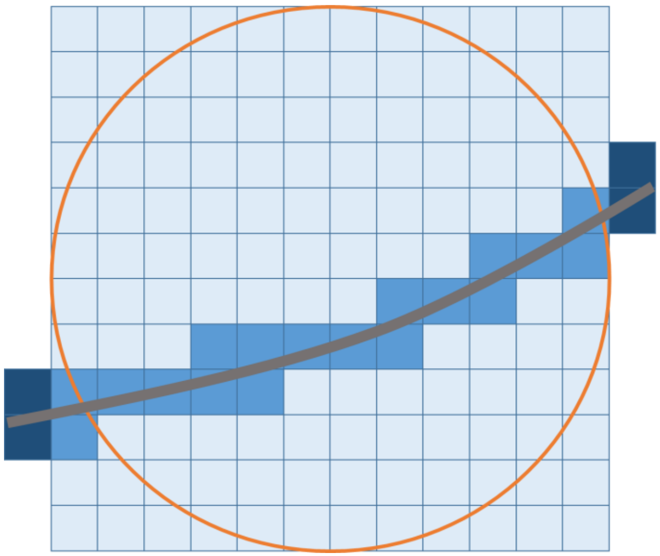
LTE MEC POC (Germany):

UC Map Distribution Performance figures (Highway, Rd Class 1-2)

- The expected download bandwith for HD Maps is 170 Kbit/s (2x 85 Kbit/s)
- Due to broadcast within a MEC area: the bandwith requirements is independent from the amount of vehicles per MEC

Key performance figures

- Tiles of relevance (Rd class 1-2): 24
- Includes: 35km (MEC plus border)
- Average tile size (Rd class 1-2): 20Kbyte
- Vehicle speed at Highway: 200km/h
- Average driving time per tile (of 2,5 km length): 45 s
- Download sequence sent 2x within 45s

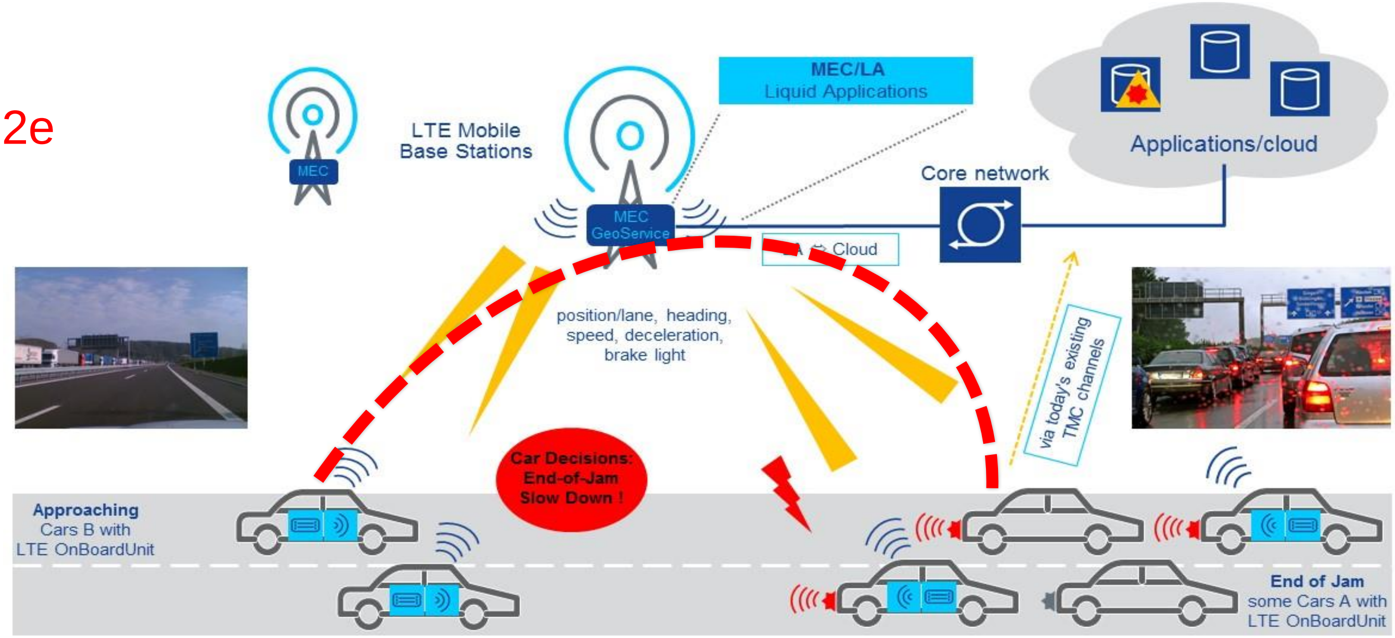


$$24\ [tiles] * 20 * 10^3 \left[\frac{\frac{byte}{tile}}{vehicle}\right] * \frac{1}{45\ [s]} = 10666 \left[\frac{\frac{byte}{s}}{vehicle}\right] \approx 85\ \frac{Kbit/s}{vehicle}$$

LTE MEC POC (Germany):

UC End-of-Jam warning: **measured e2e latency: < 20ms (1 MEC)**

13 ms e2e

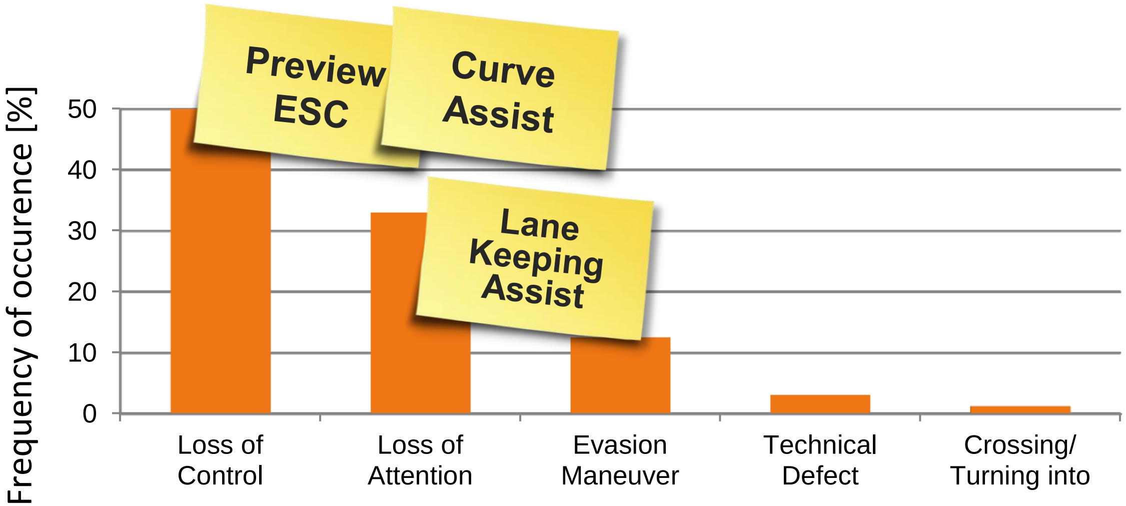


- Bi-directional interaction between Car2X-connected vehicles via LTE and MEC to the backend.
- Geo-referenced communication from vehicle functions (position/lane, heading, speed, deceleration, brake&warning lights) by the vehicle.
- In the backend the traffic jam situations are detected and appropriate jam warnings will be sent geo-referenced.
- The vehicle decides on its own, based on information about direction and lane, if the warning is relevant for the vehicle/driver.

Dynamic eHorizon for CAD – Cloud based assistance
High Relevance of "Road Departure" Accidents

- 48.5% of all fatal accidents are "road departures "
- 20.1% of all accidents of passenger cars in Germany are "road departure" with injured passengers

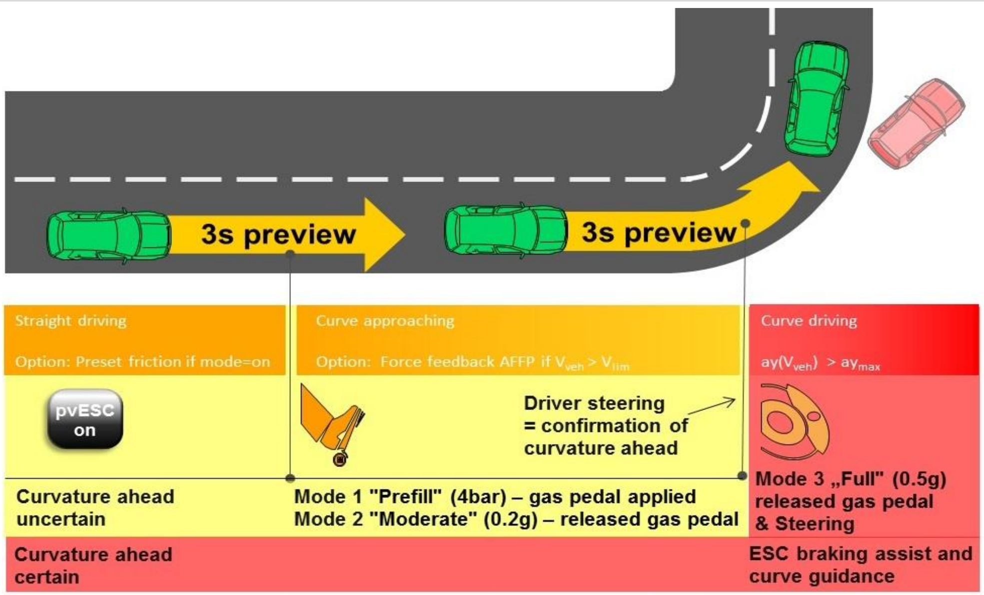
Distribution of "road departure" Situations:

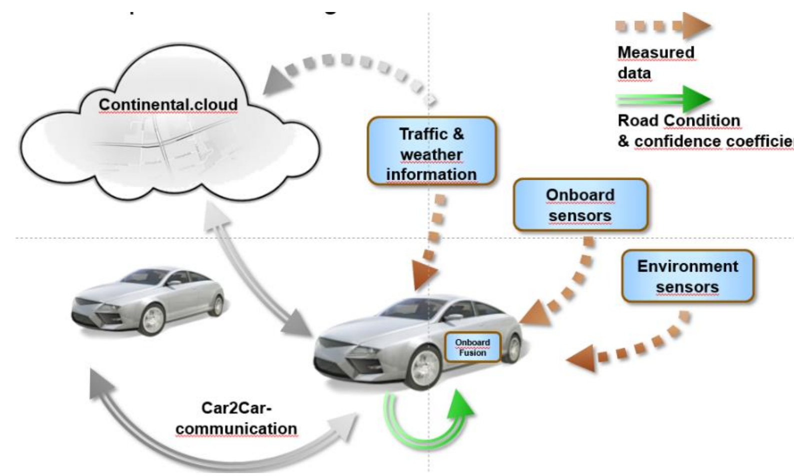


(from German In-Depth Accident Study GIDAS, 12/2011, 13800 accidents)

Dynamic eHorizon for CAD
Use Case: Road Departure Protection

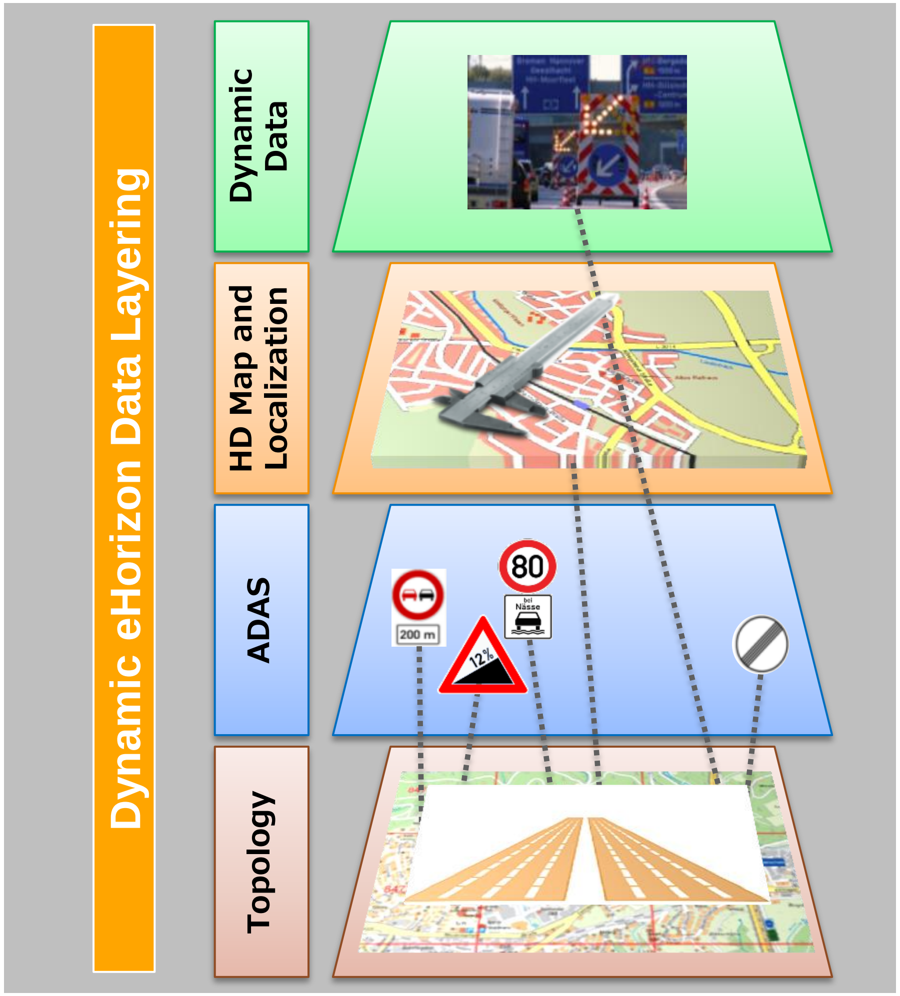
- Local sensors
- eHorizon provides:
  - road curvature ahead, weather, dyn. Speed data, traffic signs, statistical data on driver behavior
- Cloud technologies: data fusion based on statistics, Artificial Intelligence





ESC:Electronic Stability Control

eHorizon Concept
Layer Model, Fresh Data Allover



Dynamic Data

- Information on Dynamic Events along the road (e.g. construction area, traffic jam, potholes, average speed)

High Definition (HD) Map and Localization

- Landmarks and camera based data, high precision updates of landmarks on the map
- Describes road including all lanes, occupied/non-occupied areas
- Highly precise lane information

ADAS / Road Furniture

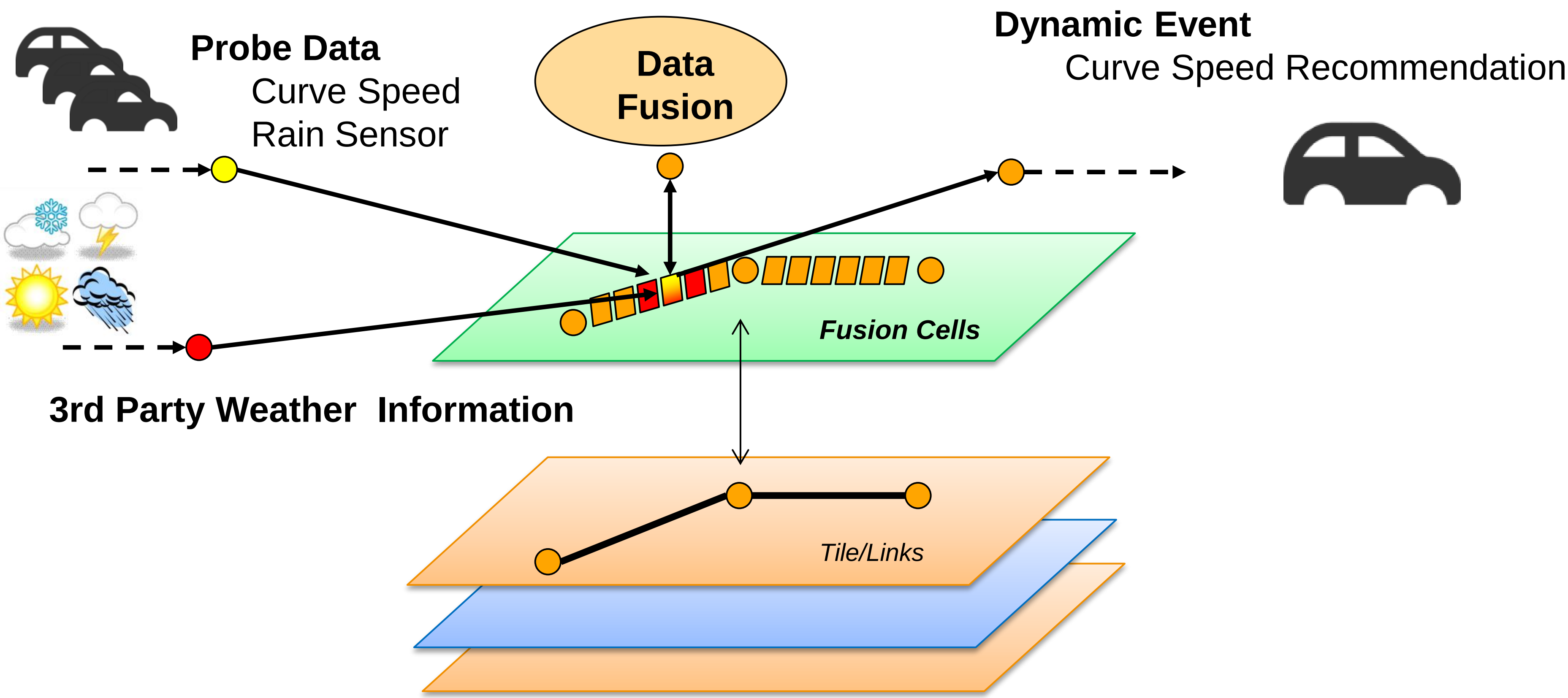
- Semantics and Rules, e.g. Speed Limits, Non-Overtaking areas, conditional signs, slope info, curvature info

Topology / Road Geometry

- Topology and Basic layer like Routing
- Enables referencing of information and further layering in relationship to a frame of reference

Dynamic eHorizon for CAD, UC Road Departure Protection

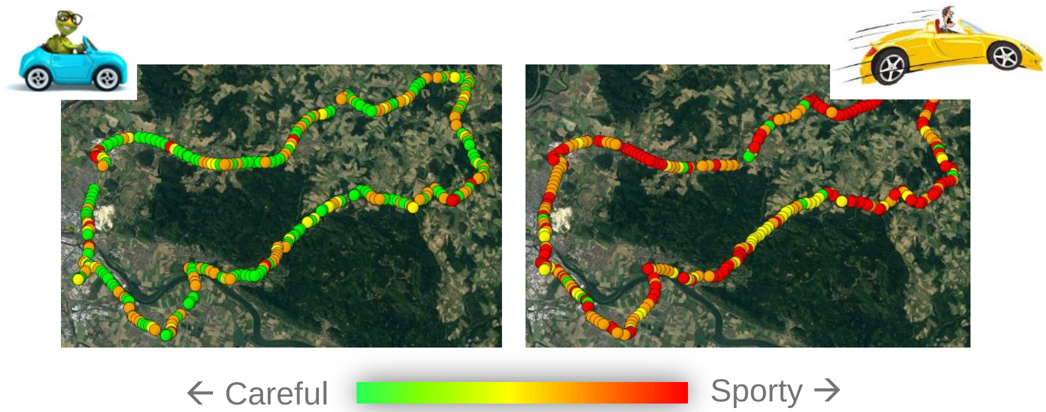
Intelligent Curve Speed Assist – Cloud based data analytics



Dynamic eHorizon for CAD, UC Road Departure Protection
Drive Style Recognition – Cloud based Artificial Intelligence

Classify driving sequences in categories and characterize them

Challenge: 3 unknown
➔ unsupervised Machine Learning techniques



CAR DISPLAY

Artificial Intelligence : 1950 → 2017

“All models are wrong but some are useful”
George Box

CAD and eHorizon Requests to Telecom Infrastructure
Conclusion

- Smooth AD driving requires cloud data – and connectivity ✓
- First AD solutions capable with existing Telecom Infrastructure (2G / 3G / 4G) ✓
- Next Gen Telecom Infrastructure (like LTE MEC, LTE V, 5G) supports higher bandwith, lower latency and higher availability and has to be stepwise evolved ✓
- Multiple communication pathes (like DSRC / ITS G5 and e.g. LTE) complement the infrastructure for more value added services ✓
- Continental runs several CAD trials based on different communication infrastructures to prepare the future ✓

Thank you
for your attention!

Dr. Frank Försterling
Continental Automotive GmbH
Head of R&D, Intelligent Transportation Systems
Siemensstrasse 12, D-93055 Regensburg, Germany
+49 941 790 8785
Frank.Foersterling@continental-corporation.com