Connected and Automated Driving
Requirements for digital telecom infrastructure

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

Dr. Frank Foersterling
Continental
Automated Driving
Close the Loop Between Driver, Vehicle & Environment
Connected and Automated Driving - CAD
Integration of Map and RT Cloud Data into Environmental Analysis

Dynamic 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

(1) Vehicle Sensor Cocoon

(2) Extended preview information

Car Sensor range
0-300m

Cooperative Services RT

up to 500m

Up to several km

Cooperative Services with predictive tasks

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
Integration of different Modes of Communication

V2X vehicle-to-vehicle Communication (e.g. ITS G5)

V2B2V vehicle-to-backend-to-vehicle communication (cellular, e.g. LTE)

Infrastructure-to-backend communication (Wired connectivity)

Continental Cloud

V2X vehicle-to-infrastructure communication (e.g. ITS G5)
CAD with dynamic eHorizon
Use Case driven approach – via multiple modes of communication

V2X vehicle-to-vehicle Communication (e.g. ITS G5)

V2B2V (e.g. LTE)

Infrastructure-to-backend communication (Wired connectivity)

V2X vehicle-to-infrastructure communication (e.g. ITS G5)
Connected and Automated Driving
Evolution towards AD and 5G communication

- **MONITORED DRIVING**
  - Level 0: Driver Only
  - Level 1: Assisted
  - Level 2: Partial Automation
  - Level 3: Conditional Automation

- **NON-MONITORED DRIVING**
  - Level 4: High Automation
  - Level 5: Full Automation

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**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

**Source: Vodafone**

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Connected and Automated Driving
Vehicle-to-X enables new safety functions (ITS G5, DSRC)

Technology ready for deployment

- V2V sends & receives status
- V2V enhances environmental sensing
- V2I connects infrastructure
- V2X enables cooperation

Functionality

- Cooperation functions
- Coordination functions
- Assistance functions
- Warning functions

Continental
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
Bitte decken Sie die schraffierte Fläche mit einem Bild ab.

Wenn Sie ein neues Bild einfügen: Klicken Sie mit der rechten Maustaste auf das Bild und wählen "In den Hintergrund", um das Bild hinter das Quality Seal zu bringen.

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

Continental participates
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

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**Dynamic Map**

Hierarchical structure of digital ‘Map’ layered by time frame

**Update Time Frame**
- **Dynamic (< 1 sec)**
- **Semi-dynamic (< 1 min)**
- **Semi-static (< 1 hour)**
- **Static (< 1 month)**

**Linked Layers**
- Link

**Basic Map**

**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

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Digital Infrastructure Requirements for CAD
Reliable hybrid telecom infrastructure – validate LTE MEC

**ITS G5 Communication**
Direct vehicle to vehicle

**ITS G5 Communication**
Short Range

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

Vehicle-to-vehicle is about proximity, path prediction and collision anticipation/warning:
- Intersection & Lane Change
- Rear end

Vehicle-to-infrastructure is about broader road conditions:
- Incidents
- Alerts

V2X via location-cast is about Electronic Horizon far ahead of the vehicle:
- Weather/road/traffic conditions
- Incidents
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

→ 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
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

<table>
<thead>
<tr>
<th>Radius</th>
<th>Map Tiles (2.5 x 2.5)</th>
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<tbody>
<tr>
<td></td>
<td>Inside</td>
</tr>
<tr>
<td>2.0</td>
<td>0</td>
</tr>
<tr>
<td>6.0</td>
<td>9</td>
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</table>

<table>
<thead>
<tr>
<th>Layer</th>
<th>Size (GB) per Functional Road Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-1-2</td>
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<tr>
<td>ADAS</td>
<td>0.05</td>
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<tr>
<td>Lane</td>
<td>1.5</td>
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<tr>
<td>Localization</td>
<td>0.5</td>
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<tr>
<td>Sum</td>
<td>2</td>
</tr>
</tbody>
</table>

Key data
- HD map tile size: 2.5 km x 2.5 km
- Average size of a complete tile (1-5): 200 Kbyte
- 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

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LTE MEC POC (Germany): UC Map Distribution Performance figures (Highway, Rd Class 1-2)

- The expected download bandwidth for HD Maps is 170 Kbit/s (2x 85 Kbit/s)
- Due to broadcast within a MEC area: the bandwidth 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

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

![Diagram showing the frequency of road departure situations](image)

(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
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

Probe Data
Curve Speed
Rain Sensor

Dynamic Event
Curve Speed Recommendation

3rd Party Weather Information

Data Fusion

Fusion Cells

Tile/Links

Probe Data
Curve Speed
Rain Sensor

Dynamic Event
Curve Speed Recommendation

Fusion Cells

Tile/Links

3rd Party Weather Information
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

SPORTY

FEATURE ANALYSIS
- LONG ACCELERATION
- LAT ACCELERATION
- THROTTLE PEDAL
- ENGINE SPEED
- ENGINE REGU TORQUE

APPLICATION STATUS

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3% CALM
3% NORMAL
100% SPORTY
1% CRAZY

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Artificial Intelligence : 1950 → 2017

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

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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 bandwidth, lower latency and higher availability and has to be stepwise evolved

Multiple communication paths (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!

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