5G-MOBIX German Trial Site Results and Lessons learnt on 5G for CAM

Introduction on DE Trial Site

Sebastian Peters, Technische Universität Berlin

DE TS Webinar, June 22nd 2022

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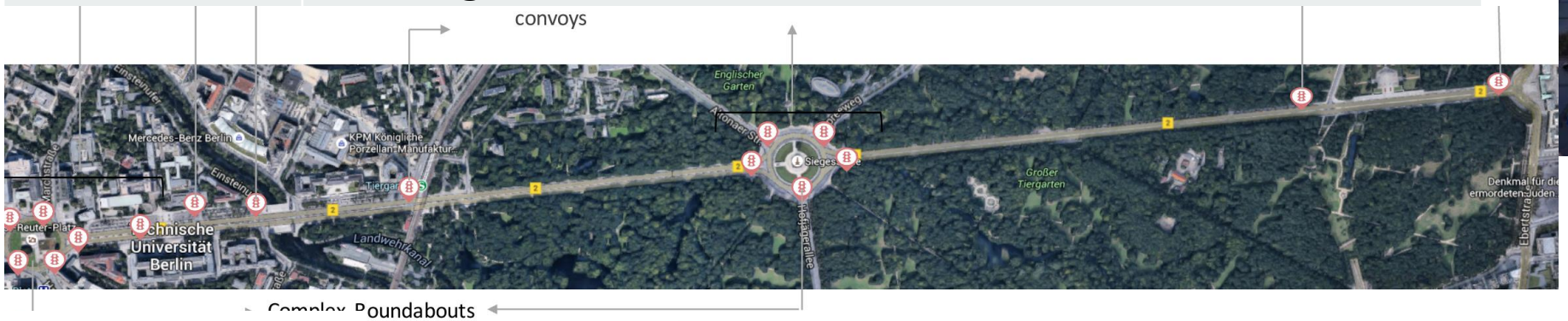
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825496

DE Trial Site description

DE TS	
Partners	GT-ARC, TUB, Valeo, Vicomtech
Location	Berlin, open road in urban environment
Vehicles	3
OBUs	4x 5G Valeo-Peiker TCU 2.0, 3x Quectel RG500Q-EA 2x Quectel RMU500-EK, 1x Telit Fn980m
RSI / MEC	9 eRSUs with far edge MEC. PC5 Sidelink RSUs deployed on 2 sites . Near Edge MEC MobiledgeX (Berlin node), research MEC at TUB
Use cases	• UCC#2/US#2 **eRSU-assisted platooning** • UCC#3/US#2 **EDM-enabled extended sensors with surround view generation**



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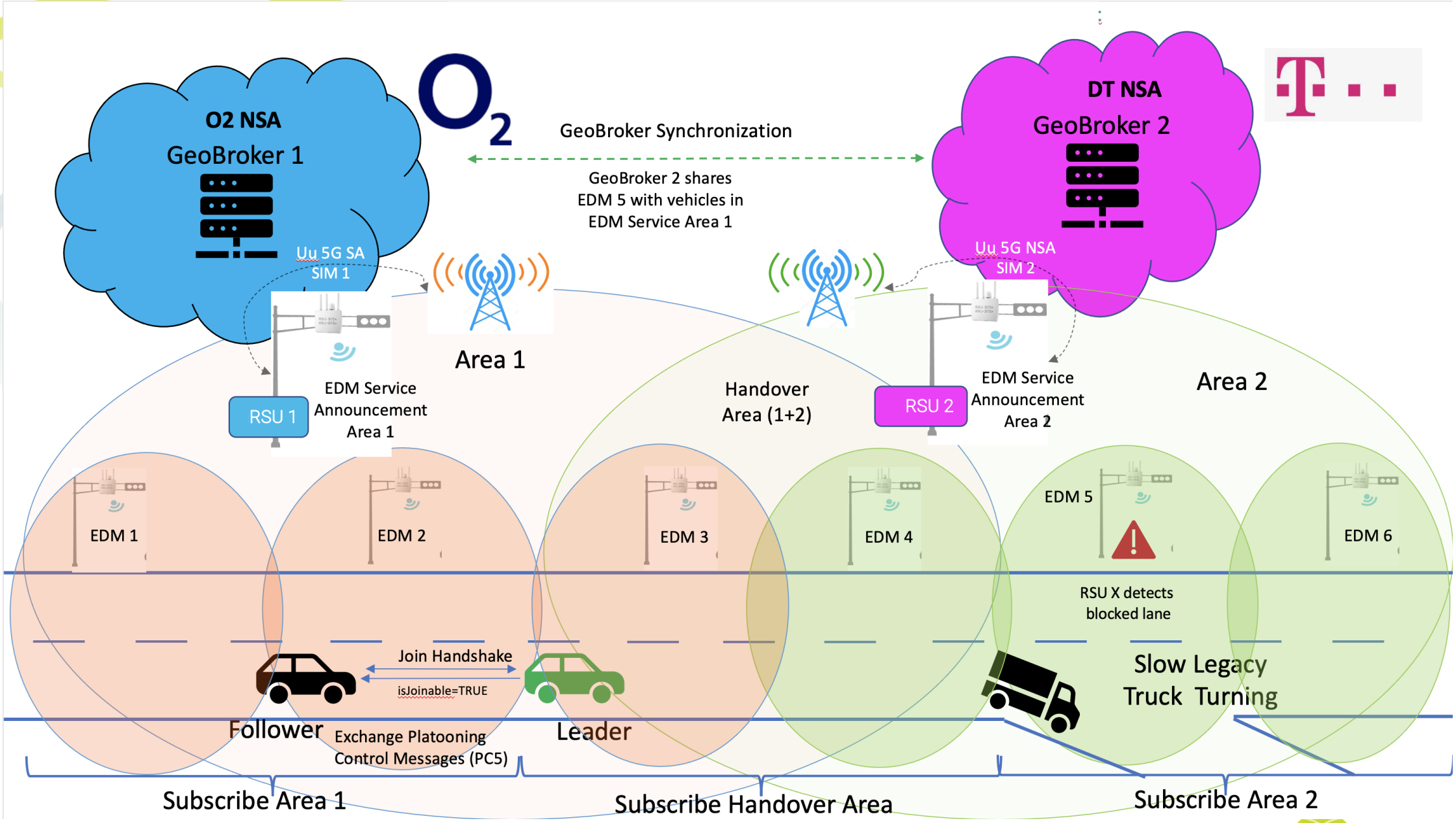
O2 NSA
GeoBroker 1
O2
GeoBroker Synchronization
GeoBroker 2 shares
EDM 5 with vehicles in
EDM Service Area 1
DT NSA
GeoBroker 2
Uu 5G SA
SIM 1
Uu 5G NSA
SIM 2
Area 1
RSU 1
EDM Service
Announcement
Area 1
Handover
Area (1+2)
RSU 2
EDM Service
Announcement
Area 2
Area 2
EDM 1
EDM 2
EDM 3
EDM 4
EDM 5
EDM 6
RSU X detects
blocked lane
Join Handshake
isJoinable=TRUE
Slow Legacy
Truck Turning
Follower
Exchange Platooning
Control Messages (PC5)
Leader
Subscribe Area 1
Subscribe Handover Area
Subscribe Area 2

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eRSU-Assisted Platooning

- Form platoon (Joining messages)
- Platoon exchanges PCMs (PC5)
- Connect to O2 Geobroker 1
- Rx EDM messages relevant Areas
- EDM service 1 detects slow vehicle, DENM event received (Uu)

- **O2 Area: Establish connection**
- XBI9: CS23 and CS24 standard C-ITS messages dissemination via MQTT Geobroker Uu or directly via PC5.
- XBI5: CS14 information exchange between MECs

- OBU detects border crossing
- Multi-modem/multi SIM
Change to MNO 2
- EDM messages reception briefly interrupted

- **Network switch**
- XBI5: CS4 Multi-modem multi-SIM solution
- Service interruption due to network switch

- - Connect to DT Geobroker 2
- Rx EDM messages relevant areas
- Slow vehicle approaching DENM event received from EDM service 1
- Perform overtake manoeuvre

- **DT Area: Application continuity after network switch**
- XBI5: CS4 Service continuity thanks multi-modem multi-SIM solution
- XBI5: CS14 inter-MEC exchange. Rx DENM via MQTT from Area1 in Area2

Extended Sensors Setup

Edge-Cloud

Vehicle Discovery Service (VDS)

EDM

MQTT Broker

WebRTC proxy

Border

EDM data synchronisation

Edge-Cloud

Vehicle Discovery Service (VDS)

EDM

MQTT Broker

WebRTC proxy

VDS feed / VDS query

Video stream startup

VDS feed / VDS query

DGPS

VDS client

Peer ID

WebRTC TX

Cameras

Video stream

Video stream startup

DGPS

VDS client

Peer ID

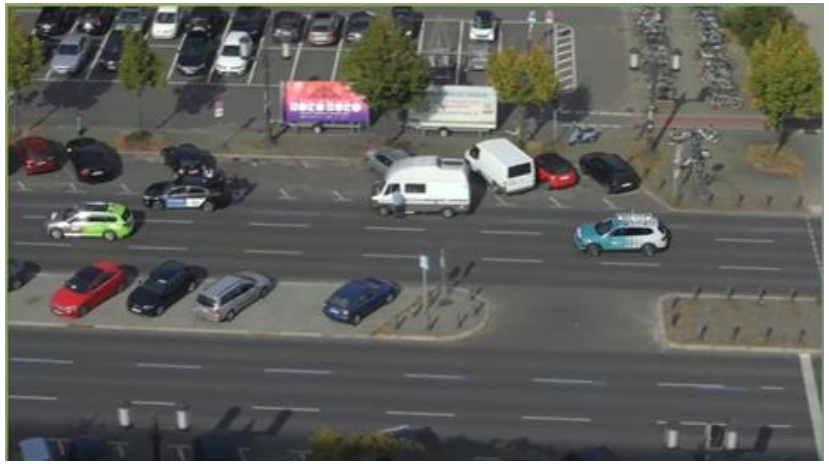
WebRTC RX

Surround View generation

Extended Sensors User Story Overview

- Vehicles connect to closest MEC
- Vehicles send dynamic data to MEC (EDM)
- Data is synchronised between MECs
- Vehicle A queries its EDM to discover a vehicle to get perception
- Vehicle A requests ES session to Vehicle B

- **O2 Area: Establish connection**
- XBI9: standard C-ITS messages
- XBI5: information exchange between MECs
- XBI10: MQTT Geobroker for message dissemination



- ES session stablished: video streaming from Vehicle B to Vehicle A
- OBU detects border crossing
- Multi-modem/SIM handover to MNO 2
- Video streaming briefly interrupted

- **Network** switch
- XBI1: Multi-modem multi-SIM solution
- Service interruption due to network switch

- Affected vehicles connect to MEC of MNO2.
- ES session is recovered: video streaming restarted
- QoS adjusted to MNO2 coverage quality.

- XBI5: Service continuity thanks multi-modem multi-SIM solution
- **XBI** 8: Dynamic QoS Continuity

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5G for CCAM solutions

Dual-modem/dual-SIM solution

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5G for CCAM solutions

- Dual-modem/dual-SIM solution (10 min) - TUB Sebastian Peters
- Adaptive QoS solution (10 min) - VICOM Angel Martin

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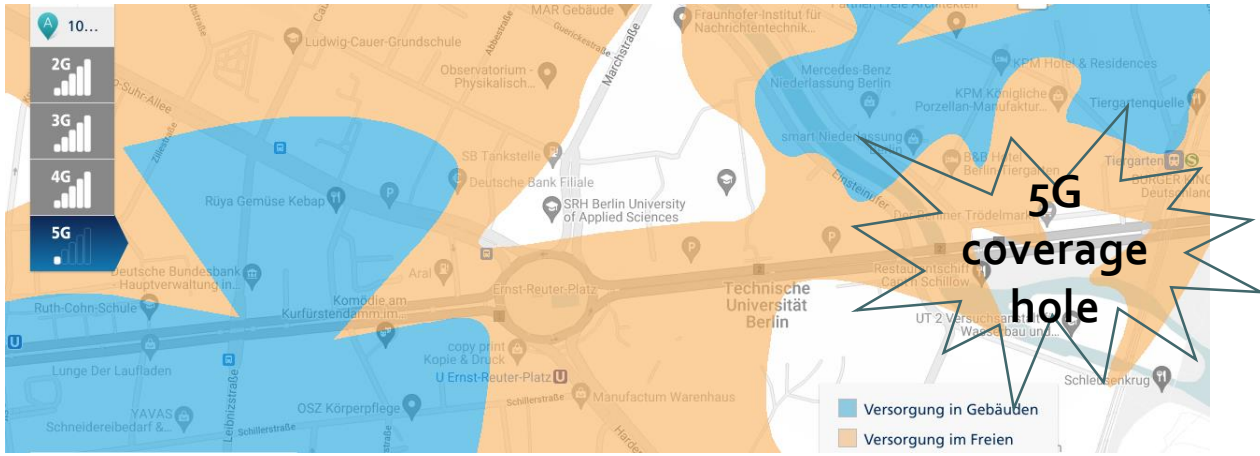
Dual-modem/dual-SIM solution
Overall Concept

- A custom solution to utilize multiple mobile networks has been developed in the DE TS based on dual-modem/dual-SIM
- The overall concept is based on **implementing a location-based switch** of the mobile network from one operator to another
  - At specific location X: Perform a switch to another operator as outcome of a decision making component of a prediction function that exploits crowdsourced coverage maps
  - An "In-advance coverage-hole notification" facilitates the **proactive creation of a new session** over another available mobile network with 5G coverage to minimize mobility interruption time



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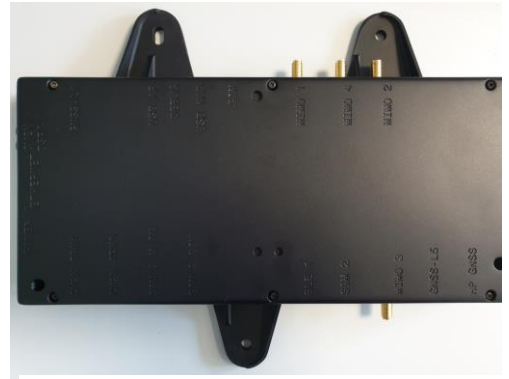
Dual-modem/dual-SIM solution
Scenario

- 2 commercial 5G NSA networks for testing the solution
  - Virtual border at 5G coverage hole to simulate cross-border scenario
  - Each modem has its own MQTT application client associated using the respective mobile network
  - When the location X is reached by the vehicle the application establishes connection via other modem's MQTT client.
- Utilized Hardware
  - 1 x 5G Modem with DT SIM (Vulcano 2.0 TCU)
  - 1 x 5G Modem with O2 SIM (Quectel RM500Q)
  - 1 x Cohda Wireless MK6c
  - 1 x Neousys Nuvo-8108GC as On-Board Unit

Vulcano 2.0 TCU



Quectel RM500Q

Cohda Wireless MK6c

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Dual-modem/dual-SIM solution
Technical Realization

- Python Application utilizing GPS of Cohda box
  - A received location-based trigger causes the change of MNO by calling the Linux network manager command-line client:
    - deactivateO2 = 'nmcli con down \'o2\"
    - activateDT = 'nmcli con up \'DT\"
  - Two potential ways of exploiting the coverage map:
    - Query database for full route ahead and store switching locations locally
    - Subscribe for "In-advance coverage-hole notification"

In-vehicle deployment of dual modem / dual SIM solution

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Dual-modem/dual-SIM solution

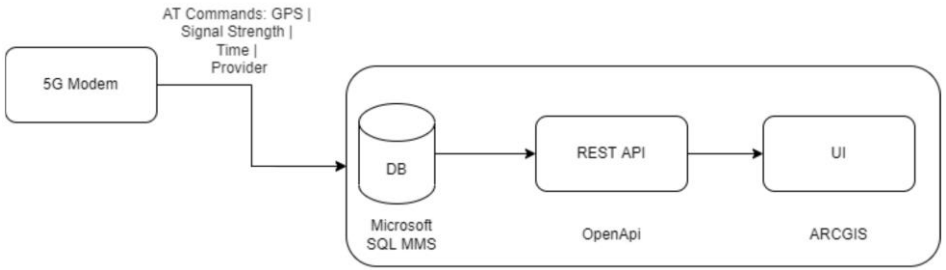
Coverage Map Approach

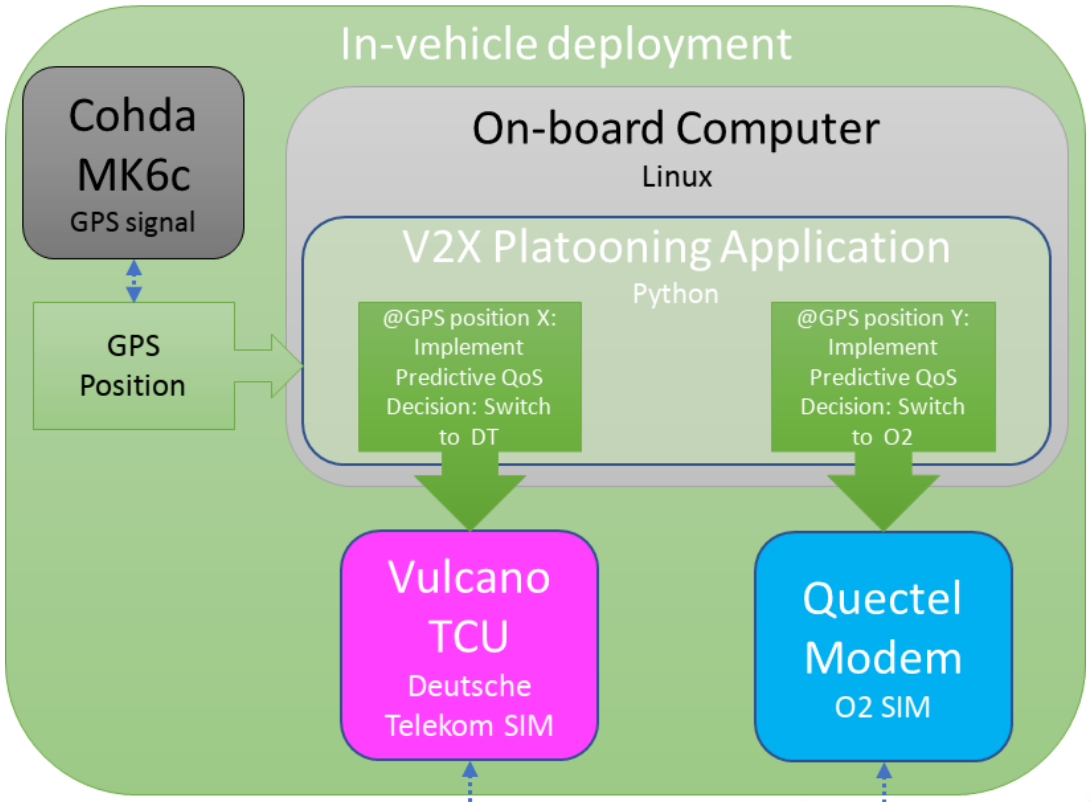
Coverage Map Database

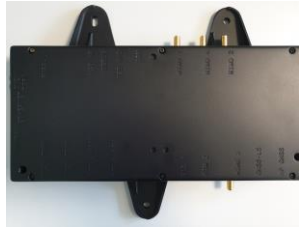
	id	signalStrength	networkProvider	cellId	frequency	gpsNmea	
1	6	-122	Telekom	102	6200	$GPGGA,092855.809,5230.756,N,01319.317,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...
2	7	-96	Telekom	199	6700	$GPGGA,092855.809,5230.397,N,01320.028,E,1,12,1.0,0.0,M,0.0,M,,6F	$GPGSA,A,...
3	8	-141	Telekom	107	6500	$GPGGA,092855.809,5230.707,N,01318.635,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...
4	9	-104	Telekom	105	7000	$GPGGA,092855.809,5230.689,N,01318.316,E,1,12,1.0,0.0,M,0.0,M,,60	$GPGSA,A,...
5	10	-35	Telekom	154	6400	$GPGGA,092855.809,5230.654,N,01317.781,E,1,12,1.0,0.0,M,0.0,M,,65	$GPGSA,A,...
6	11	-96	Telekom	119	6000	$GPGGA,092855.809,5230.604,N,01316.986,E,1,12,1.0,0.0,M,0.0,M,,68	$GPGSA,A,...
7	12	-108	Telekom	186	6500	$GPGGA,092855.809,5230.557,N,01316.359,E,1,12,1.0,0.0,M,0.0,M,,65	$GPGSA,A,...
8	13	-77	Telekom	102	6300	$GPGGA,092855.809,5230.756,N,01319.317,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...
9	14	-91	Telekom	199	6800	$GPGGA,092855.809,5230.397,N,01320.028,E,1,12,1.0,0.0,M,0.0,M,,6F	$GPGSA,A,...
10	15	-110	Telekom	107	6600	$GPGGA,092855.809,5230.707,N,01318.635,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...
11	16	-134	Telekom	105	6800	$GPGGA,092855.809,5230.689,N,01318.316,E,1,12,1.0,0.0,M,0.0,M,,60	$GPGSA,A,...
12	17	-82	Telekom	154	7000	$GPGGA,092855.809,5230.654,N,01317.781,E,1,12,1.0,0.0,M,0.0,M,,65	$GPGSA,A,...
13	18	-36	Telekom	119	6400	$GPGGA,092855.809,5230.604,N,01316.986,E,1,12,1.0,0.0,M,0.0,M,,68	$GPGSA,A,...
14	19	-59	Telekom	186	6100	$GPGGA,092855.809,5230.557,N,01316.359,E,1,12,1.0,0.0,M,0.0,M,,65	$GPGSA,A,...
15	20	-145	O2	102	6200	$GPGGA,092855.809,5230.756,N,01319.317,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...
16	21	-48	O2	199	6000	$GPGGA,092855.809,5230.397,N,01320.028,E,1,12,1.0,0.0,M,0.0,M,,6F	$GPGSA,A,...
17	22	-148	O2	107	6600	$GPGGA,092855.809,5230.707,N,01318.635,E,1,12,1.0,0.0,M,0.0,M,,63	$GPGSA,A,...

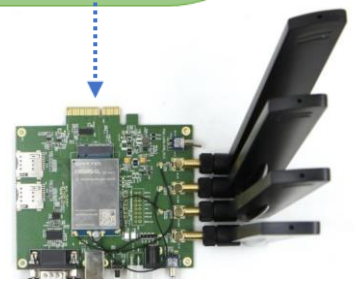
Measurement Representation

Coverage Mapper Architecture









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Dual-modem/dual-SIM solution
Conclusions

- True Dual-SIM Dual-Active functionality in 5G modems will supersede our dual-modem concept, eSIM functionality will enable replacement of conventional SIMs -> Predictive QoS approaches will see a deeper integration on the vehicle V2X application side
- The DE TS trials of the custom multi-SIM solution have shown the viability of utilizing the GPS position to implement mobile network switching decisions for V2X applications that can tolerate reconnections
  - In contrast to EDM service more complex stateful-applications require the appropriate handling on the respective network and application layers before breaking the connection

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Thank you

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