



Creation and Deployment of HD Map Data

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Gefördert durch:



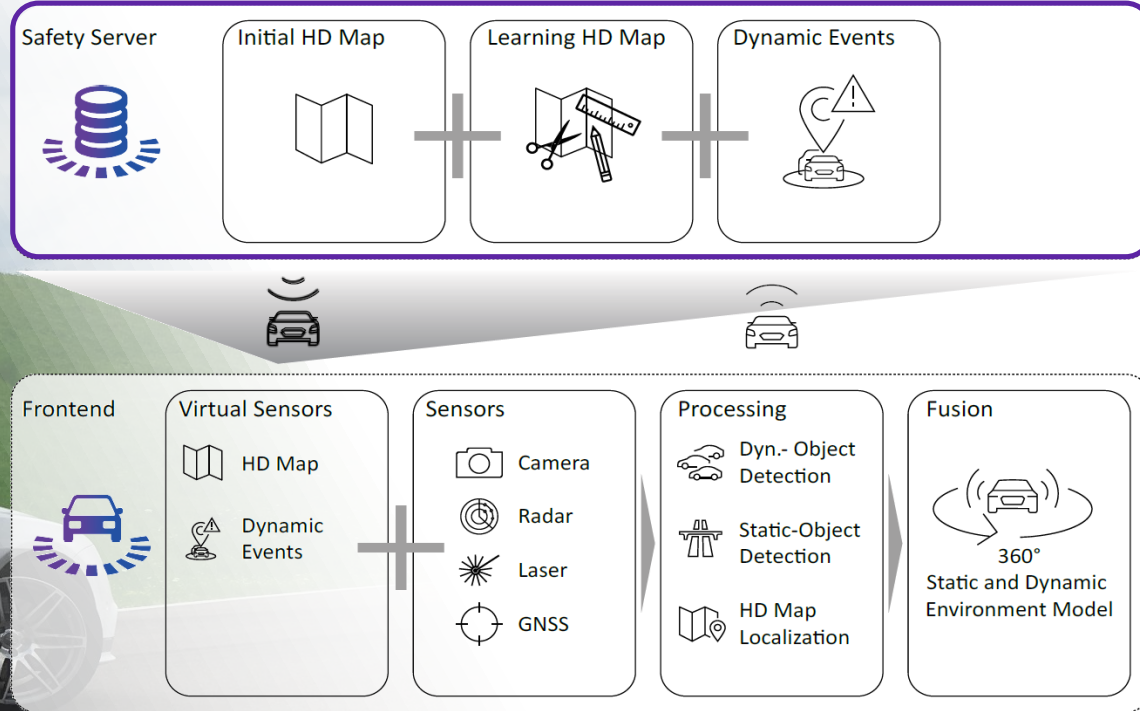
aufgrund eines Beschlusses
des Deutschen Bundestages



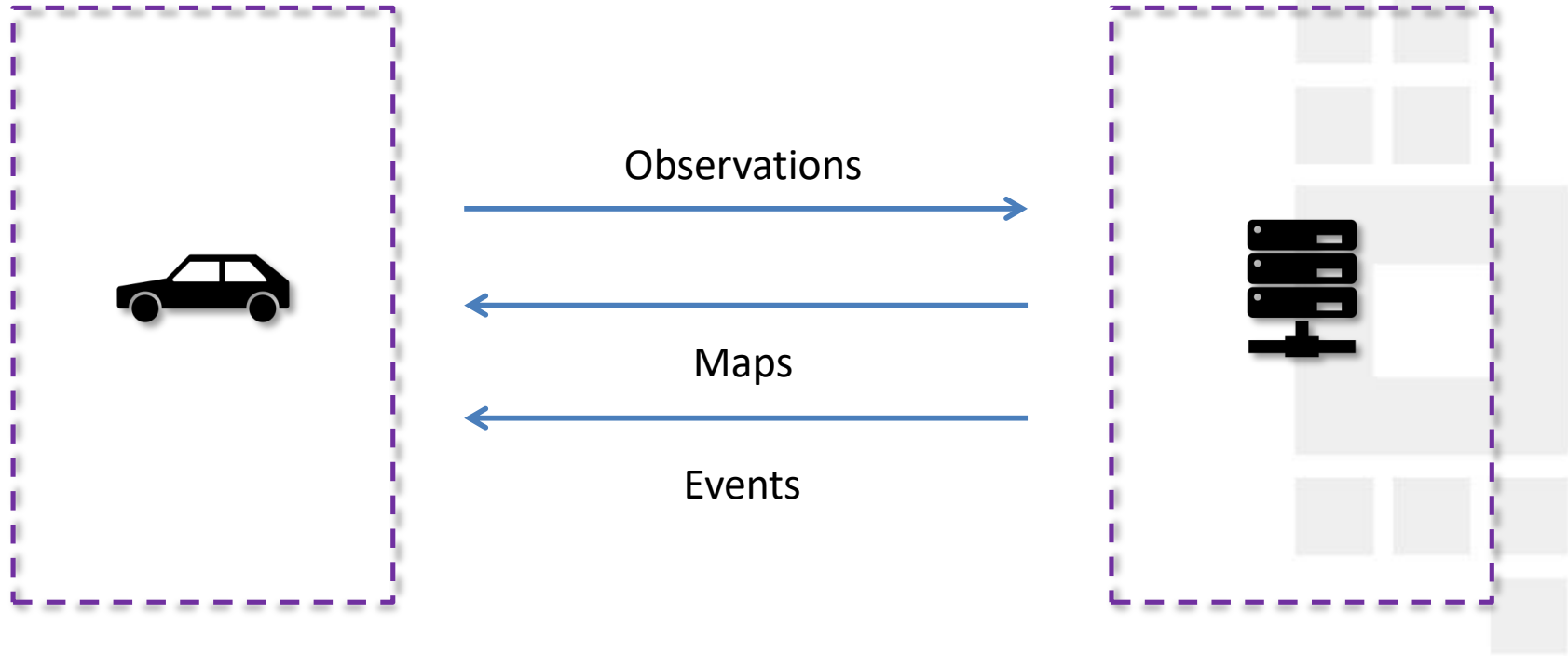
Backend

HD Map on the Safety Server

Backend HD Map on the Safety Server

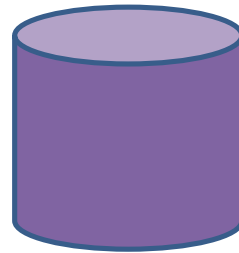


HD Map Data on the Safety Server



HD Map Data on the Safety Server

PostgreSQL 9.x
PostGIS



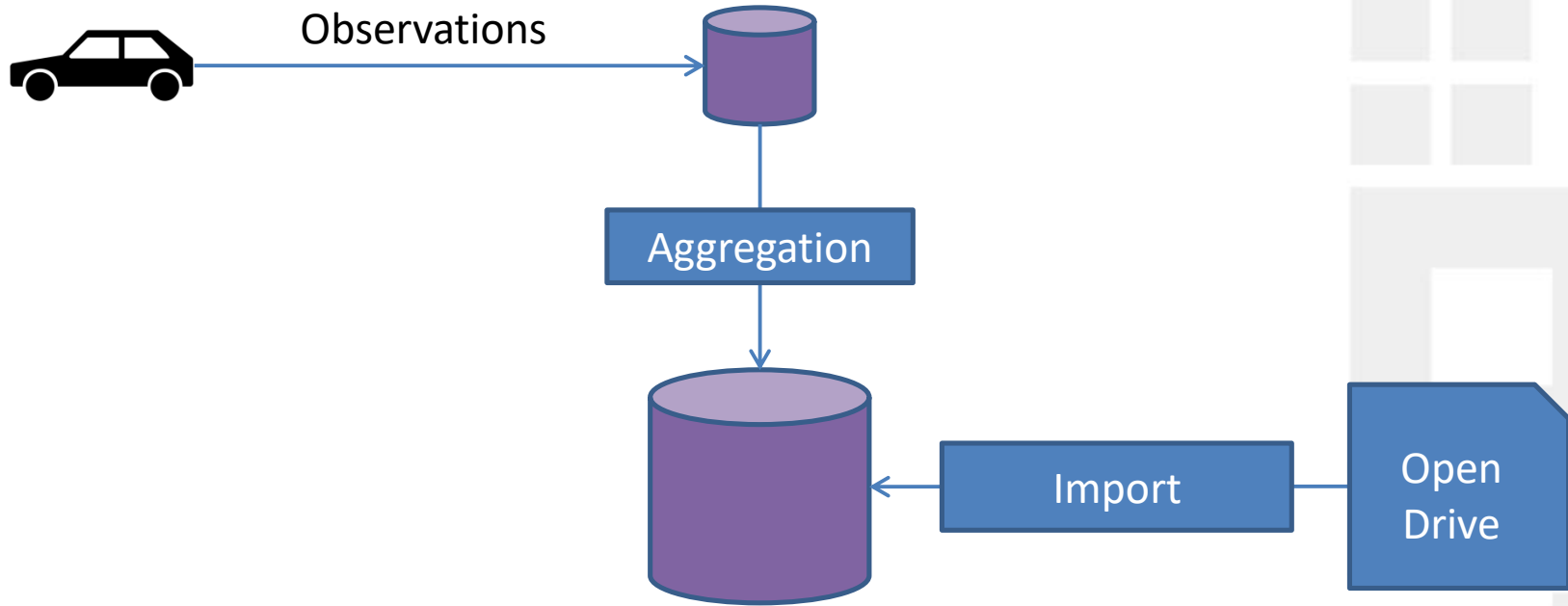
Importing the HD Base Map

Start with 3D Mapping's ground truth data:

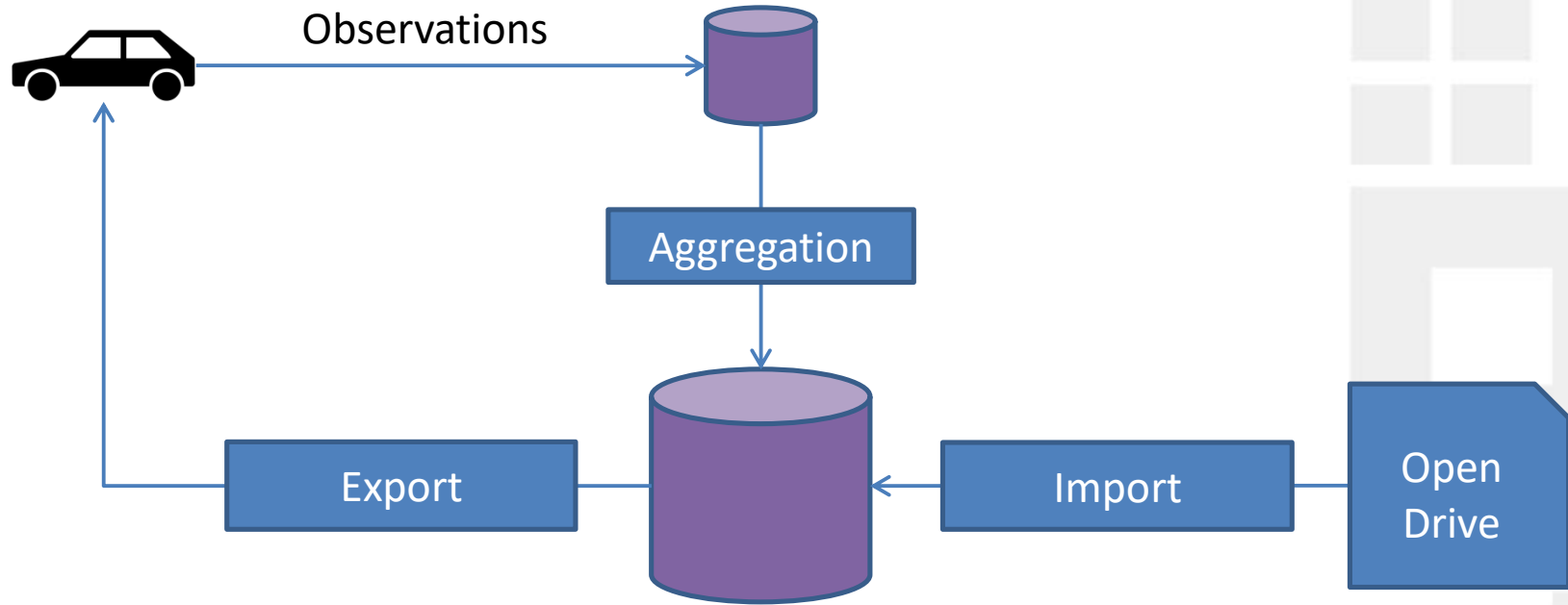
- Parse the standard OpenDrive format
- Convert data to the Ko-HAF map DB schema



Aggregating Vehicle Observations



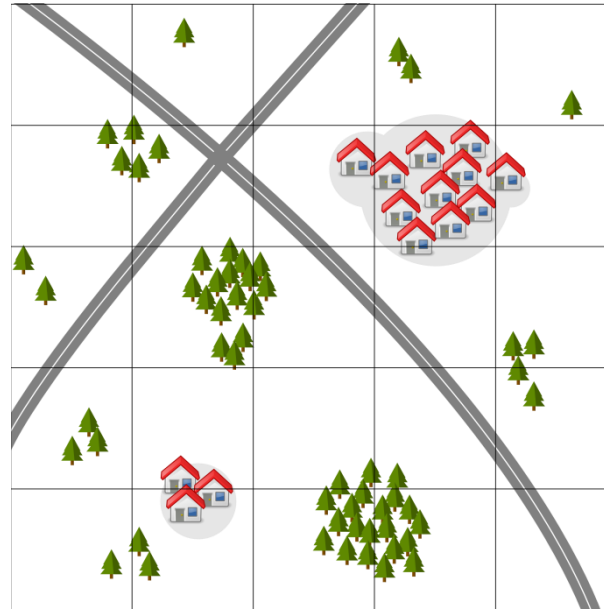
Exporting HD Map Data



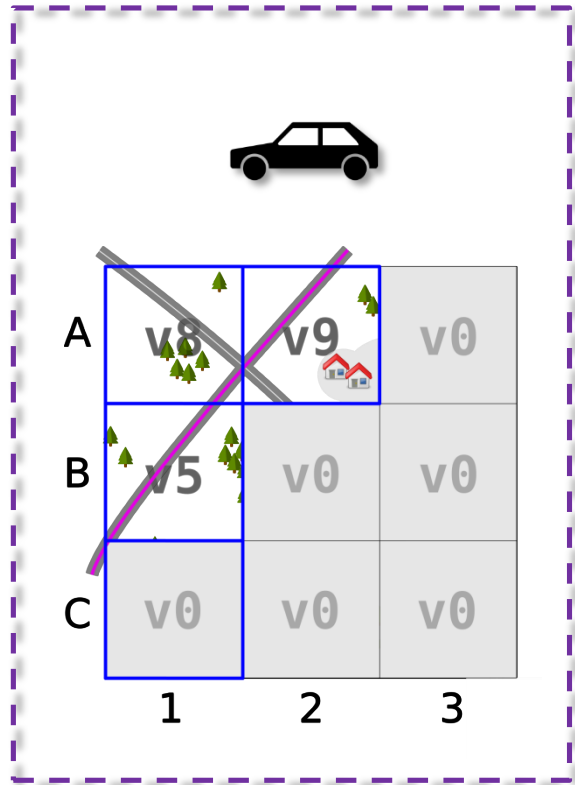
Exporting HD Map Data

- Web service provides map data to vehicles
- Encrypted communications via LTE
- Compact binary encoding
- Download of map data is possible on demand, can factor in...
 - current vehicle position
 - planned route
 - mobile radio network coverage
 - ...

Exporting HD Map Data: Tiles



Exporting HD Map Data: Updates



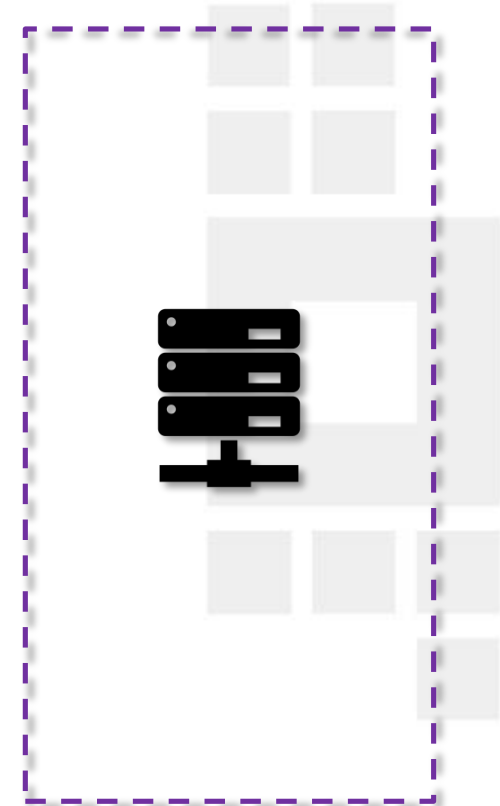
Request



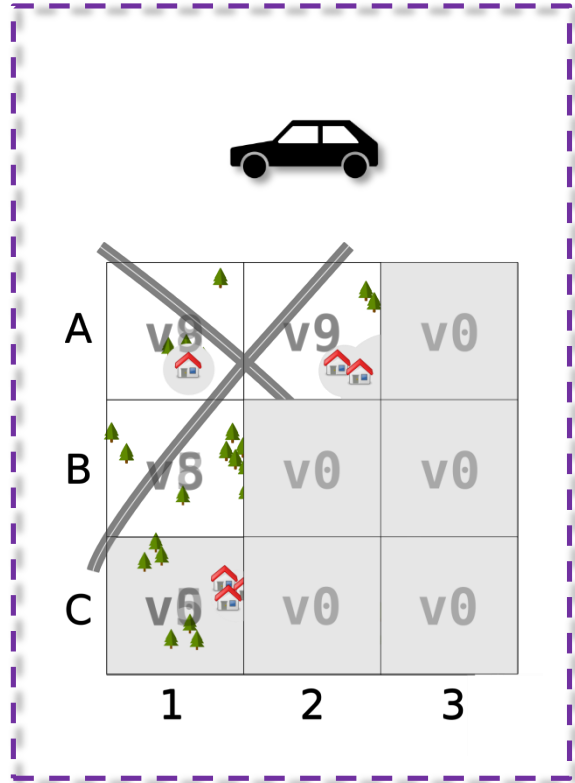
GetMapTiles

A1:8 A2:9

B1:5 C1:0






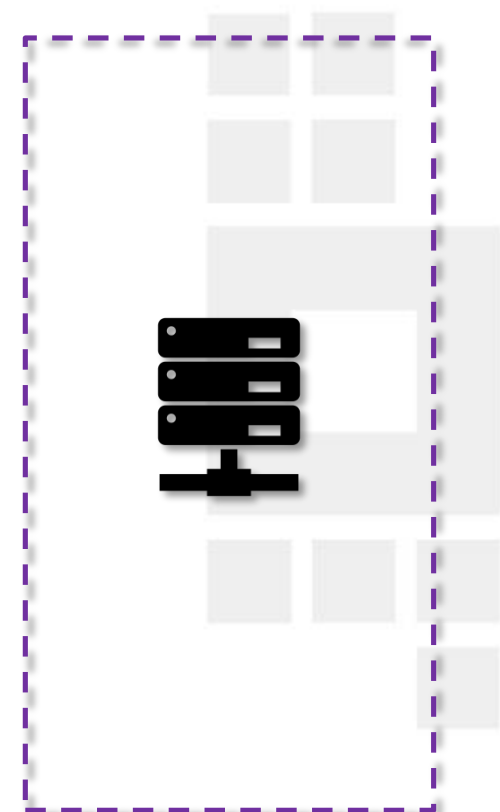
Exporting HD Map Data: Updates



Response

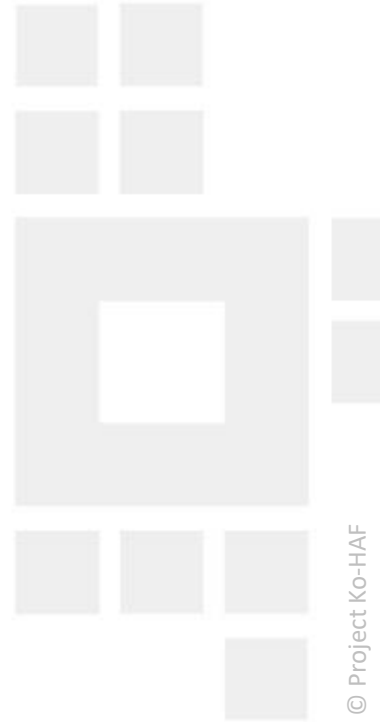


- A1:9 + - 
- B1:8 
- C1:5 
- A2:9 OK



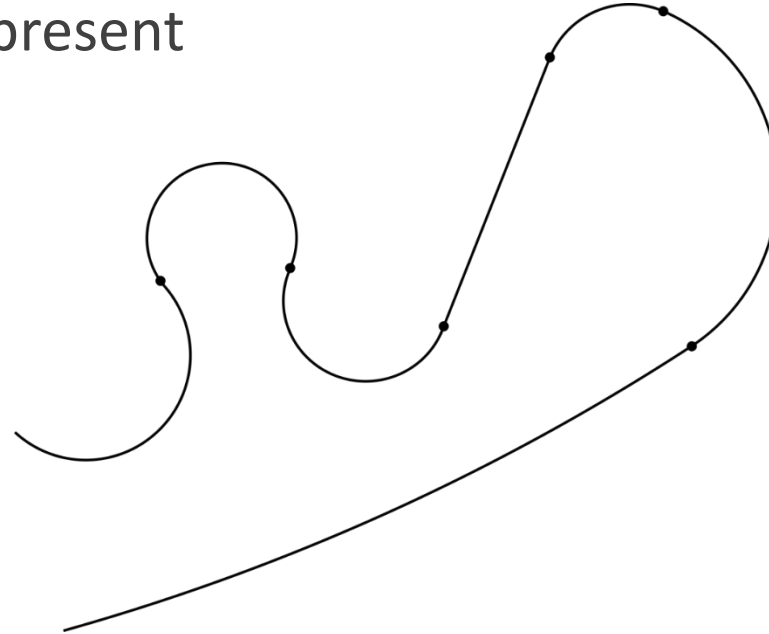
Exporting HD Map Data: PBF

- Encoding map tiles as Protocol Buffers
- Goal: Low bandwidth use on LTE connections
- Some optimizations:
 - Relative coordinates using variable-length integers
 - Indexed storage of strings
 - Format allows encoding updates as diffs



Exporting HD Map Data: SMAP

- Arc splines to represent linear features



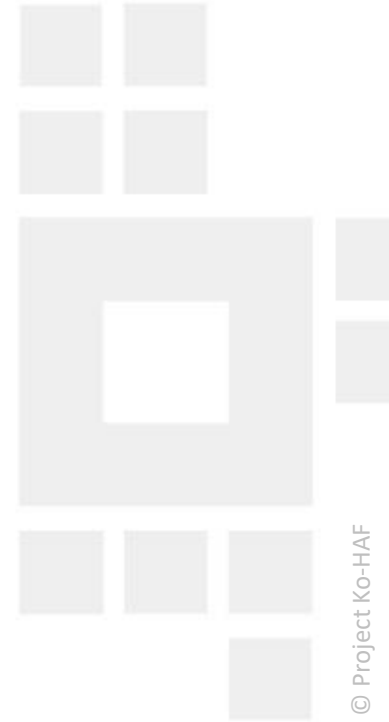
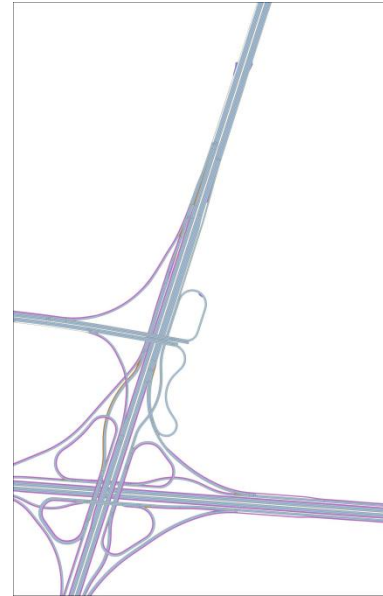
Exporting HD Map Data: SMAP

- Approximation using SMAP (Smooth Minimum Arc Paths)
- Smooth arc splines
- Maximum error can be freely chosen
- Provably minimal number of segments → memory usage
- Efficient representation in storage
- Efficient calculations, including:
 - curvature
 - distance
 - offset curves

Exporting HD Map Data: Evaluation

- On average: 70 kB per tile
- Largest tile: 381 kB

Tile 11316/8403
Frankfurter Kreuz



Exporting HD Map Data: Evaluation

- On average: 70 kB per tile
- Largest tile: 381 kB
- 14–33 kB/km (dual-carriageway motorways)
- 260 MB (\pm 80 MB) for Germany's motorways
- Planned re-use of the format for the @CITY research project

HD Map: Interactive Demonstration

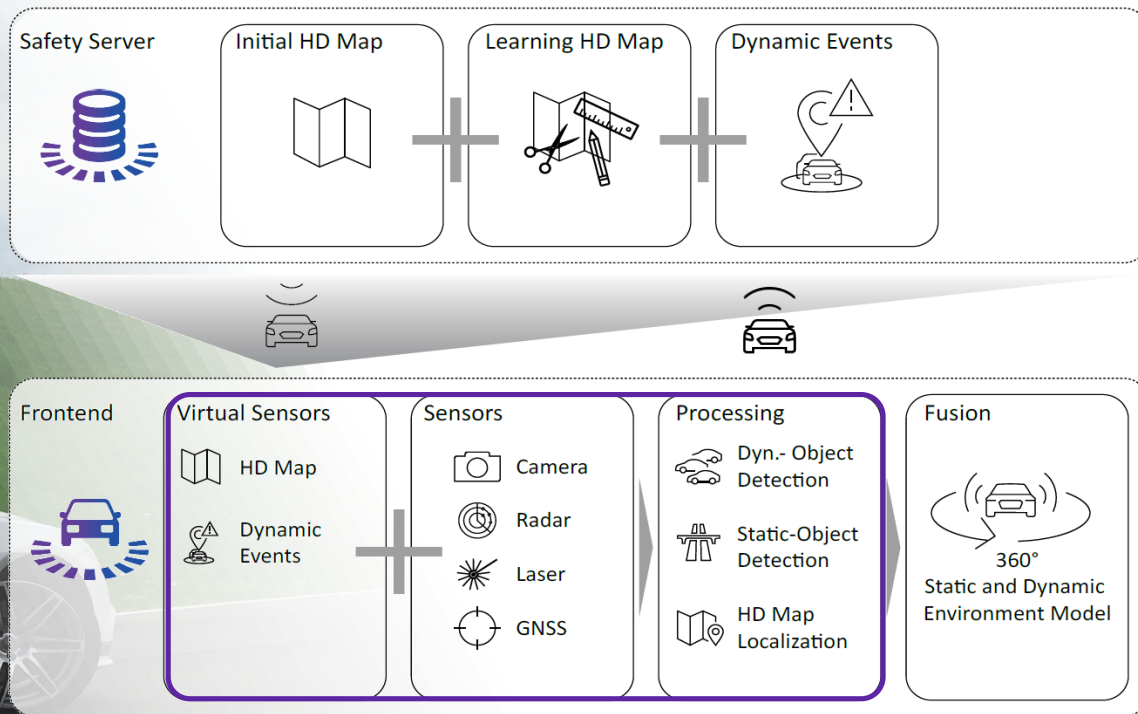




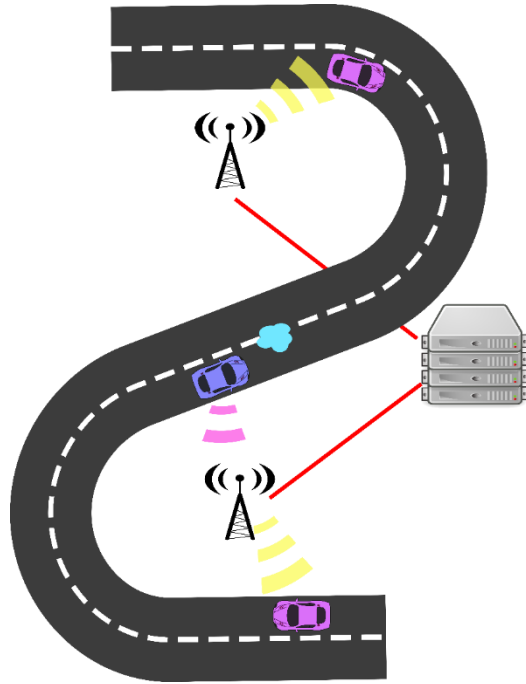
Frontend

Sensor Data Upload

Frontend Sensor Data Upload



Communication Infrastructure



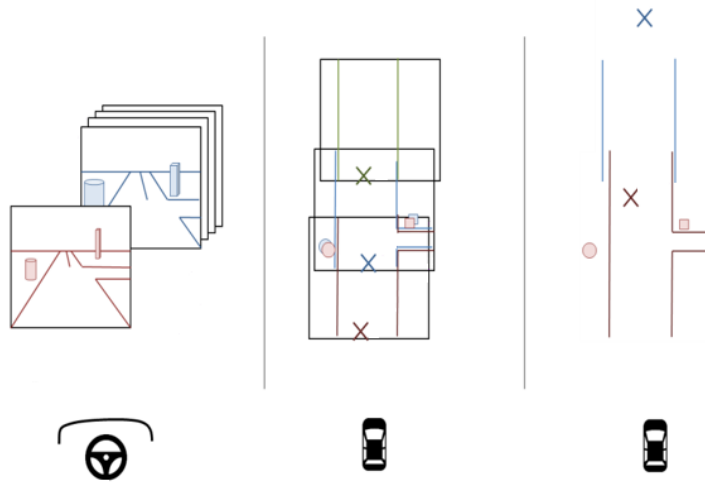
- In Ko-HAF a mobile network based vehicle to server communication is used
- The sensors data is uploaded from the vehicles via this mobile network communication to the server
- The HD-Map parts are sent from the server, hosted at the infrastructure provider, via LTE to the vehicle

From Sensor Data to Upload Data



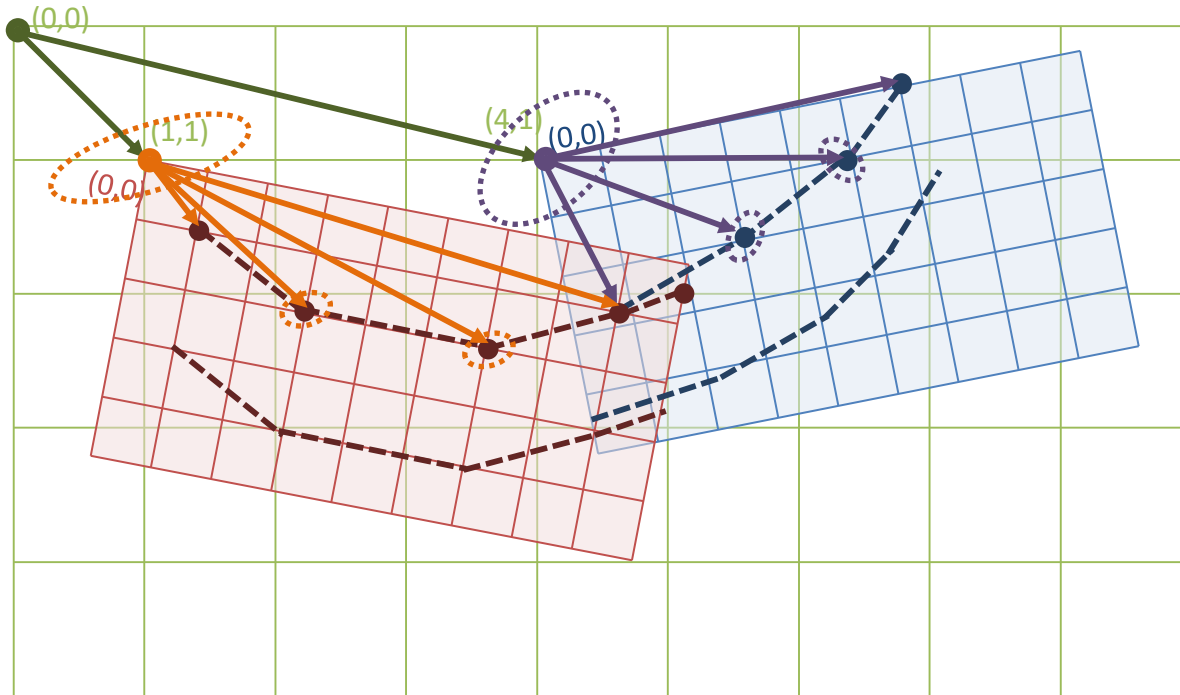
- The amount of data recorded by sensors like LIDAR, RADAR or even cameras is very high
- The communication capacity of the mobile network is very limited compared to this data amount
- Data needs to be reduced

From Sensor Data to Upload Data



- Data reduction by pre-aggregation
 - Recoding data in the ego-perspective with multiple frames per second
 - Transformation of the frame to a virtual top view
 - Pre-aggregation of multiple frames to road parts of a few hundred meters

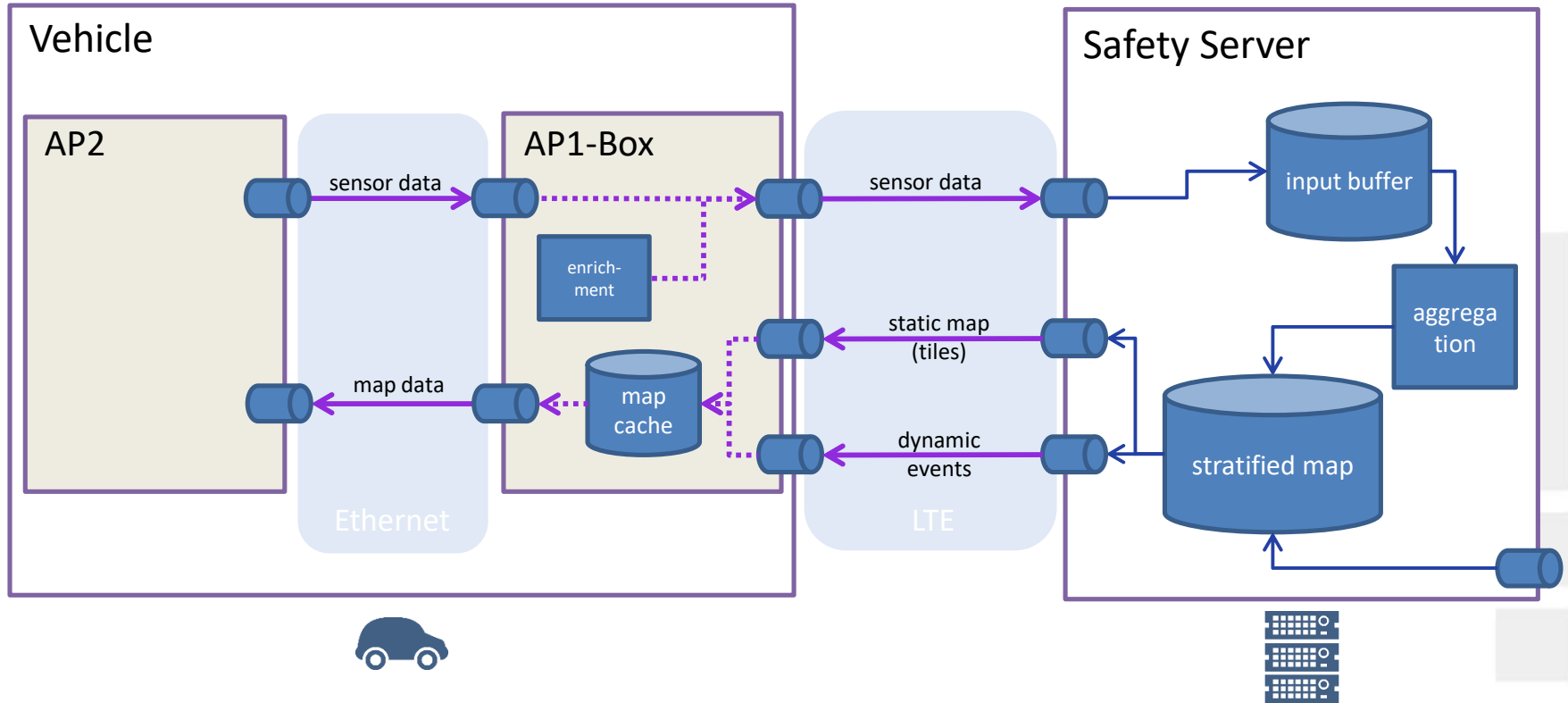
Format of the Uploaded Data



- Relative coordinates with a segment
 - Global coordinate to refer a segment

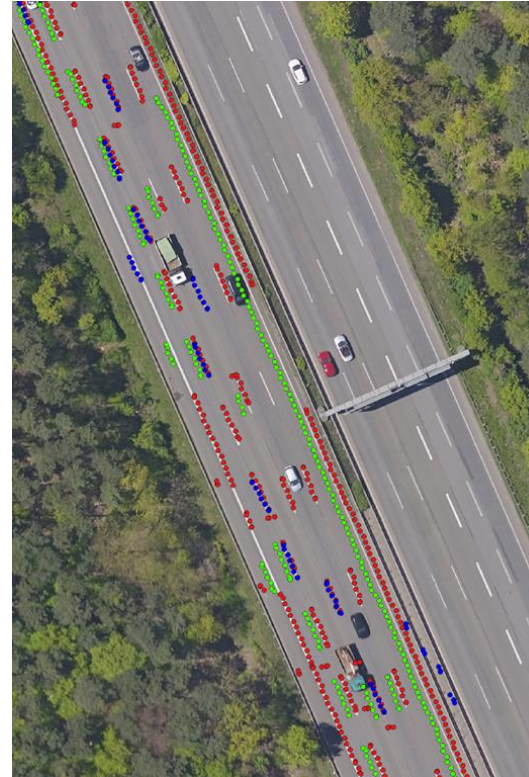
- A segment contains all types of objects like lines, signs, ...

Communication Overview

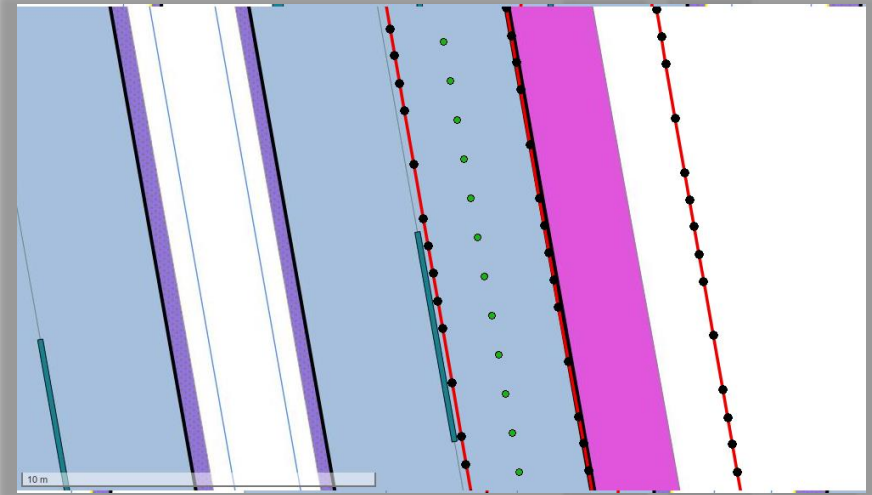
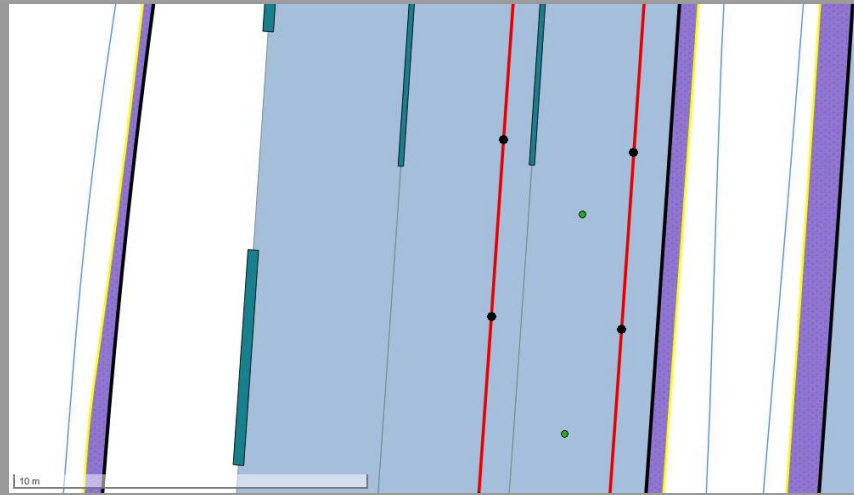


Uploaded Data

- Borderlines
 - Type
 - Color
 - Borderline samples
 - Covariances ...
- Street signs
 - Type
 - Attributes
 - Covariances ...

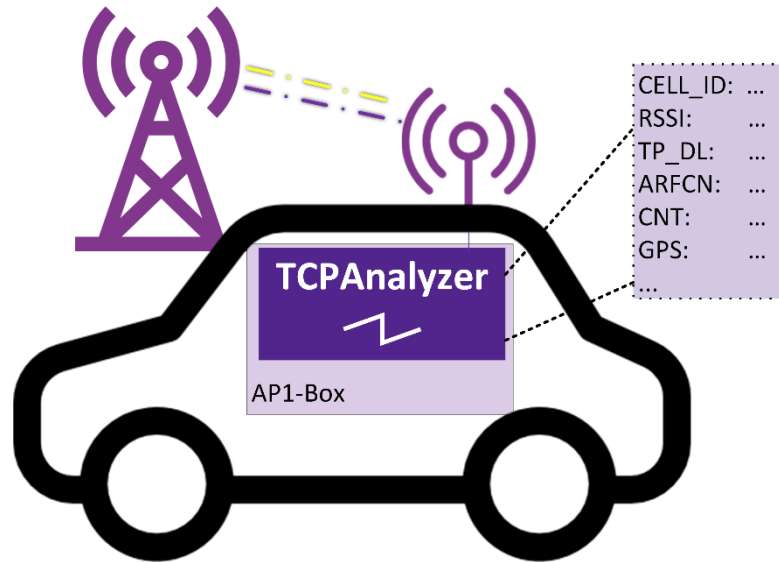


Line Aggregation

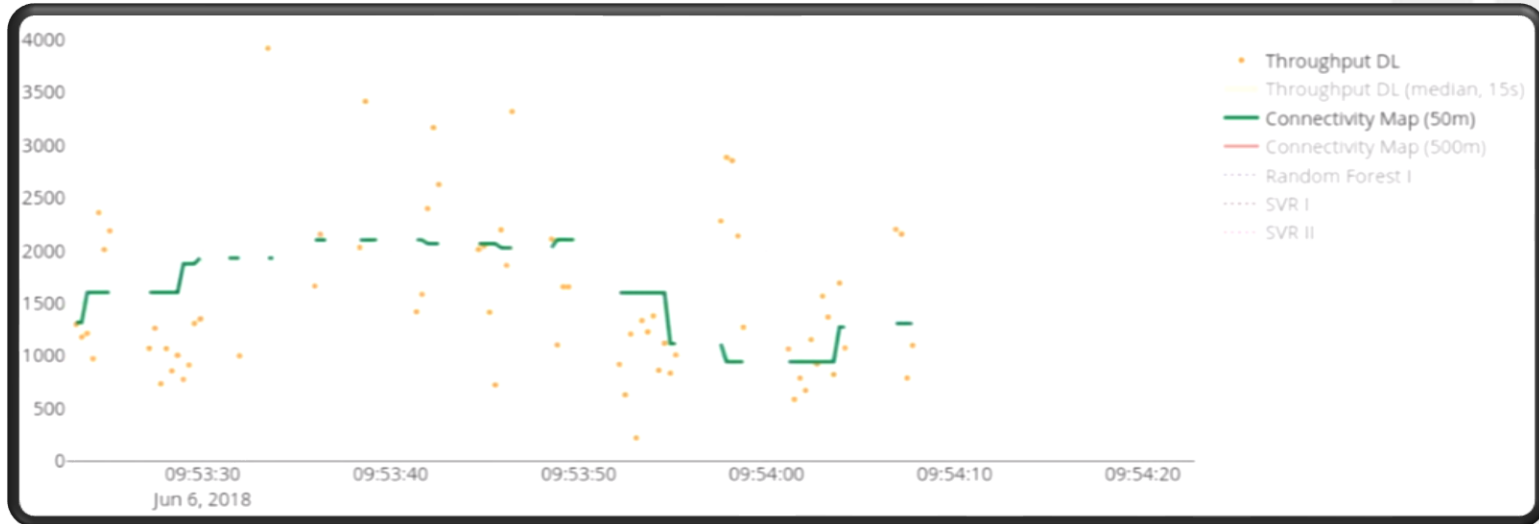


Uploaded Data



- Mobile Network
 - Cell Id
 - Network Type
 - RSSI
 - Throughput
 - Round Trip Time
 - ...








Demo: LTE Throughput Prediction




Demo: HD Map as a Virtual Sensor


Visualization 




-  Current position of the car
-  Forecast with state of the art onboard sensors
-  Forecast enhancement through Ko-HAF
-  Data gets uploaded to the safety server

Gefördert durch:

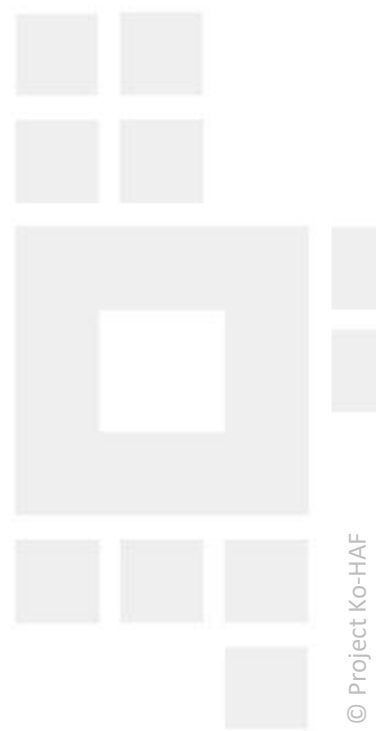


Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages



Ostbayerische
Technische Hochschule
Amberg-Weiden





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