

Generating Test Cases from Real Field Data to ensure V2X Interoperability

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Knowledge for Tomorrow



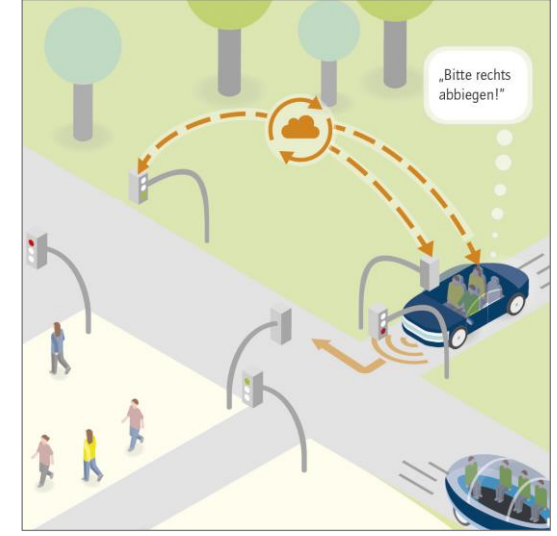
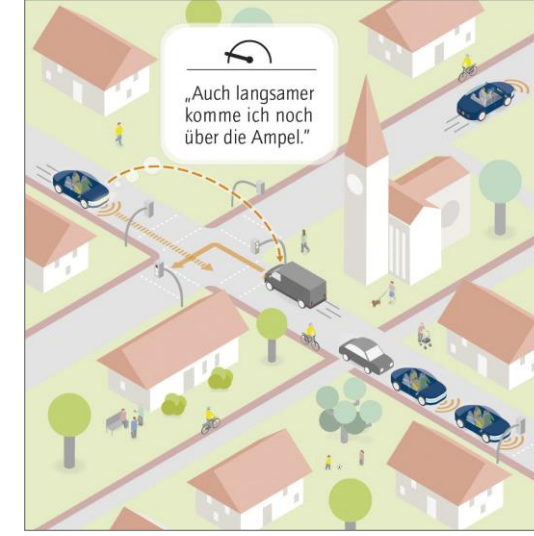
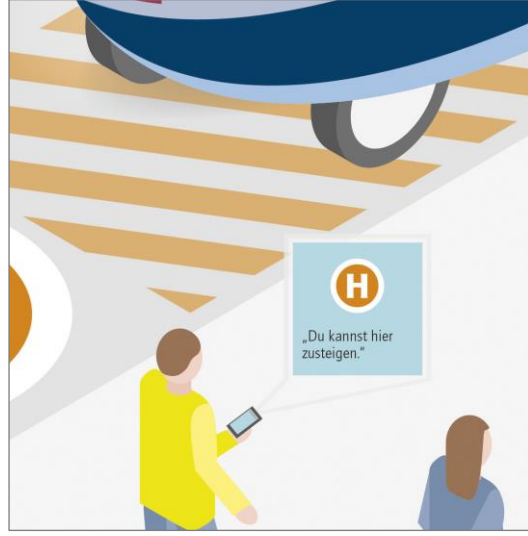
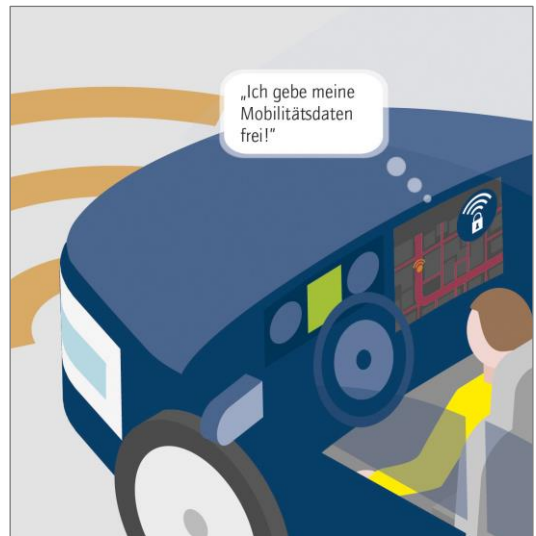
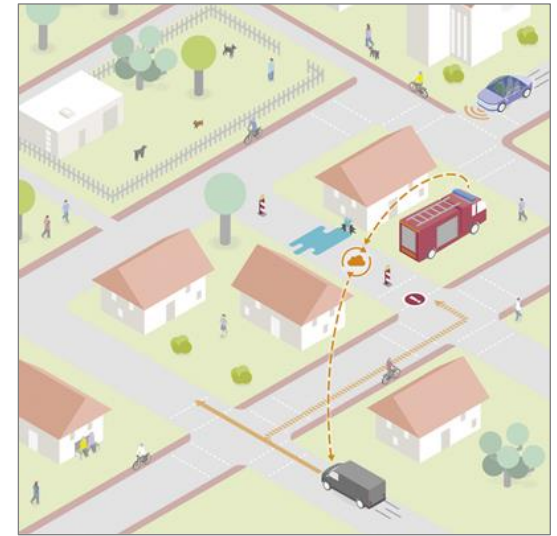
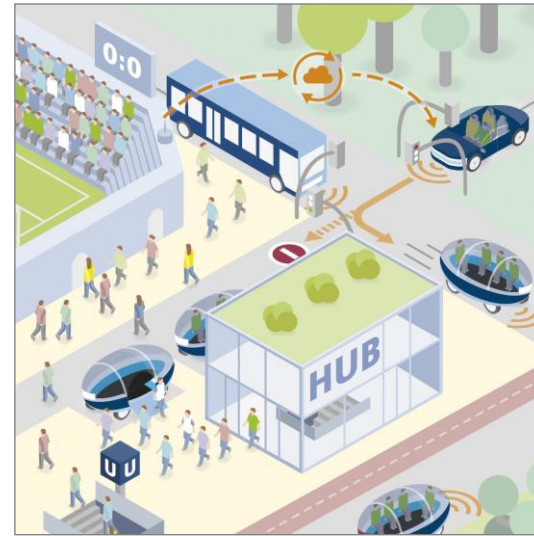
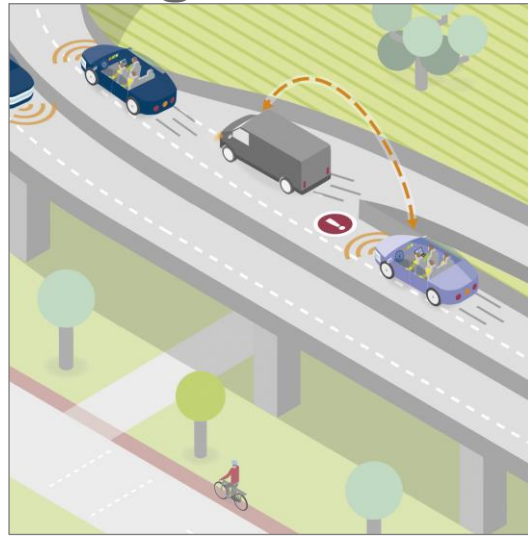
Motivation – Need for Testing

- V2X is one of the main parts of traffic system's digitalization,
- It is feature-rich and complex,
- Many stakeholders are involved in the system, (Automaker, Infrastructure-Supplier and –Manager, Authorities, etc.)
- Conformity and especially Interoperability/Compatibility are crucial for the system's function,
- Although not yet in operation, safety-critical use of V2X is a must to increase road-traffic's capacity (e.g. Signal Phase and Timing),
- The situation gets even more critical when it comes to automated and co-operative driving.



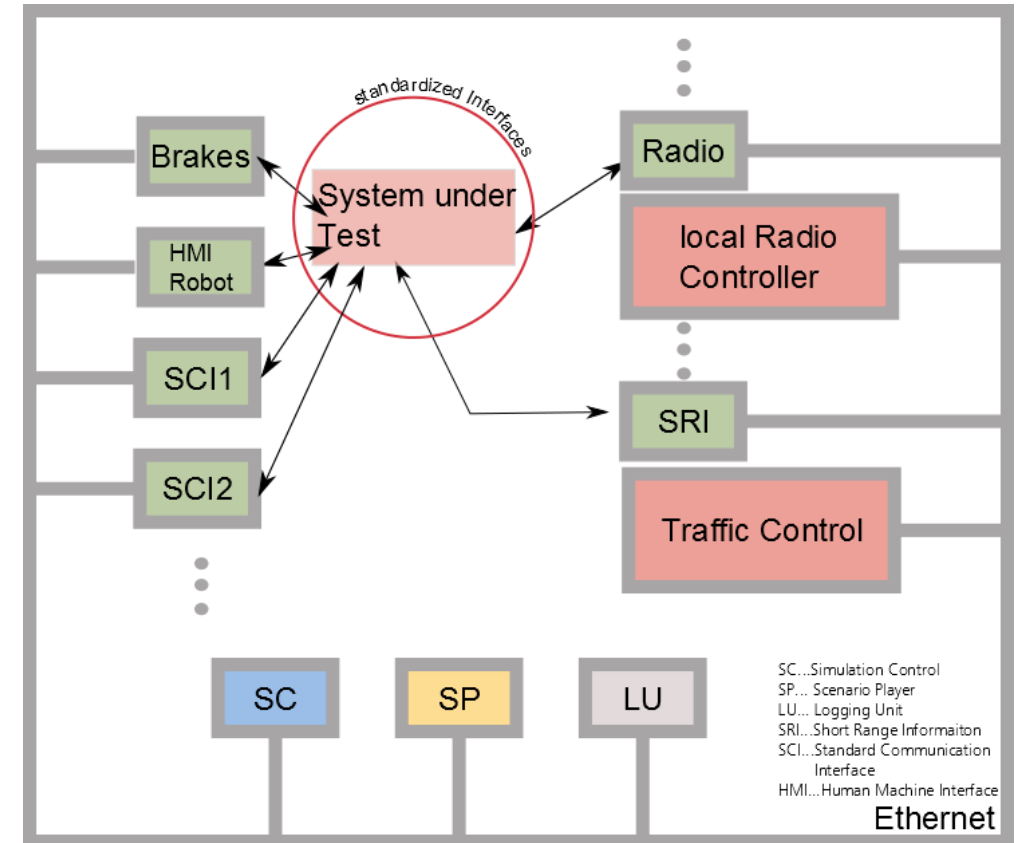
→ Comprehensive Testing, especially in-lab testing is one of the most-common methods to ensure interoperability, conformity and (functional-) safety.

Motivation – Need for Testing



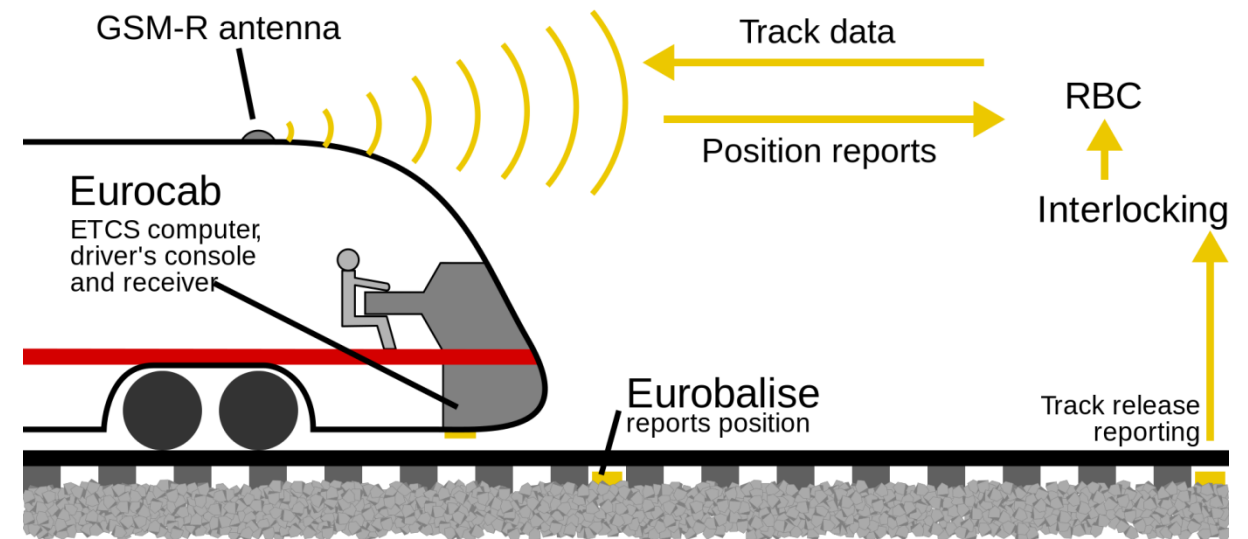
Motivation – Lab Testing

- Due to digitalization in-lab testing for V2X is simple. At least the interface between car and road is standardized (ETSI). Of course, backside between communication unit and car/infrastructure-components is manufacturer-dependent.
- Common and applicable testing-setups are Hardware/Software-in-the-loop.
- In combination with a test-adaptor to interface between communication unit and the system behind (car/traffic light/etc.) the technological setup is complete and available.
- But what about the test specification?



Return of Experience: Functional testing in the railway domain

- In the railways there has to be a communication between track and train due to high masses and low friction.
- In the past there was a (more or less) dedicated and specialized system for every track.
- Today cross-boarder traffic across Europe is needed and the system has been standardized and harmonized (called ETCS: European Train Control System).
- Tech: max. 830 Bit per message, safe.
- Interoperability became one of the main issues during the deployment of ETCS.
- Lab-Testing the Eurocab in independent Laboratories has been put into the law, to resolve the interoperability issues.

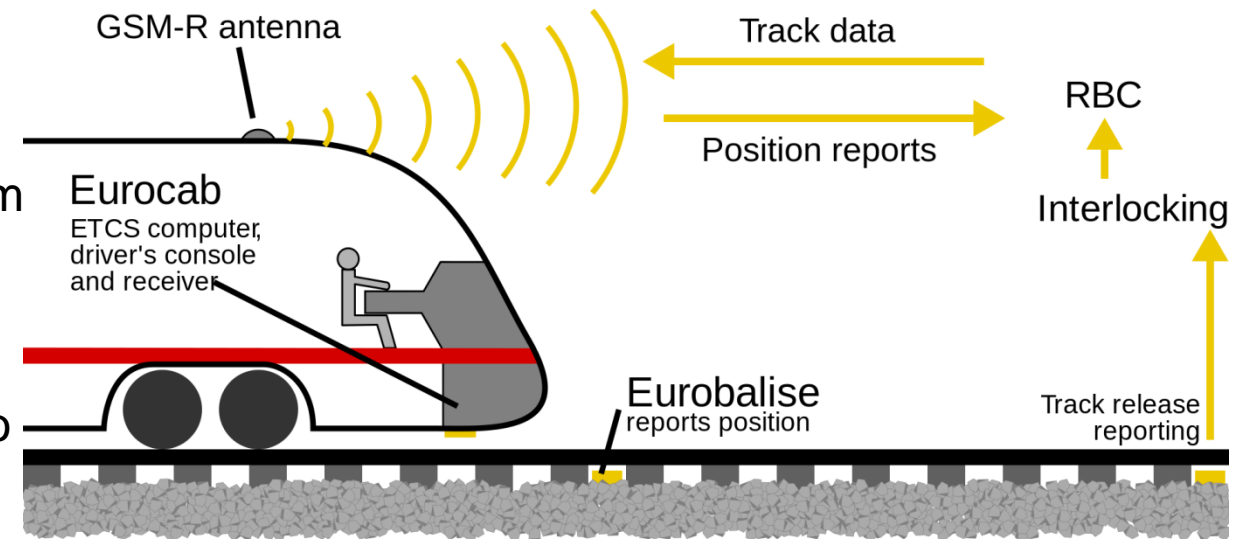


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Return of Experience: Functional testing in the railway domain

- Main issue:
 - Creating the test specification.
- Why?
 - Moving target (continuous upgrade of the system specification),
 - Has been created manually,
 - Complex but in-adequate toolchain,
 - Hardware has been put into service in parallel to the development of the test specification,
 - Many stakeholders involved.
 - Today there are more than 70.000 test steps per test campaign...



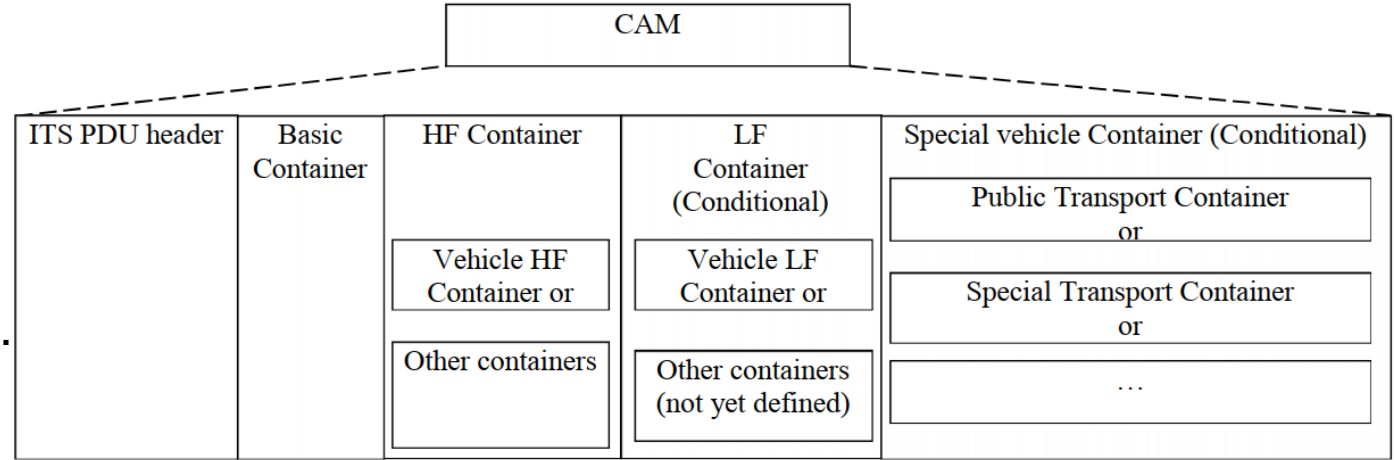
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- Sounds familiar?
 - Back to V2X.



Focus: Cooperative Awareness Message (CAM)

- Probably the CAM message will be the first message implemented by many vehicles.
- Specification is available (ETSI EN 302 637-2),
- Main purpose: Inform other road users about each others position, dynamics and attributes.



A.28 DE_ExteriorLights

Descriptive Name	ExteriorLights
Identifier	DataType_28
ASN.1 representation	<pre> ExteriorLights ::= BIT STRING { lowBeamHeadlightsOn (0), highBeamHeadlightsOn (1), leftTurnSignalOn (2), rightTurnSignalOn (3), daytimeRunningLightsOn (4), reverseLightOn (5), fogLightOn (6), parkingLightsOn (7) } (SIZE(8)) </pre>

B.19 referencePosition

Description	Position and position of the originator ITS-S. The <i>generationDeltaT</i> shall be set to the reference position of the bounding box. The <i>positionConfidence</i> shall be set to unavailable. If <i>semiMajorOrientation</i> is set to the position of the originator ITS-S. This definition is in accordance with the <i>semiMinorConfidence</i> .
Data setting and presentation requirements	The DE shall be presented as specified in ETSI TS 102 894-2 [2] <i>ReferencePosition</i> .

B.37 exteriorLights

Description	Status of the most important exterior lights switches of the vehicle ITS-S that originates the CAM.
Data setting and presentation requirements	The DE shall be presented as specified in ETSI TS 102 894-2 [2] <i>ExteriorLights</i> .

B.22 speed

Description	Driving speed and speed accuracy of the originator ITS-S. The speed accuracy provided in the DE <i>speedConfidence</i> shall provide the accuracy of the speed value with a confidence level of 95 %. Otherwise, the <i>speedConfidence</i> shall be set to unavailable.
Data setting and presentation requirements	The DE shall be presented as specified in ETSI TS 102 894-2 [2] <i>Speed</i> .
NOTE:	There might be a difference between the speed in moving direction and the driving speed.

From: ETSI EN 302 637-2 V1.4.1 (2019-04)



Existing test specification

- TTCN-3 Test cases from ETSI:
- <https://forge.etsi.org/rep/ITS/ITS/> (former <https://forge.etsi.org/svn/ITS/trunk>)
- Advantages:
 - formal
 - TTCN-3, simple execution, more or less human-readable.
- Is there a need for more test cases?
 - Depends on the current coverage:
 - Checkout the current test cases,
 - Search, sort the referenced requirements,
 - Check the coverage.

```
[asba_le@ts-rlst0001-dev trunk]$ ls
asn1 data javasrc ne-countries-50m.json patches requality taconfig.xml tools ttcn unittests

[asba_le@ts-rlst0001-dev trunk]$ pwd
/home/asba_le/ITS/trunk

[asba_le@ts-rlst0001-dev trunk]$ grep -ri "@reference ETSI EN 302 637-2" | sort -u
ttcn/AtsCAM/ItsCam_TestCases.ttcn: * @reference ETSI EN 302 637-2 v1.3.2, Annex B.1
ttcn/AtsCAM/ItsCam_TestCases.ttcn: * @reference ETSI EN 302 637-2 v1.3.2, Annex B.11
ttcn/AtsCAM/ItsCam_TestCases.ttcn: * @reference ETSI EN 302 637-2 v1.3.2, Annex B.12
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[asba_le@ts-rlst0001-dev trunk]$
```



Coverage in the CAM specification

- Example CAM, based on ETSI EN 302 637-2.
- Documented coverage::
 - Annex B.1, 6.1.3, 5.2, Annex B.11, B.12, B.13, B.14, B.15, B.16, B.17, 5.3.4.1, 6.2.2.1, 4.2.2
 - Important note: Only documented requirements have been taken into account.
- Currently only few requirements are covered. There is no parameter set to invoke the test cases in different scenarios. Even the covered requirements are only tested in certain situations.

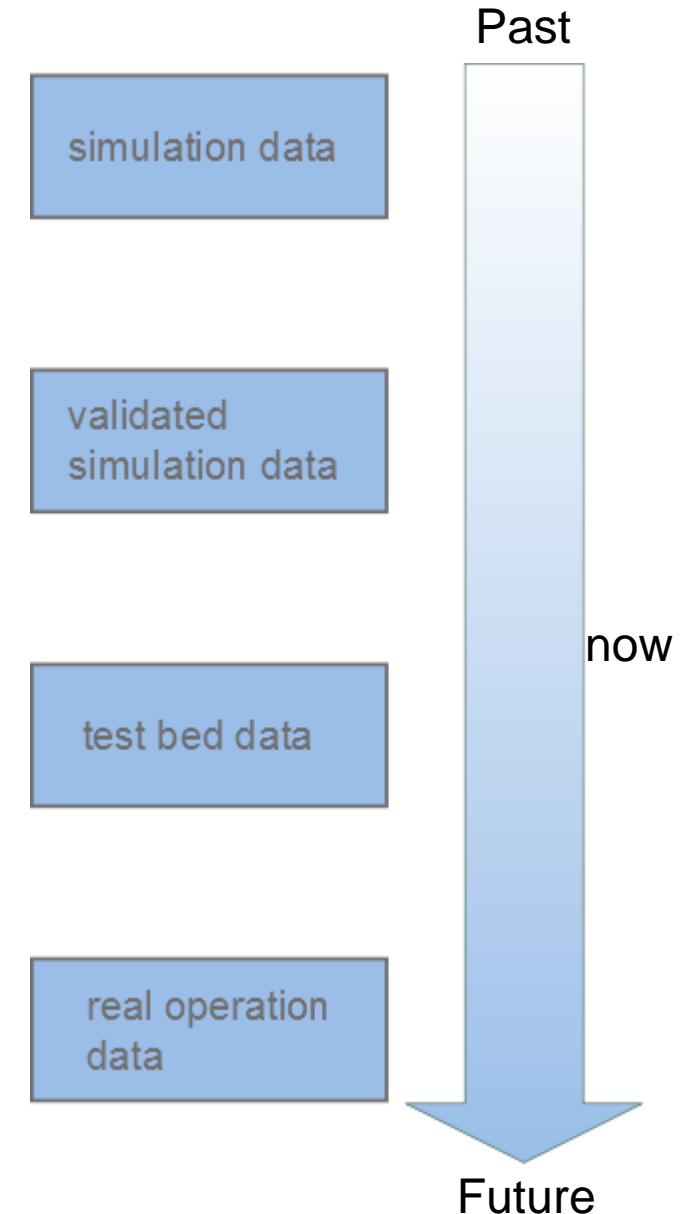
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... Coverage documented.

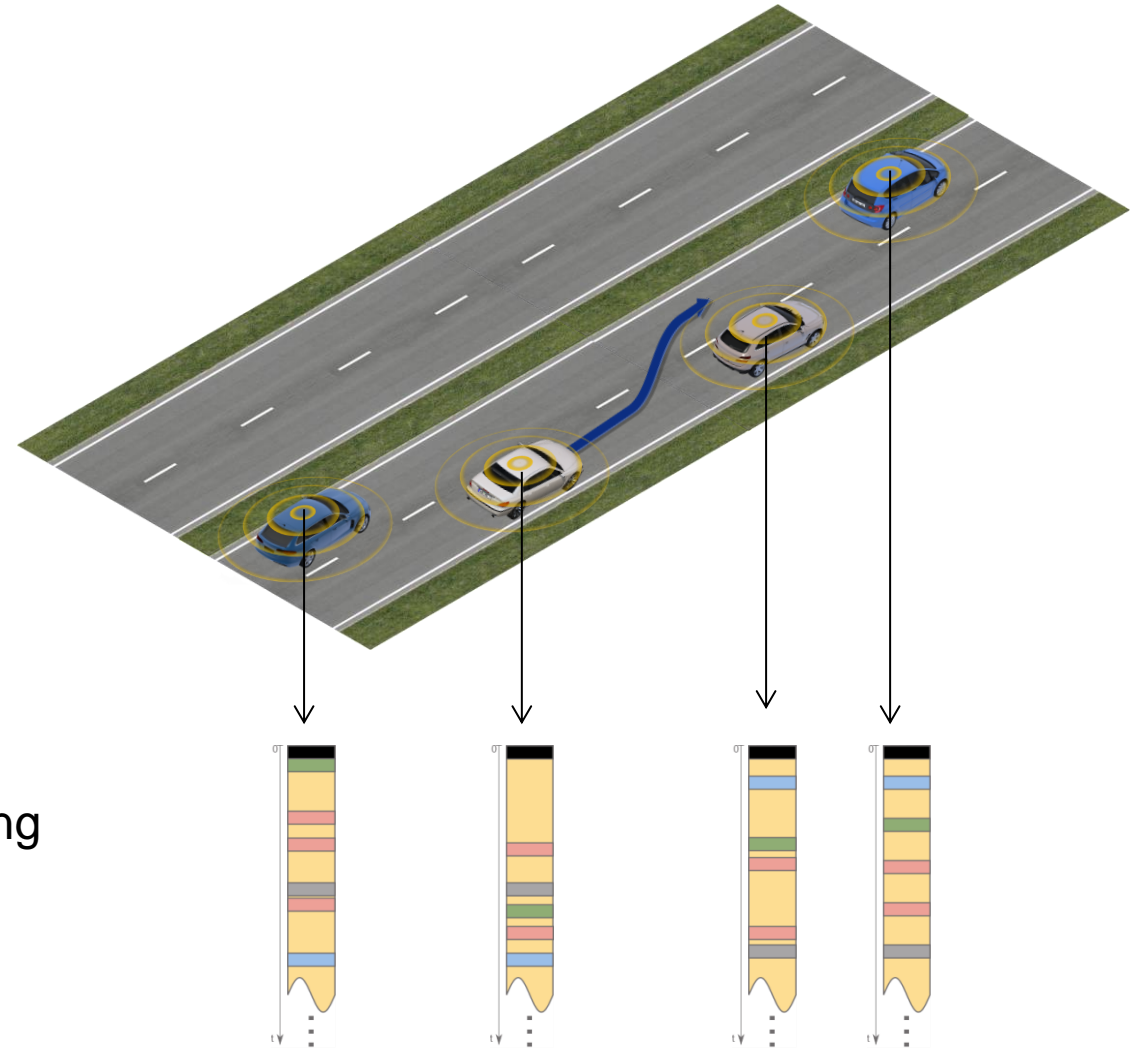
Approach

- Several test tracks (C-Roads, AIM, Test bed lower saxony, TAF, etc.) are available, equipped with road-side-units.
- First manufacturers are rolling out on-board-units in their production lines.
- Furthermore there are sophisticated simulations (e.g. SUMO) for traffic simulation available, which can be validated with the data from the real test tracks.
- Collecting all received/sent messages in a database leads to more and more growing database of real V2X-communication.
 - Certain scenarios will appear with a lot of different constraints,
 - Different manufacturers are involved in the communication
 - In the beginning there will be almost no safety-criticality



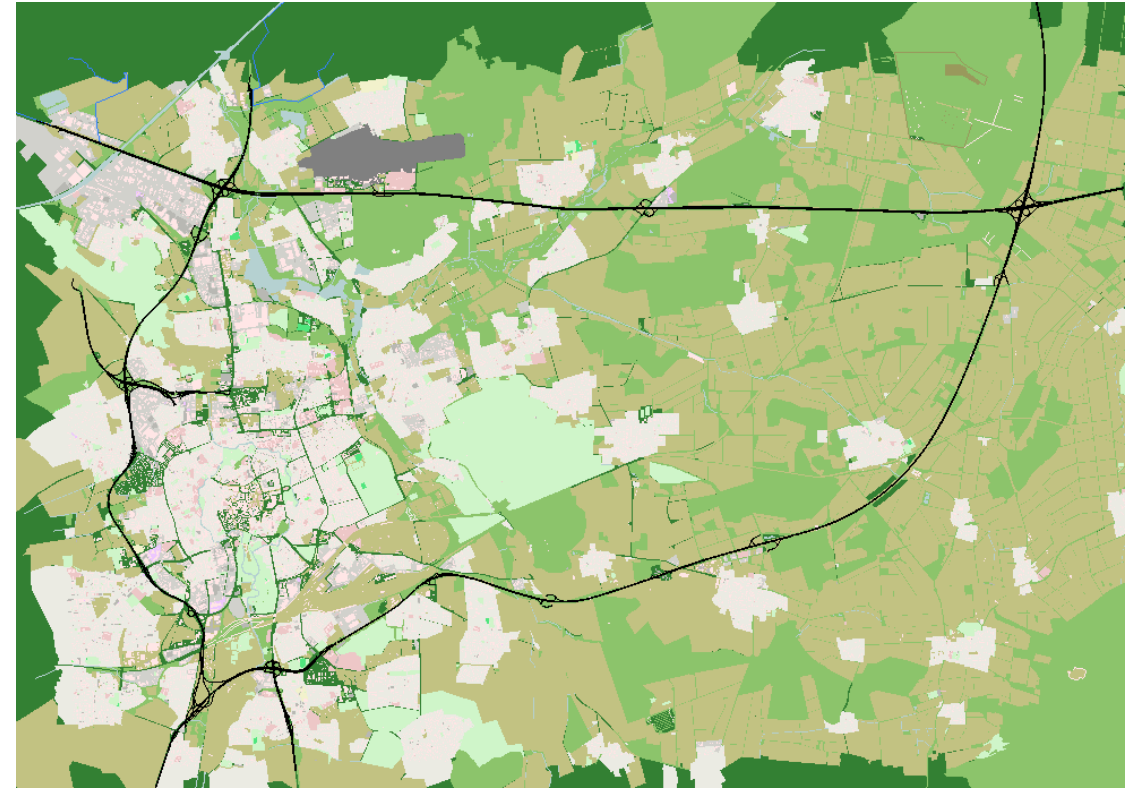
Approach – in detail.

- Assumptions:
 - All cars are emitting CAM messages,
 - Frequency 5Hz,
 - No packet loss,
 - Data Stream of every car is recorded.
- First example: Overtake maneuver, especially first lane change.
- Steps:
 - Generating Test Data
 - Pattern matching for maneuver trigger, analyzing trajectory,
 - Collecting all different occurrences of the maneuver,
 - Inspecting constraints,
 - Creating scenarios / test cases.



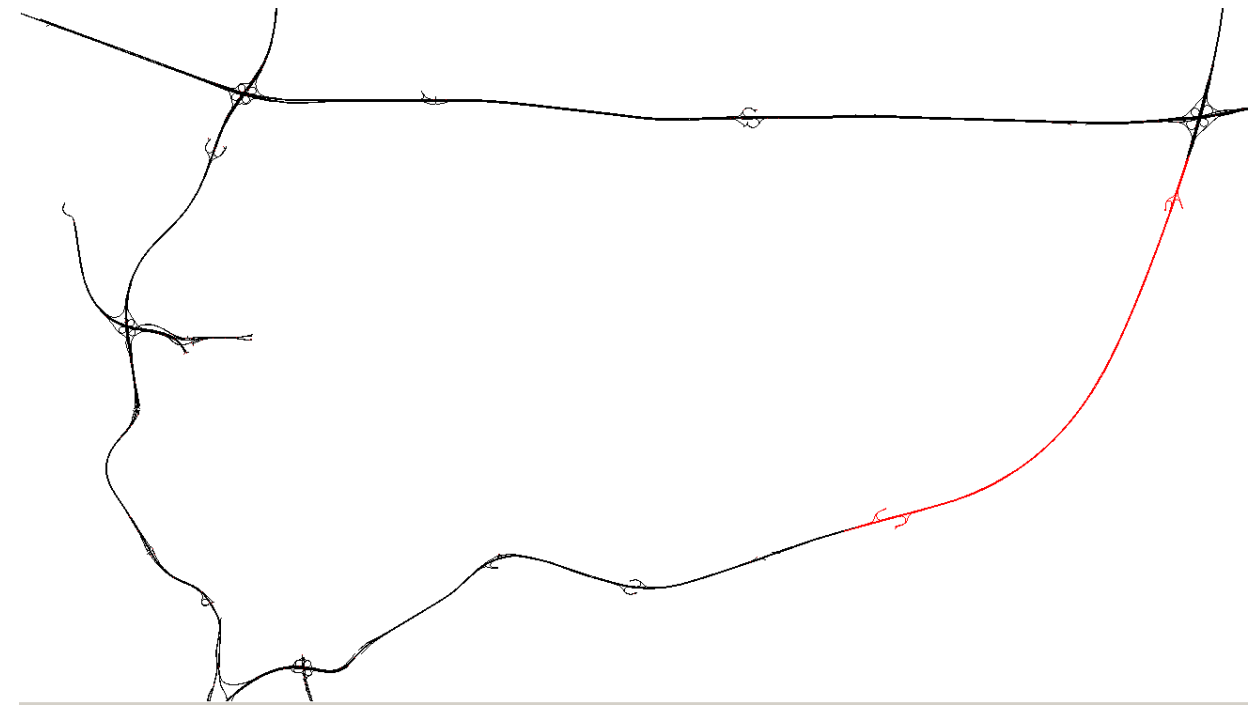
Current Status // Gathering the data

- Right now, there is no direct access to real data:
 - Only very few cars are equipped with V2X technology and are emitting any messages.
 - Not all test tracks are already in operation or are in upgrading procedures.
- To show the basic function of the method and for later extension of the test-data a simulation based approach is necessary.
- DLR's traffic simulation SUMO has been configured to simulate a certain part of the Test Bed Lower Saxony.
- In a first step only CAM messages have been evaluated, they will be available first.
- The simulation has been configured with real traffic data, acquired by the BAST.
- Simulation time 1 hr.



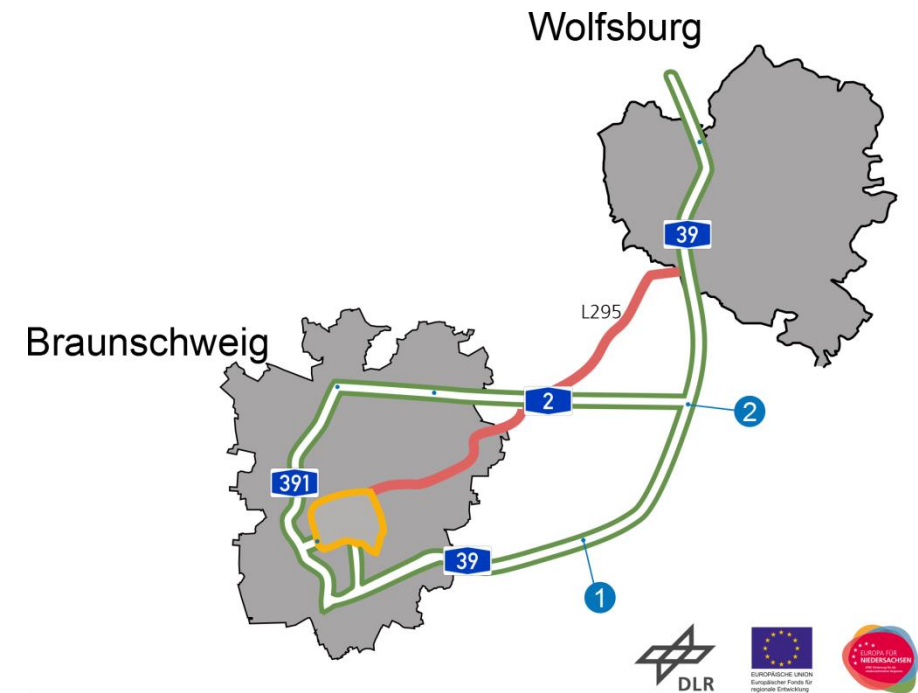
Current Status // Gathering the data

- V2X CAM Information has been emulated, reduced to:
 - stationID,
 - exteriorLights,
 - speed (w/o accuracy),
 - position.
- Important assumption: stationID stays unchanged for the maneuver.
- Due to performance reasons no live processing has been executed but the data has been stored file-based as floating car data.
- The simulation output has been acquired for approx. 8km between Exit 30 (Cremlingen) and Exit 28 (AK Wolfsburg/Königslutter). **Why this selection?**



Current Status // Gathering the data (selection)

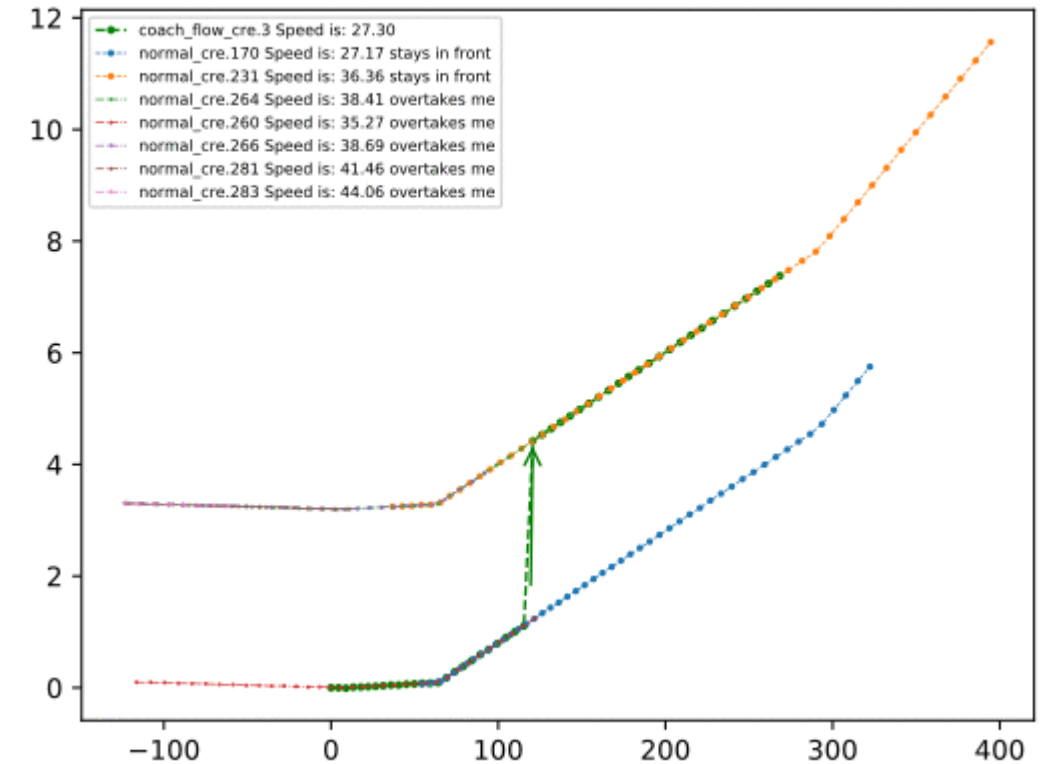
- Test Bed Lower Saxony (opening 08.01.2020).
- Between exit 30 and exit 28 a very accurate traffic acquisition will be available:
 - Accuracy better than 25cm
 - Every vehicle will be detected
- For every detected vehicle a V2X-Message (CAM) can be emulated in real time.
- The resulting data stream will be very close to future situations with V2X equipment in every car.



High precision acquisition system between (1) and (2)

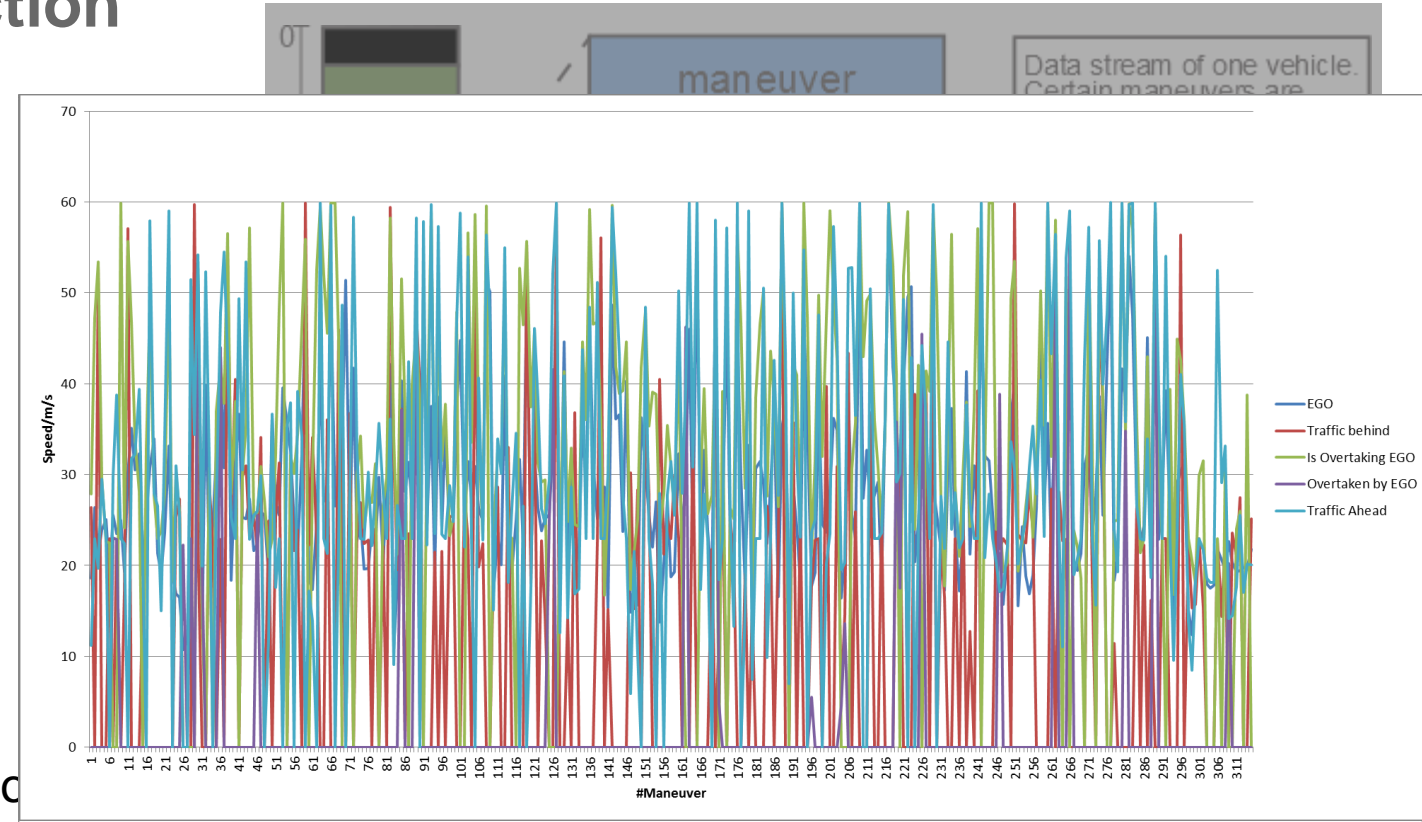
Current Status // Maneuver Extraction

- Time-based Floating Car Data has been converted to vehicle-based trajectories (gpx-format),
- Data has been analyzed for Overtake on the highway.
- Exterior lights have been filtered for left flasher.
- Vehicles using the left flasher and changing lane (gradient of trajectory) are selected for EGO-vehicle in the scenario.
- The entire scene with all cars in a certain time scope (e.g. +/- 5 secs), within a certain distance (e.g. 100m) have been selected and added to the maneuver.



Current Status // Maneuver Extraction

- All vehicles in the scene are analyzed for their trajectories in relation to the EGO vehicle:
 - Are overtaken by EGO,
 - Overtake EGO,
 - Traffic behind EGO,
 - Traffic in front of EGO.
- Relevant parameters are extracted:
 - Speed,
 - Distance,
 - Exterior Lights.
- Border identification leads to a limited number of scenarios.

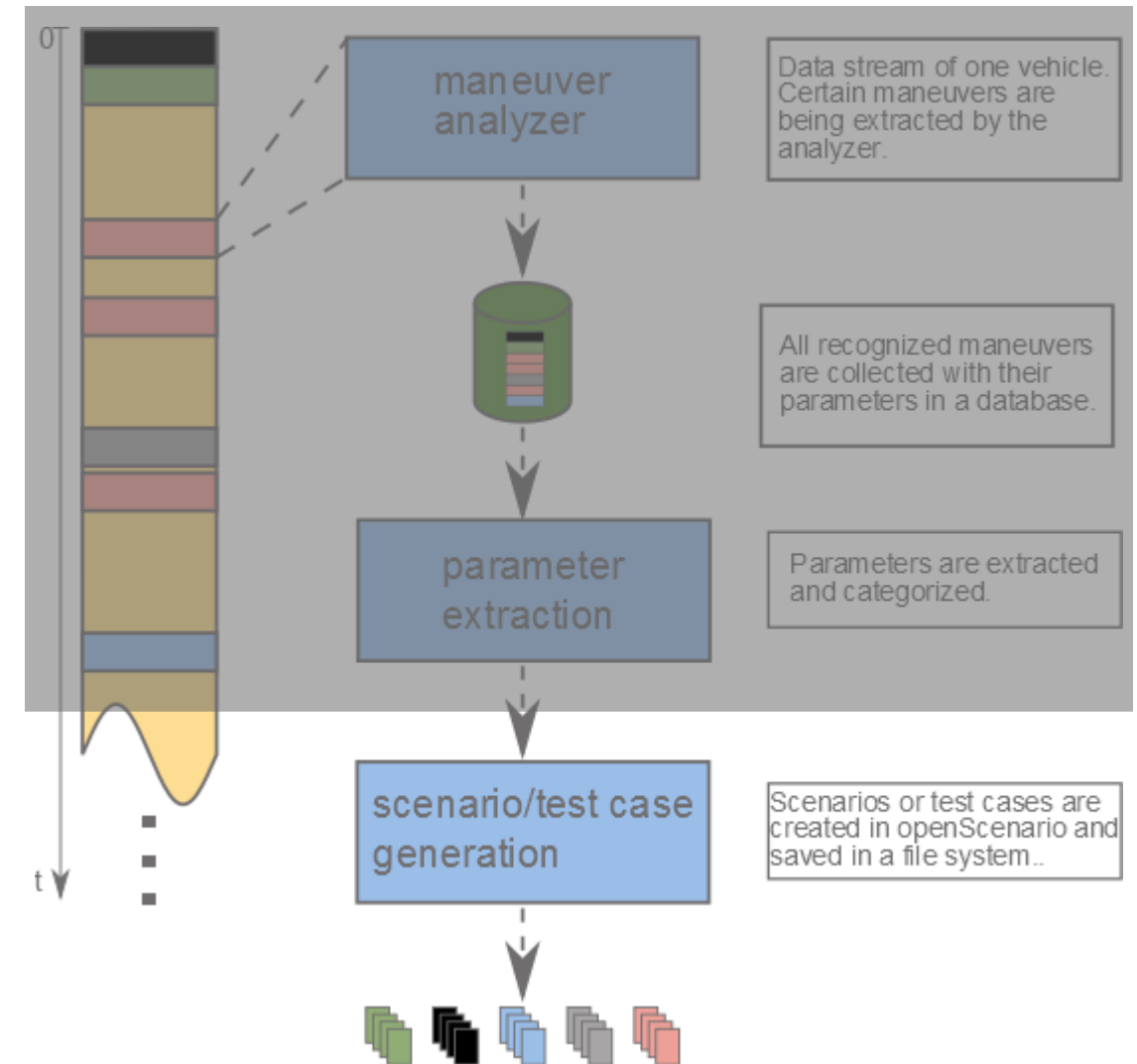


	EGO	Overtaking	Overtaken	Traffic behind	Traffic ahead
Min	10,73	0	0	0	0
Max	58,91	59,89	59,91	58,88	59,93
Median	25,69	11,45	30,72	0	25,55
Average	28,5019683	14,3743175	30,7541587	2,93177778	29,4564762



Current Status // Maneuver Extraction

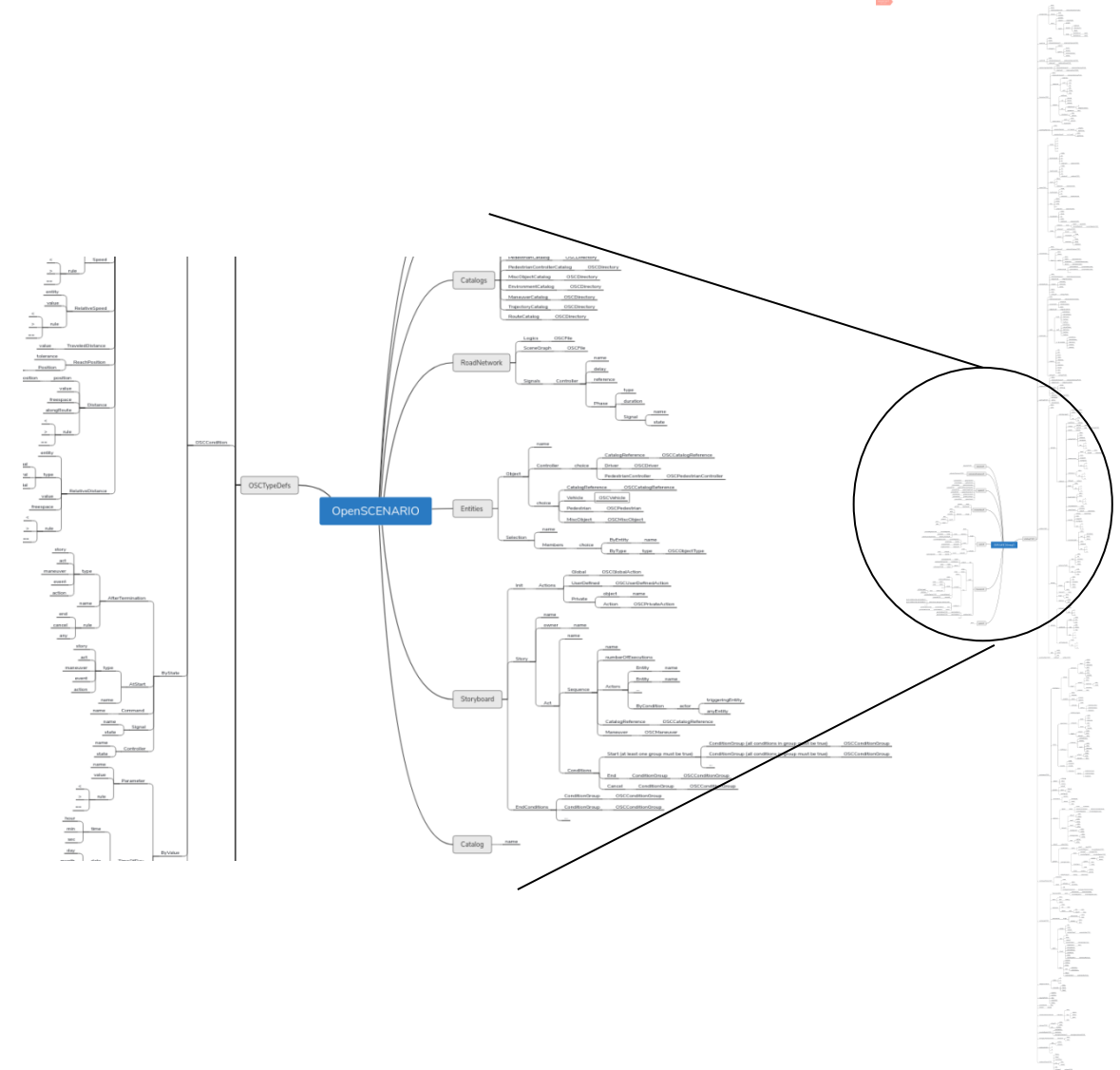
- Tool-chain has been executed with one hour simulation time (including warm-up phase), 200ms sample rate (~ 5 CAM/s).
- 231 maneuvers have been identified
- For verification purpose for every SCENARIO a graphical representation has been generated.
- Scenarios have been exported to OpenSCENARIO (v 0.9.1).



Current Status // Test Case Format

- OpenSCENARIO:

- ✓ Well known in the automotive domain
- ✓ Toolchain for creating and editing is currently under development, many projects ongoing/done (Pegasus/SETLevel4to5).
- ✓ Can be read by many simulators (VTD/Carmaker/etc.)
- ✓ Lot of potential / human-readable / text base (for easy versioning)
- ✓ first version available (incl. scheme definition)
- ✗ **Not a real test case format:** Difficult to describe expected reactions of System-under-Test
- ✗ really complex



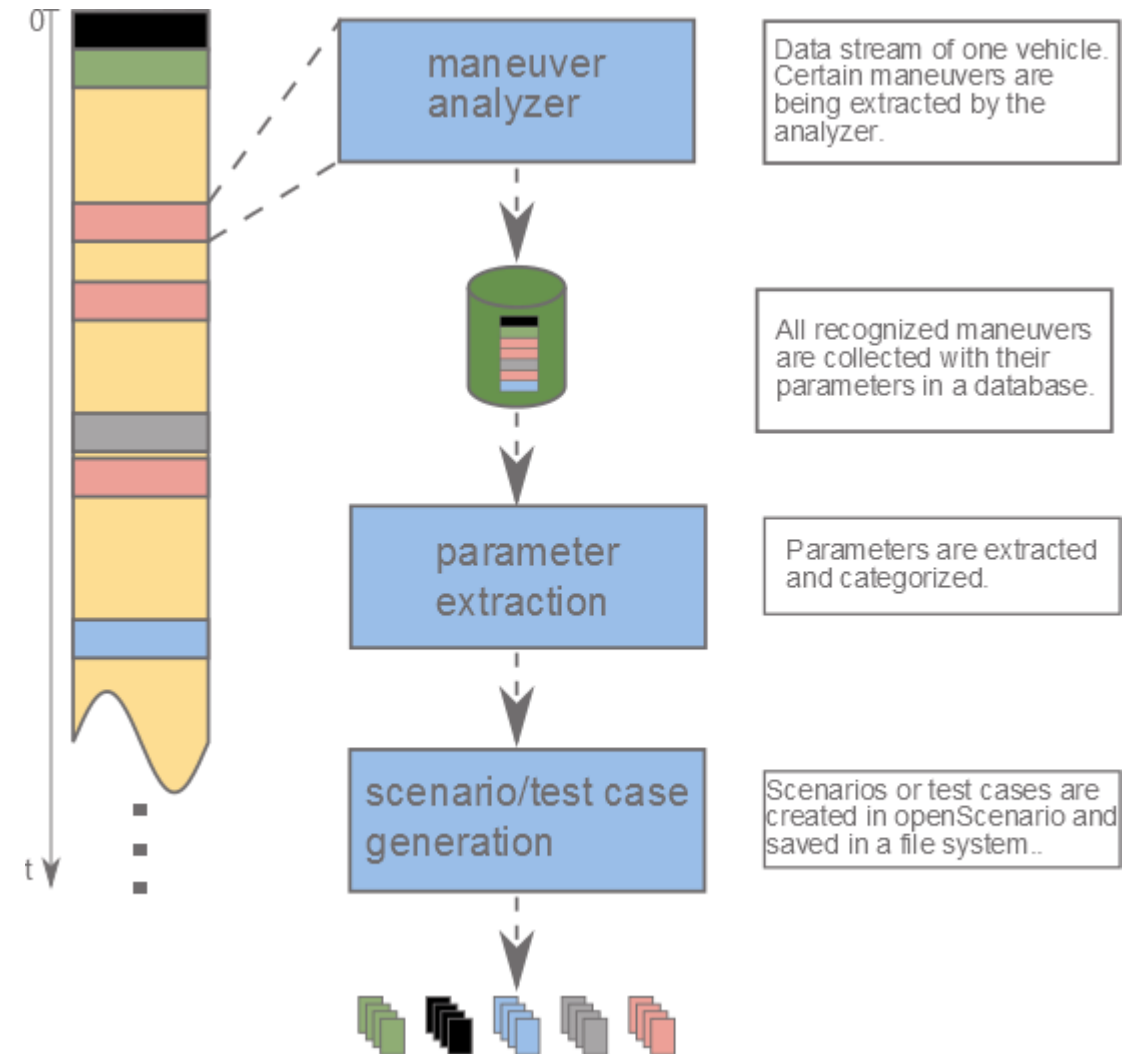
Summary

Open Points:

- Simulation is not yet calibrated,
- Almost no co-operative behavior (by intention),
- Some drawbacks by using openSCENARIO,
- Coverage not yet available.

Done:


- Simulation results usable,
- Maneuver detection works,
- Parameters can be extracted,
- Scenarios are created in openSCENARIO,
- Ready for real data (when available).



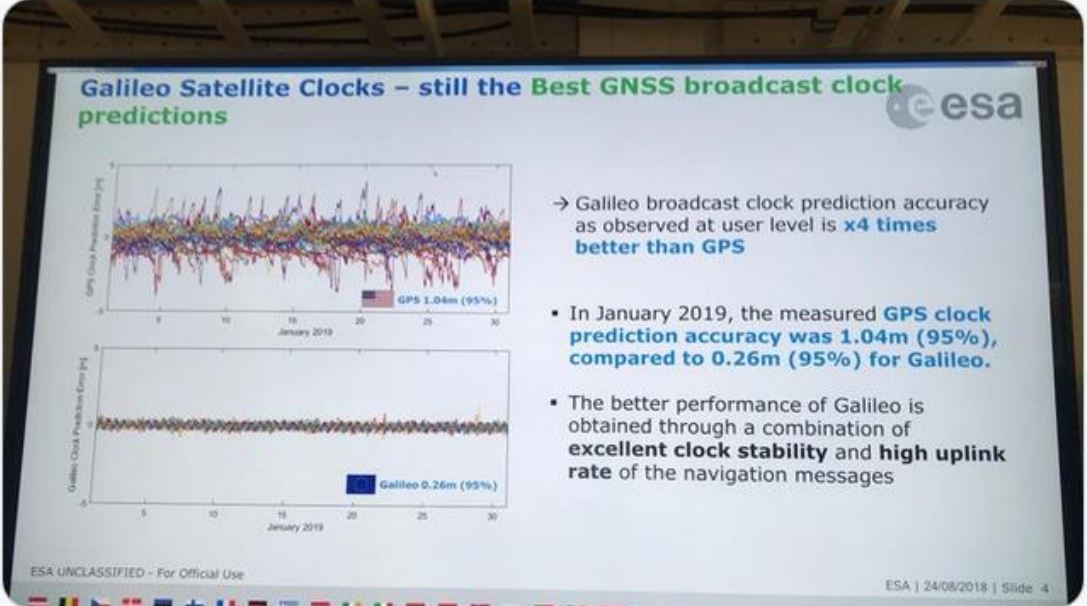
Potential of the scenarios

- Maybe there is not only V2X-testing possible, is it possible to use the scenarios also for testing automated driving functions?
- Many parameters are known in good or at least medium quality, e.g. coming to Galileo the quality of the position signal will enhance significantly.

Galileo GNSS Retweeted

 **Violeta Bulc** ✓ @Bulc_EU · 23h

This is the difference between GPS and #Galileo. Bravo @GalileoGNSS @EU_GNSS, bravo @esa.



The screenshot shows a presentation slide with two line graphs. The top graph is titled 'GPS Clock Prediction Error (m)' and shows a wide spread of data points with a red box indicating 'GPS 1.04m (95%)'. The bottom graph is titled 'Galileo Clock Prediction Error (m)' and shows a much tighter cluster of data points with a blue box indicating 'Galileo 0.26m (95%)'. To the right of the graphs, text states: '→ Galileo broadcast clock prediction accuracy as observed at user level is **x4 times better than GPS**'. Below this, two bullet points are listed: '▪ In January 2019, the measured **GPS clock prediction accuracy was 1.04m (95%), compared to 0.26m (95%) for Galileo.**' and '▪ The better performance of Galileo is obtained through a combination of **excellent clock stability** and **high uplink rate** of the navigation messages'. The slide footer includes 'ESA UNCLASSIFIED - For Official Use' and 'ESA | 24/08/2018 | Slide - 4'.

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