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DRIVE C2X

Accelerate cooperative mobility

Deliverable D32.1

DRIVE C2X FOT System Validation

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Executive summary

Introduction

This document reports on the results of Work Package (WP) 32. This work package was responsible for the validation of the DRIVE C2X reference system on a single test site, called the System Test Site (STS). The reference system is the software that is developed within the project and should run on the test sites. The main added value of WP32 is that the entire reference system is installed in practise on a single test site. This has the advantage that major errors are detected early on preventing the other six test sites from running into similar problems. Also, the nature of the STS allows the evaluation of the reference system by using an independent system that operates stand-alone from DRIVE C2X. Finally, the organisation of several test events where all vehicles participate allows testing the overall interoperability of the reference system.

The role of STS is taken by the Helmond test site in the Netherlands, which is operated by TNO. The test site is named DITCM, an abbreviation of Dutch Integrated Testsite for Cooperative Mobility.

The purpose of this deliverable is to validate the system in as much depth as possible and present the results to test sites who are intending to use the system and to developers to explain remaining issues. The results of this work package are direct input for Work Package 33 (WP33) regarding test site adaptations, WP34 regarding piloting and WP44 regarding technical evaluation. Many parts of the reference system were validated to work as intended. However, as always, some parts did not pass the validation test due to some remaining issues. The follow-up of these issues falls beyond the scope of WP32 and this deliverable, however the process of how these remaining issues are handled is explained in 1.4 as well.

Chapter 1: Methodology

Test weeks were organised in calendar week (cw) 15, 16, 21, 25, 27 and 39. During these weeks, all applications available were tested on all vehicles. Basically, the tests followed a controlled testing approach. Per application a number of relevant scenarios were planned and vehicles got instructions on how and where to drive. During each test run all or at least multiple applications were tested. This has generated a vast amount of test data that formed the basis for the analysis.

The report structure capture the rationale of the validation steps.

- Chapter 2 analyses all vehicles using the DITCM system. This is an independent system that measures the overall system performance with respect to timing, position, communication range/quality and HMI. When a vehicle does not perform well on these aspects it renders the rest of the system obsolete.

- Chapter 3 analyses the log data from all components in detail. The log data gives information about the vehicle and its driver during the FOTs following the validation phase. If the logged information has a wrong syntax or stores wrong information (e.g. position, time), there is no way in which this information can be retrieved later on. If that would be the case, SP4 cannot do an impact assessment. Also for the sake of validation, it needs to be clear that the logged data can be trusted and can be used to validate the operations of the applications.
- Chapter 4 gives an overview of the Test Management Center tools that are delivered within DRIVE C2X and that have been used in the validation tests. These tools help the FOT to define tests and to execute and monitor controlled test runs.
- Chapter 5 validates the applications. Each application is tested on all vehicles with different scenarios.
- The conclusions drawn from the work done are presented in Chapter 6.

The report structure also has clear link to the system architecture. The communication part of the architecture has already been validated during the "Cooperative Mobility Services Plugtest" that was organised in the context of WP32 together with ETSI in November 2011. In that Plugtest, it was concluded that the reference system is interoperable with non-DRIVE C2X-implementations.

Some limitations of the validation approach include:

- Many of the test weeks were effectively used as integration tests, resulting in many software updates. After many software update, the previous test results often became obsolete. Therefore the results in this report originate from the most recent validation week cw39.
- From this test week the events or vehicles have been analysed that were illustrative for the components/applications; the malfunctioning systems have been omitted.
- Each test site is unique in terms of its road layout and its (proprietary) test site specific systems.
- DRIVE C2X does not contain a document that includes a comprehensive set of measurable requirements against which the reference system can be formally validated. The goal of validating the reference system in this context is therefore interpreted as an evaluation of the reference system on the STS with respect to the intended functionality.

Chapter 2: Validation via the DITCM system

The STS is equipped with many Roadside ITS Stations (RIS). These RIS have implementations of the complete networking stack, including a Geonetworking implementation and up to the various DRIVE C2X messages (CAM, DENM, etc.). The RIS can run two completely independent systems in so called dual mode. This has been used on several RIS to run 1) a DRIVE C2X-independent implementation used to validate the DRIVE C2X logging components and 2) implementation of the DRIVE C2X reference RIS platform with the required roadside components of several applications.

The STS is equipped with a camera system that monitors a large part of the test site. This system is able to track every single vehicle and measure its position over time with an accuracy of about 1m at 100ms intervals. Cameras inside several test vehicles have been used to compare the HMI output with the log data. The analysis resulted in the following conclusions:

- Time synchronisation: Most vehicles are time synchronized and the system time variation remains between -1500 ms and +500 ms compared to UTC (with exceptions of up to 16 s). For time critical applications the measured time variation is not considered to be sufficient. However, no hard requirements have been defined on the timing resolution and long term stability for DRIVE C2X applications, so it cannot be stated whether this is within the specification. The analysis of the applications in WP44 and WP45 will indicate how well the functions perform given the technical capabilities. The measured time variance could have a significant effect on applications when outdated messages would be rejected, but the analysis of applications (Chapter 5) suggests that message generation time is not handled this way.
- Communication range: vehicles show large differences in communication performance. For example, one vehicle only had a range of 80 meters where most other vehicles had a minimum of 250m. The range also differs for the front and rear side of the vehicles, depending on the mounting of the antenna.
- Positioning: overall, the expected GPS accuracy is reached, although differences between vehicles exist regarding the update rate of the CAM messages (between 1 and 10Hz). No hard requirements for positioning have been defined for the DRIVE C2X applications so whether this is sufficient cannot be concluded. Vehicle headways have not been validated as this information was not available from the logging.
- HMI: almost all annotated events are logged as presentation or revoke events by the HMIDP. The time lag between logged HMIDP events and the video annotations varies apparently in a random manner and typically is within 1 second. The HMIDP logs the risk status of presented application information, but this is not always sufficient to reconstruct the prioritization of displayed information from simultaneously triggering applications, i.e. which of these icons are shown in full or miniaturized in a corner of the screen. Such situations in which multiple applications trigger simultaneously and with similar risk status are likely to occur in real world events. Furthermore, the structure of the logs requires heuristic post-processing to extract usable data from the logs, because the logs contain events suggesting changes in the state of the HMI, which are actually not observable by the driver.

An overall observation is than the specific implementation on a vehicle has significant impact on key aspects of the system, like time synchronisation, communication range, and positioning accuracy. These aspects should therefore be checked before a FOT is started, because potential problems are difficult or even impossible to correct afterwards from the logging.

Chapter 3: Validation of Facilities

This chapter validates the critical components in the facility layer that log information into the DRIVE C2X log files. Analysing the log files is the only way in which validation of the internal working of the system is possible. Facility components that store log information include ITU, POTI, CAM, DENM and VDP. Components SPAT, TOPO and LDM did not log any data into the log files.

The architecture of the logging is such that all messages are encoded. Therefore it is difficult to quickly check the semantics and syntax without software tools. These tools are not provided by SP2. A necessary first step included the development of a tool (called the LogMover) that decodes the messages and stores them in a database. The logging system depends on the exact version of a specific log component used. However, no version number is stored in the log files, which introduces inconsistencies between the assumed meaning of the content of the log files and its actual meaning. That made it difficult to track down differences in the log encoding between vehicles, even during the same test run. It is especially relevant for test sites to manage the log definitions when future updates are still expected. As long as the definition of the logging is not frozen, and/or the logging system improved on this aspect, this issue remains.

As a general observation, complete systems blocks do occur for up to 3 seconds, likely due to the Java garbage collection. On one vehicle this occurred even once per minute. After such a block, the VDP logging sometimes needed 5 seconds to recover and to provide valid speed values again. Since this phenomenon occurs regularly and affects logging, it is considered as an issue for FOTs.

The following conclusions per facility component were drawn:

- ITU logging is not validated because the logging was incorrect. The ITU logger application was updated without also updating the component definition (abstraction-file). Also, since the ITU-logger decoder has not been supplied to be used during the validation weeks, it was not possible to decode and validate the logs that were available.
- POTI logging was validated and found to be functionally correctly.
- CAM logging was validated, and found to be functionally correctly. It has been observed that outdated GPS positions are sent out through CAM, without the correct "position confidence" or lowered frequency. This has a major impact on other components and applications. Test runs have been observed where vehicles sent out outdated position information in their CAM messages, resulting in invalid distances between vehicles. Hence, applications relying on CAM draw wrong conclusions from their whereabouts resulting in faulty information to the driver. It is recommended that the position confidence should be checked upon sending CAMs, and that the confidence should be logged for data processing and technical evaluation.
- DENM logging was validated and found to be functionally correct.
- VDP logging was validated and found to be functionally correct, although some required measurands are missing. The fields that are missing vary per vehicle, but also the way in which some fields are encoded causes a significant reduction in accuracy, e.g. accelerations were rounded off to integer values.

When the ITU, and CAM issues are solved and the content of the VDP logs is improved, the components are expected to run as required. The test sites need to check and monitor the vehicle-specific interfaces to VDP and GPS.

Chapter 4: Test Management Center Tools

Two tools for test management are available supporting FOT execution: the WebScenarioEditor [1] and the Codar viewer. No elaborate validation has taken place, although the tools have been used regularly during all test weeks. The experiences are described in the report.

The Codar viewer worked fine and was used to monitor the progress of tests, to visualise the whereabouts of vehicles and the occurrence of events from the messages on a vehicle's HMI. The functionality to stage an event by creating and sending out DENM on a RIS was tested, but never used during the validation tests (where only predefined RIS events were used).

The WebScE supports the creation and running of scenarios and a 3G connection to vehicles could be set-up. A critical point for test sites is that the scenario definition cannot directly be extracted and is not available for analysis afterwards. Another point is that a tighter coupling between the WebScE and the test site is deemed very useful (RIS settings and log files). Test sites are advised to determine how they want to correlate the scenario definitions (input) and the log results of the experiments (output). Another issue is that currently all log data is stored in a database, but this database is not open to test sites. It is advised to give test sites full access to their data.

Chapter 5: Application validation

The approach for the application validation is to evaluate the responses of the DRIVE C2X reference system and application components to DENM and other events. The evaluation is presented in a bottom up approach, following the sequence of events from the DENM, via applications triggering the HMIS and HMIDP. The final step, presenting the information on to the driver, was already validated in Chapter 2.

The HMIS logs the application requests to display information, including a priority, risk status, sign type and distance to the event. In order to use the HMIS logging for evaluation of applications, first the consistency of the HMIS logging with the information displayed via HMIDP was checked. This showed that not all vehicles log the applications that are presented. Some applications (e.g. GLOSA, MAI) are not logged correctly. AEV, WW and SVW are not (always) sending revoke messages, resulting in message being shown for up to 10s longer than required, possibly inhibiting other messages from being displayed.

Generally stated, all applications that have been included in the validation tests have shown to be working in at least a couple of vehicles. However, there has not been a single application that worked in all vehicles. Also there was no single vehicle where all applications worked fine. Almost all the applications have specific issues. It is acknowledged that for a FOT not all applications need to run on all vehicles. Therefore it depends on the FOT which issues need specific attention.

Chapter 6: Conclusion

The validation has identified a list of issues which are recommended to be resolved before the DRIVE C2X reference system can be used in a FOT, checked during piloting, and monitored during technical evaluation. Each chapter revealed key issues that need special attention.

The piloting phases of the FOTs are necessary to ascertain that the combination of reference system and proprietary systems work properly. In particular the following deserves special attention:

- Modification of the software components are expected both due to planned changes in response to the validation recommendations and due to test site specific adjustments. It has been observed that changes in one component may unintentionally affect other components. Therefore, the test sites are advised to ensure that their full software platform is working properly, and not just the modified components. The piloting phases of the FOTs are most appropriate for this.
- Test sites need to realize that the DRIVE C2X reference system is not (yet) plug-and-play. The implementation on the actual hardware devices and software settings has a big influence on the proper operation. Also, each test site is unique in terms of its road layout and its (proprietary) test site specific system so unexpected behaviour may still occur in specific situations.

As explained in the introduction, a process has been installed that deals with these remaining validation issues. For each detected validation issue, the associated developer is responsible for fixing the issue and re-validating the fix. This process is coordinated by WP34. Also representatives from WP35, WP43 and WP44 formed a Data Task Force that inspects the new data logs.