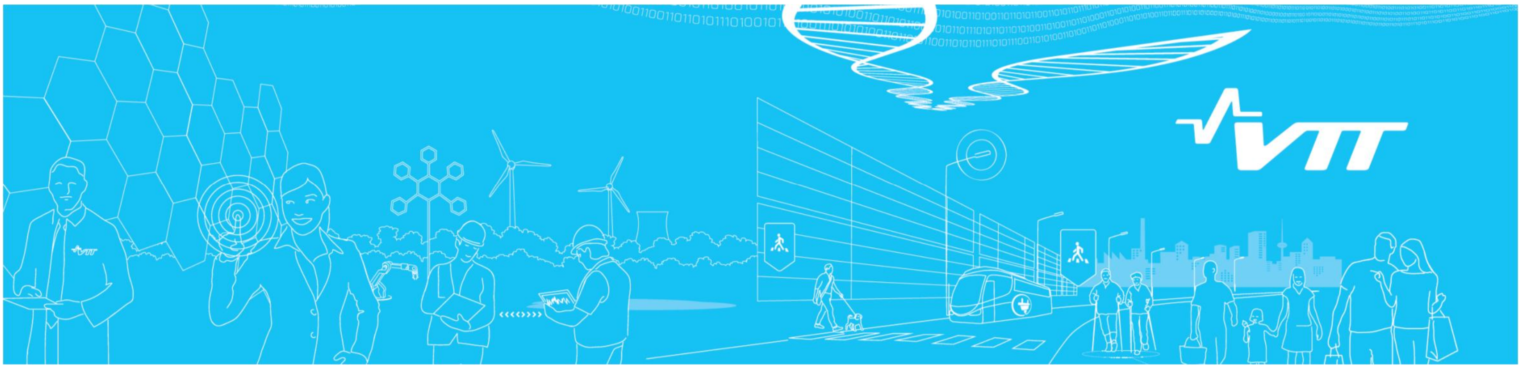

RESEARCH REPORT

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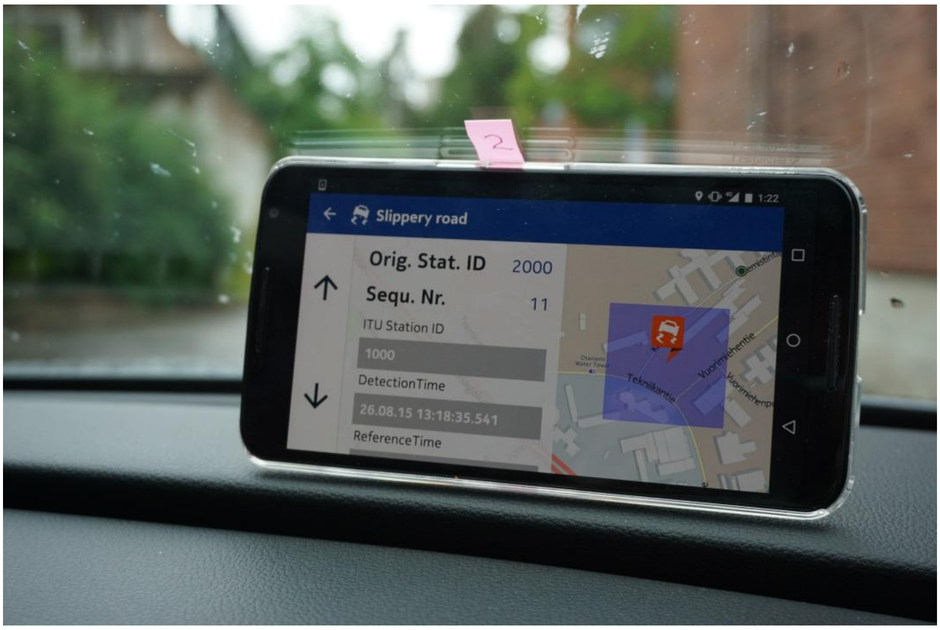

Technical Assessment of NordicWay Coop Demonstration

Authors: Kimmo Kauvo, Sami Koskinen

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Summary

This report presents the findings from a technical assessment made for a proof of concept implementation of a traffic information system within NordicWay project. The NordicWay project pilots cellular Cooperative ITS (C-ITS) services in a road network which extends from Denmark and Norway to Sweden and Finland. The proof of concept demonstration targeted the Finnish implementation of the services. HERE and Infotripla supplied the technology and VTT carried out an assessment.

Ten scenario tests were run during a single demonstration day, collecting log data from network servers and mobile phones. These scenarios included sending traffic information simultaneously to eight mobile phone users, warning them e.g. about an obstacle on the roadway and short-term roadworks.

The tested system performed well in all tests, providing information to correct users in target areas. The technical assessment reviewed the performance of the information system against a set of quality criteria, raising from project goals as well the European ITS Platform (EIP) quality criteria. The targets addressed by the proof of concept demonstration were met, with technical assessment providing some notes and recommendations for further development of the system in view of upcoming large-scale trials.

Confidentiality	Public

Tampere 7.9.2015

Written by	**Reviewed by**	**Accepted by**
Kimmo Kauvo, Senior Scientist	Satu Innamaa, project manager	Karri Rantasila, project owner

VTT's contact address
Kimmo.kauvo@vtt.fi

Distribution (customer and VTT)
NordicWay Coop consortium

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1. Introduction

1.1 NordicWay project

The NordicWay project pilots cellular Cooperative ITS (C-ITS) services in a road network which extends from Denmark and Norway to Sweden and Finland. It is a three-year (2015–2017) real-life deployment pilot, which aims at wider deployment in the Nordic countries and elsewhere in Europe in the next phase. The road and transport authorities of Finland, Sweden, Norway and Denmark are the initiators of the project, which receives EC support through the CEF programme.

NordicWay tests and demonstrates interoperability of C-ITS services both for passenger and freight transport. The pilot involves several service providers offering the same user experience across the NordicWay corridor.

NordicWay represents a proof-of-concept as it is the first large-scale pilot demonstrating the technical feasibility of probe data collection and C-ITS service delivery using cellular communication (LTE/4G) throughout the corridor, based on European C-ITS standards. NordicWay offers continuous interoperable services to users, supporting roaming between different mobile networks and across borders.

NordicWay will demonstrate the quality improvements that C-ITS and probe data may bring to key safety services. To do so, it pilots three services and their interoperability:

- cooperative hazardous location warnings
- cooperative weather and slippery road warnings
- probe vehicle data services.

Finnish pilot within the NordicWay project, named NordicWay Coop, is coordinated by FTA, while HERE and Infotripla act as suppliers of the technology. VTT is responsible for coordination support, technical evaluation and impact assessment of piloted systems.

1.2 Technical assessment of Proof of Concept

As the first checkpoint on the way to large-scale user tests in 2016, a technical demonstration day of the proof of concept (POC) implementation delivered by HERE and Infotripla was organised on 26 August 2015 in the Otaniemi area. More than 30 visitors were invited to see the demonstrator in action (Figure 1).

Figure 1. Demonstration day tent

Besides introductions and hands-on demonstrations, the day consisted of several recordings and technical tests made for validating the prototype implementation. HERE had set up nine detailed scenarios and data logging according to VTT's requirements. After these scenarios were run and the public pilot had ended, VTT run an additional scenario consisting of repetitive tests and video collection to analyse the dynamics and consistency of the system.

The primary objectives of the NordicWay Coop project are to study the functionality of traffic safety messages over 4G LTE wireless networks, the results of cooperative transmission of traffic information and the system's readiness for wider use as well as commercial potential. A proof of concept was to meet the following requirements:

- Delivery of traffic-related safety messages in accordance to ITS Directive via 3G/4G network
- Multi-cell and multi-operator support
- Consumer application in a smartphone
- End-to-end from road (mobile application / user input) to TMC
- Map-based user interface for TMC staff (provided by Infotripla)
- Mobile application allowing for entry and display of traffic-related safety events on a map
- Displayed alerts for drivers that are in the area of impact region of an event
- Delivery of mobile-sourced traffic safety events to TMC
- Delivery of TMC-sourced traffic safety events to mobile applications

- 6 traffic safety event message types to be supported:
  - Animal, people, obstacles, debris on the road (user display / user entry)
  - Temporary slippery road (user display / -)
  - Unprotected accident area (user display / user entry)
  - Short-term road works (user display / -)
  - Reduced visibility (user display / user entry)
  - Exceptional weather conditions (user display / -)
- Logging of traffic safety event messages at the mobile phone (with timestamp and GPS location) and time-aligned logging within the cloud for post-test analysis
- 10 users in a controlled LTE environment to demonstrate traffic-related safety message delivery and logging capabilities while supporting analysis of system message flow and latencies.

The main purpose of the technical assessment was to evaluate the current status of the demonstration systems against the aforementioned requirements and considering upcoming large-scale testing. The implementation should fulfil ITS Directive 2010/40/EU, detailing new requirements for traffic information provision to drivers. Since the directive itself does not hold detailed quality criteria, the NordicWay project uses EIP quality criteria (Table 1) for assessing the performance of information provision. NordicWay project aims minimally at advanced (***) quality level.

Table 1. EIP: Initial Target Values for the Level of Quality (all SRTI events/conditions, except wrong way driver) [Framework Guidelines for Data and Service Quality Requirements, EIP Sub-Activity 3.2, Jan Lohoff et al. 2015]

	Parameter	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)	★★★★
SRTI (all SRTI events/ conditions except wrong way driver)	Timeliness start (95%)	**Best effort**	Validation (if nec-essary) after first detection < 10 min Time between occurrence and first detection: Best effort	Detection & vali-dation < 5 min after event occurrence	Detection & validation < 3 min after event occurrence
	Timeliness update/end (95%)	**Best effort**	Best effort	Detection & vali-dation < 10 min after event change/end	Detection & validation < 5 min after event change/end
	Latency (content side) (95%)	**< 10 min**	< 5 min	< 3 min	< 2 min
	Location accuracy (95%) - Area	**Administrative region**	Administrative region	Geographic area; 10 km accuracy	Geographic area; 2 km accuracy
	Location accuracy (95%) - Road	**link between Intersections**	link between Intersections	< 5 km	< 2 km
	Error rate	**< 15%**	< 10%	< 10%	< 10%
	Event coverage	**Best effort**	Best effort*	> 80% of all occurring events	> 90% of all occurring events
	** definition of criterion and value shall be further examined within EIP+*				

[1]

Further, the implementation is considered against C-ITS standards such as DENM message definition (ETSI EN 302 637-3 V1.2.2), and recent V2V implementations in DRIVE C2X project (2011–2014), which carried out the largest European C-ITS user tests to date.

This report presents the findings of the technical assessment and gives recommendations for future development of the demonstration system.

[1] Timeliness = Time delay between the event detection and the provision of the information to the end user

2. Data collection and processing

HERE and Infotripla had implemented data logging in the tested systems, collecting mainly the following data:

- From mobile phones: GPS, communicated DENM messages and the moments when showing information on the screen
- From HERE servers: DENM messages to/from mobile phones, FCD (Floating Car Data) towards Infotripla and DATEX messages sent by Infotripla
- From Infotripla servers: FCD and DATEX communication.

The logs were collected partly automatically, partly manually at the end of the demonstration day.

As the first sanity check, VTT imported GPS data in QGIS application to verify the plausibility of mobile phone movements. Figure 2 shows a snapshot of the result. All the mobile (M1-M9) data is plotted (blue line) on top of OpenStreetMap and Digiroad map layers. The Subscription areas A and B as well as the Impact area, which are introduced in the following chapter, are also presented. Figure 3 shows the closer look at the data on the map, movements of the different mobiles can be seen clearly.

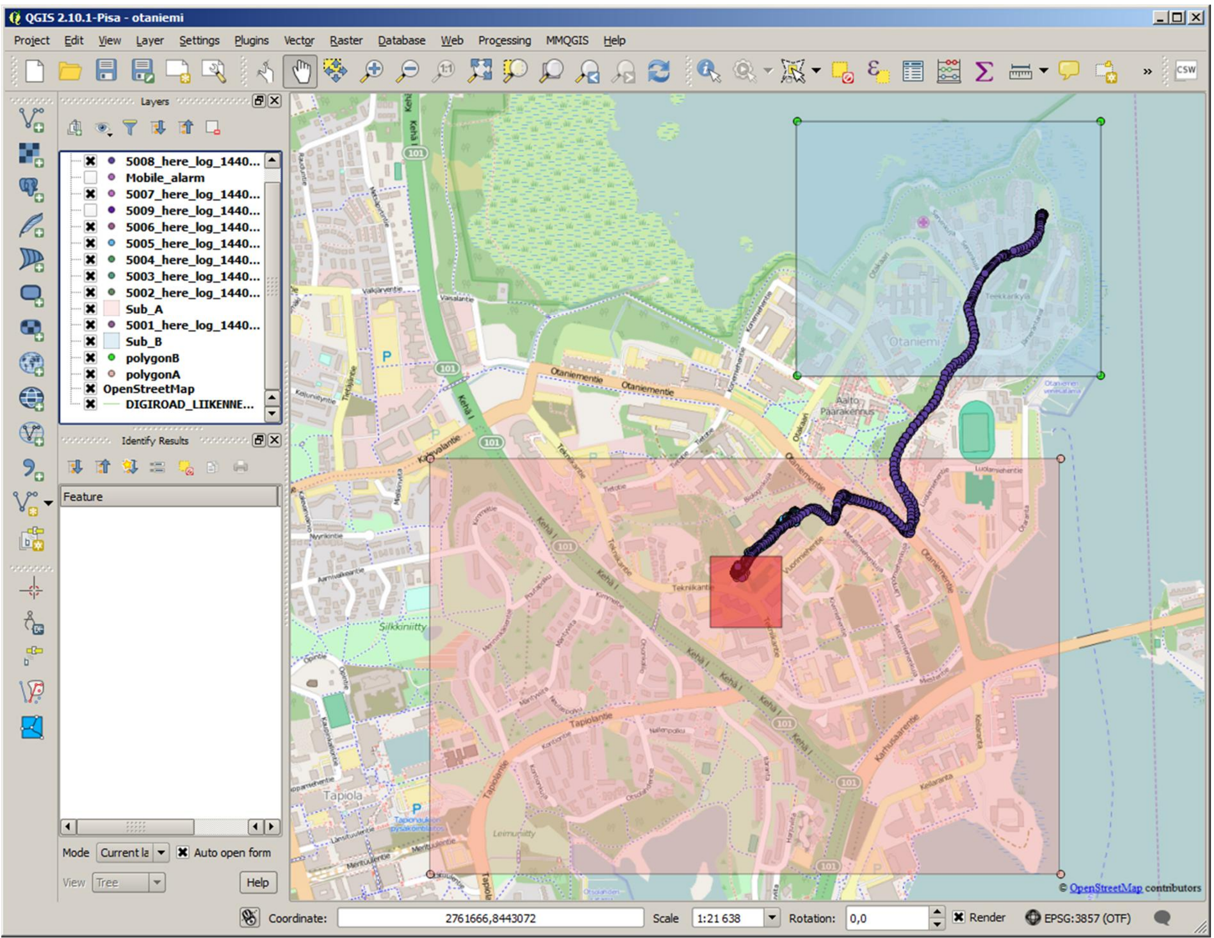


Figure 2 Mobile data on QGIS

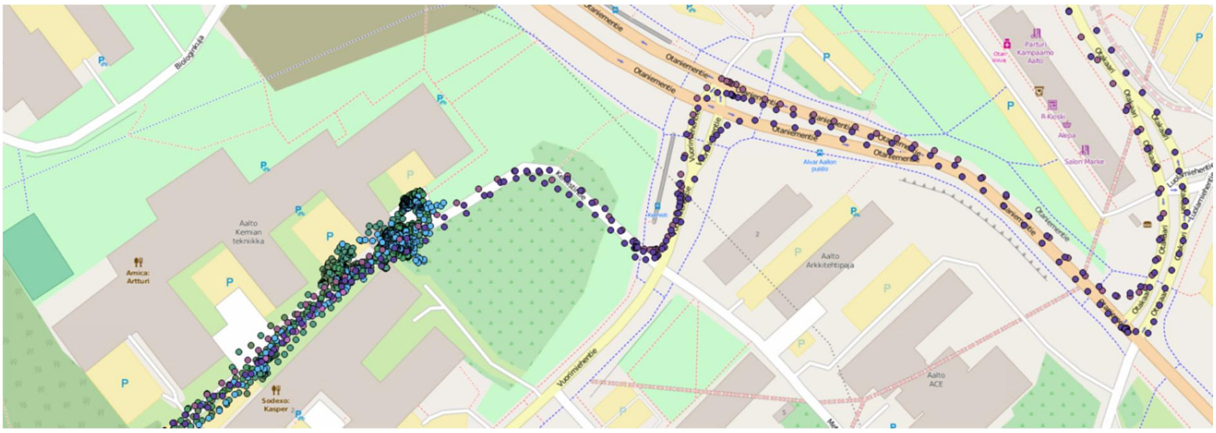


Figure 3 Closer look at the mobile data

In second phase, VTT imported all logs to databases using Java and PHP software. From the logs, a summary table was generated with several SQL scripts, consisting of indicator data for all tested scenarios. These summaries included e.g. the number of communicated messages in each test scenario and key timestamps for providing an overall view of the information flow.

3. Scenario tests

The Proof of Concept tests comprised in total of 10 scenarios, divided in three different categories:

- TMC-initiated information messages (scenarios 2A, 2B, 2D, 2C, 2E, 2F)
- Mobile-initiated information messages (3B, 3C, 3E)
- TMC-initiated dynamic scenario (4).

The following chapters summarise the findings for each scenario as well as give a brief introduction of each.

Regarding the common setup, the mobile phones were located during the scenarios either in subscription area A or B (Figure 6). Two subscription areas had been set up to test information broadcasting to correct mobile phones depending on the area they were in. If information was regarded to affect only users in subscription area A, users in subscription area B should receive no messages. Based on the received information, either an informative icon was shown on a map (Figure 4), or, if the user was at impact area or entering the impact area, a warning was given (Figure 5).

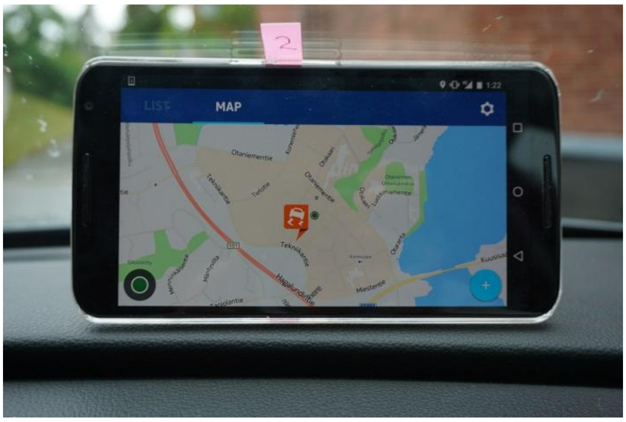


Figure 4 Informative icon was shown on a map

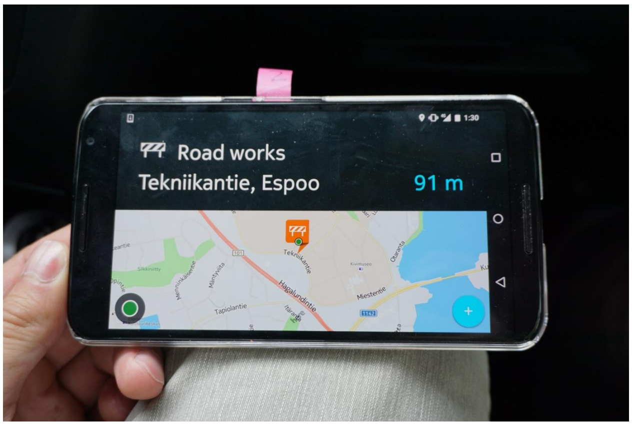


Figure 5. Warning at M2 when entering the Impact area

For each scenario, a figure is included, presenting

- the initial location of mobile phones at subscription areas
- impact area with red square
- the main location of the event with a red star.

3.1 Scenario 2A: TMC-initiated Temporary Slippery Road

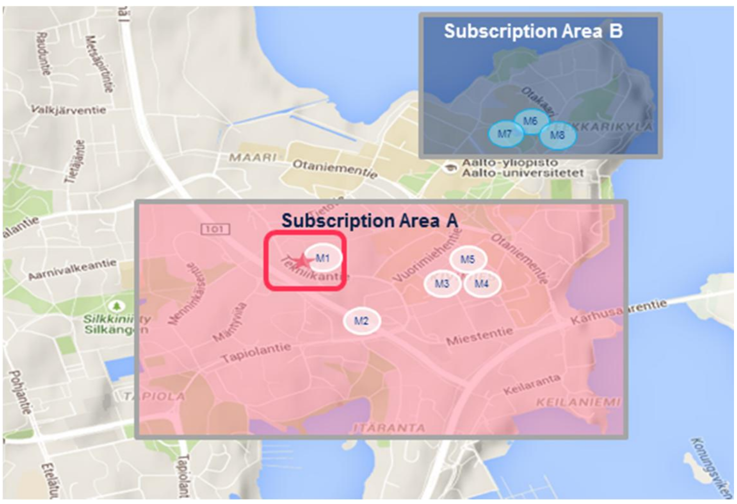


Figure 6. Mobile phone locations, subscription areas and impact area in scenario 2A.

In this scenario, a DENM message with cause code[2] indicating adverse weather condition due to low adhesion was sent to mobile phones in subscription area A. However, the message was sent and received by six phones, where it should have been sent only to five. From the logs we can see, that **the subscription area of mobile phone 7 (M7) was incorrectly configured**. It received messages from area A (only), although being located at area B. The subscription areas were manually set up in this test to suit near-by areas where the tests were carried out. Since this was a mere configuration error, **this configuration error will be disregarded in the following calculations and all scenarios**.

Mobile phone M1 was correctly the only phone to alert the driver. It did so at distance of 41 meters to the event.

DENM cause code	adverseWeatherCondition-Adhesion (6)
Number of mobile phones that showed a warning / scenario target	1/1
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

The DENM message was sent to users between timestamps 13:18:39.548–13:18:39.554. The original TMC message (Infotripla DATEX) was timestamped 13:18:37.783. The message was set to expire after 300 seconds. The logs do not include an explicit time for the end of the warning, therefore the analysis is based here on Infotripla's time of sending.

Timestamps show, that internal processing and Internet transmission times, before the message was sent on air, took in total 1.765 seconds. This delay is due to multiple servers, some on different continent, processing and transferring data.

Generally, delays of more than one second could play a role in effects of a driver warning system. However, considering the types of messages transferred in NordicWay pilot, delays can be considered acceptable. The EIP quality criteria for the implementation of similar warning systems give goals in the range of 2 minutes of more.

The EIP's total time includes e.g. a user or other information source reporting a hazardous situation, validation and broadcasting of the message. Only if the situation is detected automatically (e.g. vehicle sensors detect a crash), it could be broadcasted to other road users in a sub-second timeframe. Establishing a valid warning from messages sent manually by a few drivers will take much longer, getting closer to the EIP criteria. If we consider that it would take five seconds for a driver to send a warning, two more seconds for others to receive the information seems reasonable. From this perspective, experienced delays in the prototype system require no further streamlining of information handling.

Digging deep into the timestamps, the expiry of messages from the screens of mobile phones raises some questions. Where the message should have expired on 13:23:37.783, the first phone expired it already at 15:23:35.575 (more than 2 seconds earlier, according to its internal clock), having received it at 15:18:38.784. The last mobile to clock the expiry of the message, timestamped it 15:23:36.536 having received it at 15:18:40.805. Actually, the messages were aired practically simultaneously around 39.5. The time differences are mainly due to different mobile phones not being exactly in correct (server) time. Methods such as NTP (Network Time Protocol) had not been easy to implement on Android phones

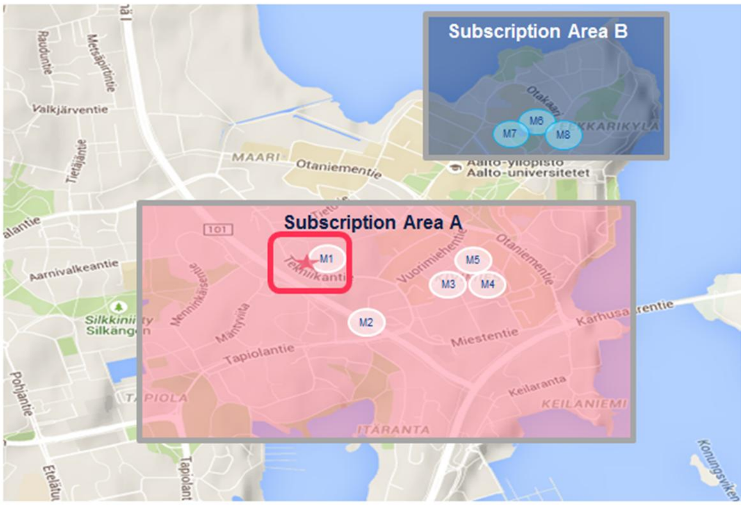
[2] Information within DENM message about the type of the information

and improving the time synchronization is a topic for future development. The average time synchronization error for M1 is discussed in Chapter 4.

Based on the logs, the time of expiry seems to be tied to phone's clock more than to e.g. the time of reception. However, the different phones expire the message with a range of nearly a second to each other and the first over two seconds before it should have been due. Although this has no large implications on the user, considering the type of warning message, **the expiry of messages is something that we recommend to double-check**.

As conclusion, despite of the unintended configuration error of M7 and mobile phone times not being fully synched with server time, this scenario worked fine.

3.2 Scenario 2B: TMC-initiated obstacle on roadway



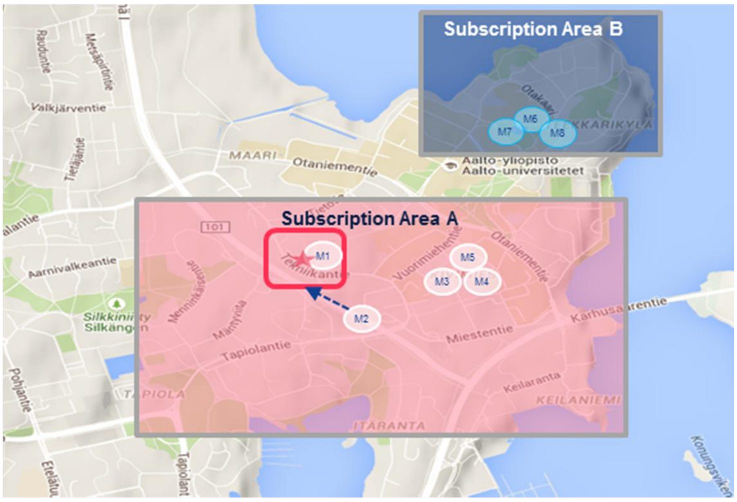
The set-up of this scenario is similar to the previous. In this case, the time difference from Infotripla's DATEX to HERE sending a DENM to mobile phones was 1.368 s, showing small but still some variance in internal processing time of the network servers. The averages of processing and transmission times will be summarized later in Chapter 4.

Expiry timestamps for phones removing the information from screen are a bit closer to each other than in the previous scenario, 44.0–44.7. However, DATEX timestamp would suggest expiry at 45.8. Being rather a detail than a large error, this analysis is not repeated for the following scenarios.

There were no false warnings. One phone correctly gave a warning. This result of this test was clearly a PASS.

DENM cause code	hazardousLocation-ObstacleOnTheRoad (10)
Number of mobile phones that showed a warning / scenario target	1/1
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

3.3 Scenario 2D: TMC-initiated short-term roadworks

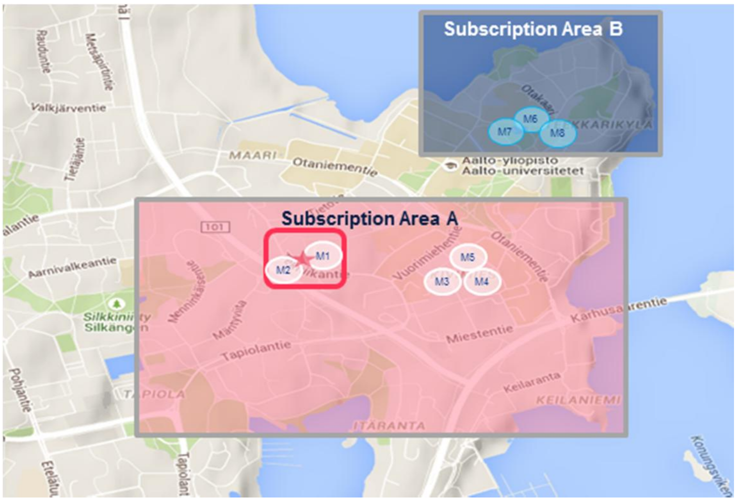


In this scenario, M1 should give a warning instantly, whereas M2 only after moving to impact area. Both mobile phones displayed the warning correctly. The warning for M2 came at 99 meters, when impact area was 200 meters (200m x 200m). The warning in M2 was dismissed manually while M1's warning was automatically dismissed (along with expiry of the warning).

Generally, logs show consistent behaviour according to the scenario plan and the test was successful. The behaviour highlighted in previous scenarios, e.g. M7 configuration error and time differences between mobile phones apply also to this scenario.

DENM cause code	roadworks (3)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

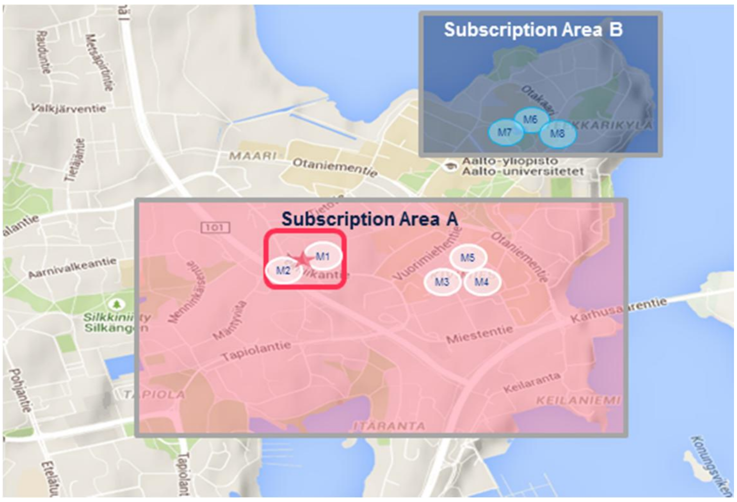
3.4 Scenario 2C: TMC-initiated unprotected accident



Both M1 and M2 gave a warning like they were supposed to. No false warnings or errors, no new issues.

DENM cause code	accident (2)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

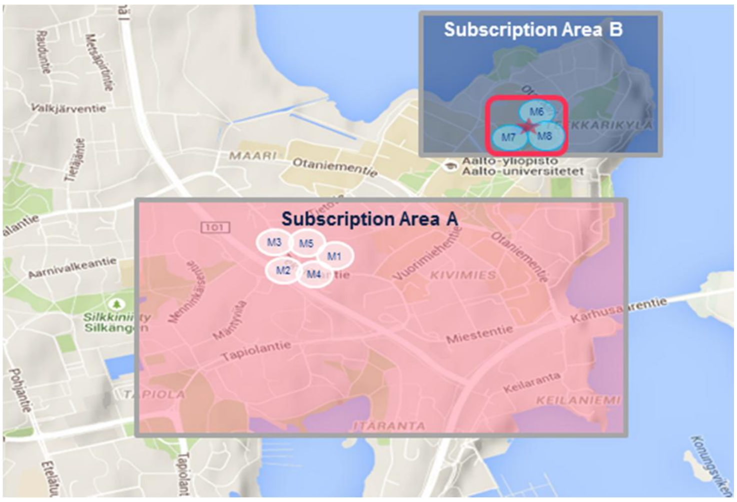
3.5 Scenario 2E: TMC-initiated reduced visibility



The execution went according to the planned scenario: only M1 and M2 warned about adverse weather condition. Other phones were located over 200 meters away. Logs show consistent performance, confirming the experiences of visual observers during the test day.

DENM cause code	adverseWeatherCondition-Visibility (18)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

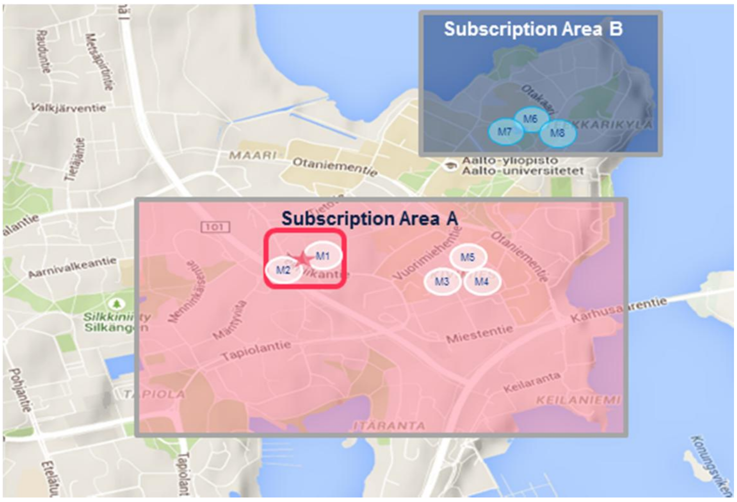
3.6 Scenario 2F: TMC-initiated exceptional weather conditions



This scenario reversed the previous tests and information & warnings were given to subscription area B users. M6 and M8 showed activity, largest distance to the event being 31 meters. M7 remained incorrectly configured to subscription area A, therefore not showing messages. Otherwise, the tested systems performed well.

DENM cause code	adverseWeatherCondition-ExtremeWeatherCondition (17)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	2/2 (M7 being configured incorrectly)
Result (pass/fail)	PASS

3.7 Scenario 3B: Mobile-initiated obstacle on roadway



Scenario 3B was the first that was initiated by a mobile phone user, initiating a warning with a few taps on the screen. Consequently, a new indicator regarding “turnaround time” could be calculated, consisting of the full time between the moment of user finalizing and sending the message up to the moment when the same user receives an acknowledge from the background systems and an icon is drawn on their map. In this scenario, this turnaround time (short loop) was 1.42 seconds. The turnaround time consists of 0.75 seconds of processing at HERE servers, the remaining time being 3G transfer times, message parsing and user interface activity.

This scenario also demonstrated confirmation of a user’s message by Infotripla and allowed testing the details and delays of the long loop of data flow: User–HERE–Infotripla–HERE–User. The confirmation came to M1 after 3.76 seconds.

In the current implementation, the users received two separate messages (Figure 7): first the message sent by a user (short loop), then a separate message from Infotripla, confirming the observation (long loop). Showing both messages on screen does not represent the final plan but is a matter for further development. The plan is to modify the information quality bit of the initial message, confirming the observation and possibly raising its priority. Unconfirmed observations might be handled differently in the final HMI than those observations that are considered to be more reliable.

As a minor detail, Infotripla currently rounds up the GPS coordinates of the original message (probably uses a different type of variable than HERE does) and that should be harmonised for April tests. On the HMI the messages also have different timestamps. However, both messages correctly expire at the same time.

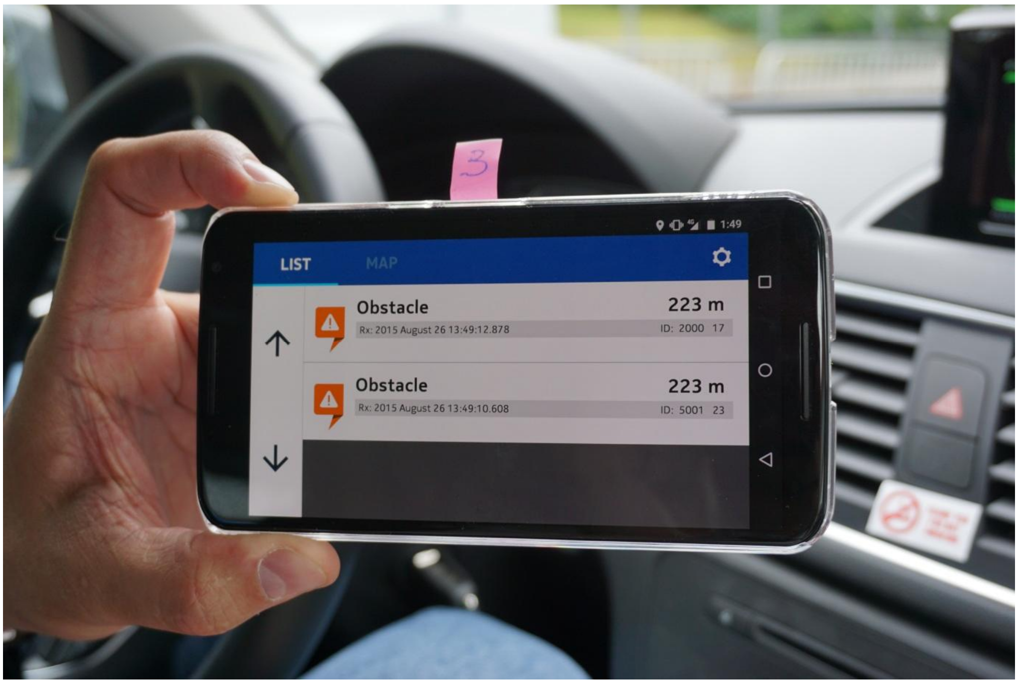
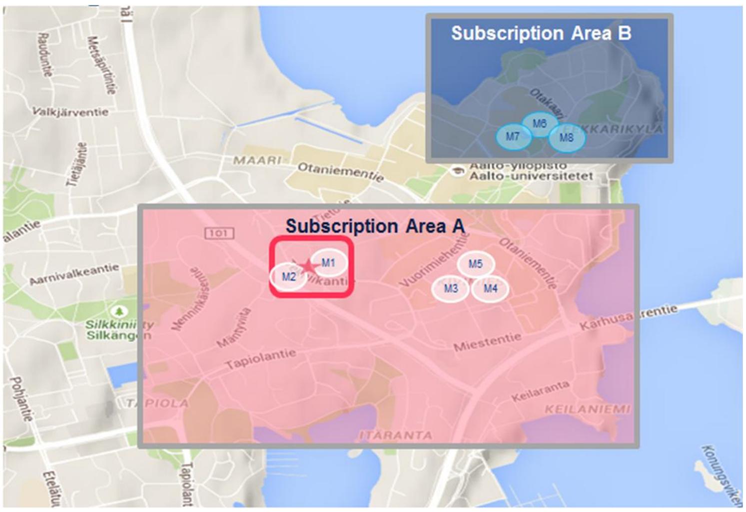


Figure 7. Acknowledge from short (HERE) and long loop (Infotripla) to a mobile phone initiated warning, therefore user sees two messages.

DENM cause code	hazardousLocation-ObstacleOnTheRoad (10)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

3.8 Scenario 3C: Mobile-initiated unprotected accident



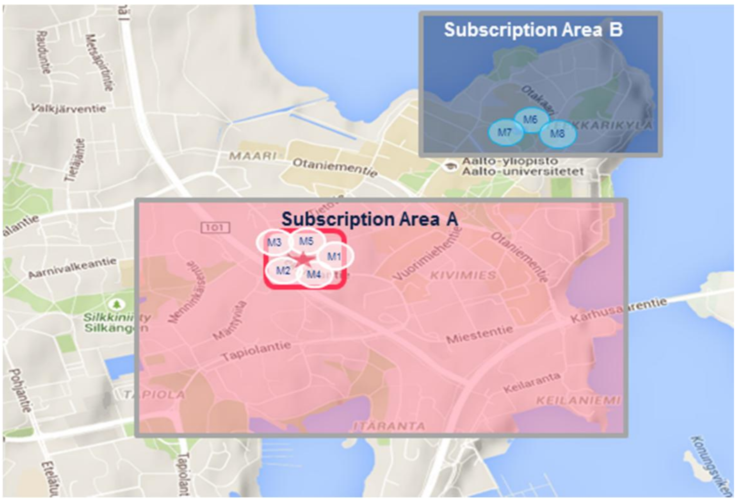
In this scenario, M1 and M2 correctly received the warning and the others did not, as planned.

Interestingly, since the expiry time of the message was long, 10 minutes, more cars got the warning when already moving to positions of the following scenario (3E). M3, M4 and M5 received warnings when entering the impact area at distances of 131–137 meters. Technically this was, however, correct operation and the test was considered successful.

Short loop time was 1.1 s and long loop confirmation came after 3.13 seconds.

DENM cause code	accident (2)
Number of mobile phones that showed a warning / scenario target	2/2
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

3.9 Scenario 3E: Mobile-initiated reduced visibility



In the last mobile-initiated scenario, M1–M5 were all to display a warning. The test went fine, but the following details are noted about logging implementation:

Intotripla logs show duplicate records for sent DATEX messages (repetition after 9 minutes). For final logging implementation, we suggest to indicate when messages are merely being repeated – or clean them away from logs. Repetitive logging may easily disturb analysis as well, since they have different timestamps.

M7 logs did not include dismissing the alert for some reason. It could be possible that this is due to manual cut of the logs of that day, being the last activity? In the large-scale tests, preferably all logs showing a start of a warning will include the end timestamp as well.

DENM cause code	adverseWeatherCondition-Visibility (18)
Number of mobile phones that showed a warning / scenario target	5/5, considering the M7 configuration error
Number of mobiles that received a message / scenario target	5/5
Result (pass/fail)	PASS

3.10 Scenario 4: TMC-initiated dynamic scenario

VTT run additional repetitive tests and video collection to analyse the user interface and dynamics of the system. Mobile phones M2 and M5 were inside a moving car and a TMC simulator originated a short-term roadworks message. The roadwork was set at coordinates 60.1817, 24.8234. The scenario consisted of five runs that were also recorded on video. As a sanity check, the Figure 8 shows the trails of the M2, M5 and the red impact area.

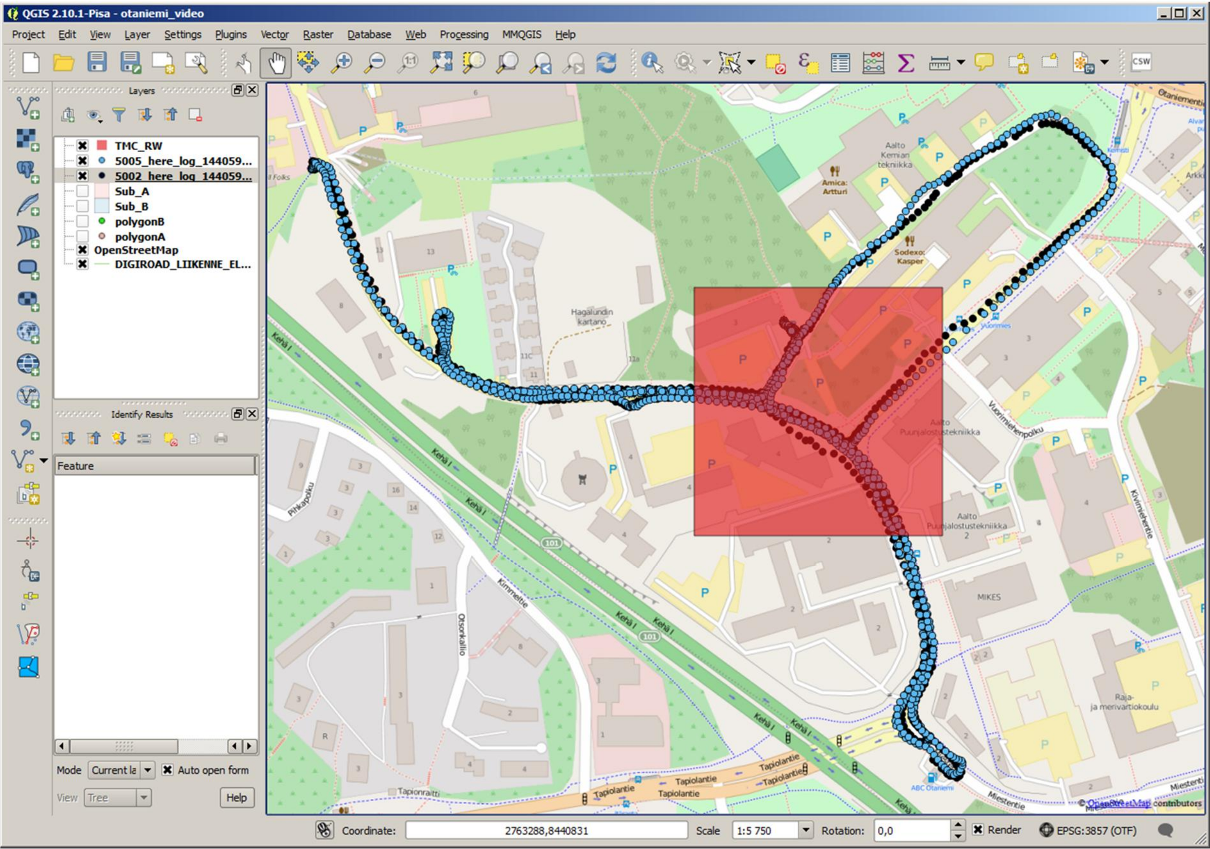


Figure 8. TMC-initiated dynamic scenario, M2 and M5 inside a moving car

The system for video recording was the Video VBOX Lite by Racelogic, an in-car video system with the following features: accurate GPS logging at 10 Hz, 2 video camera inputs, SD card logging, rugged enclosure and customisable UI graphics.

Figure 9. Video VBOX Lite

Five video shots were recorded using the same procedure. One camera of the VBOX was recording the front view from the car and the second camera was recording the mobile user interface. GPS time, coordinates, speed and acceleration were inlayed on the video.

The VBOX had an old firmware and therefore the GPS time was not the same as the NTP time (~15 s off). Snapshots of these videos were compared to the QGIS application at the moments of show/dismiss icon.

Figure 10. VBOX video with inlaid timestamp, coordinates, speed, acceleration and M5 user interface

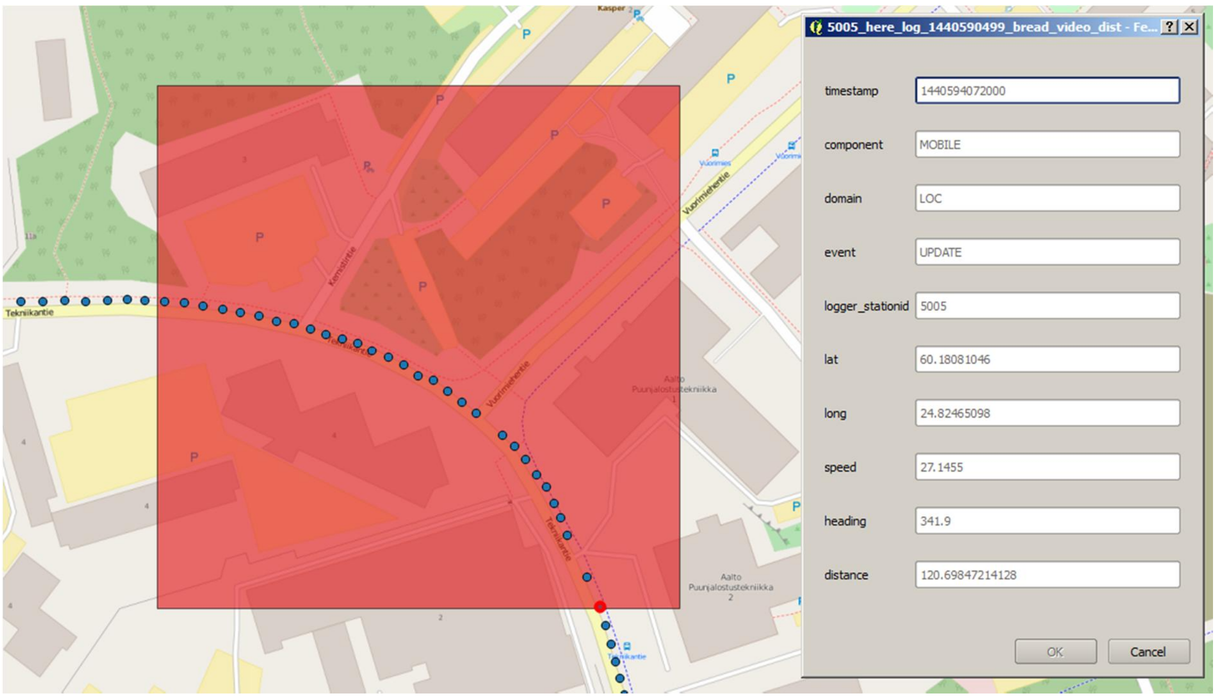


Figure 11. QGIS: red dot shows the same position with heading and speed as the video

The following table lists the distances logged versus distances from the recorded video. The distances displayed on the mobile UI match pretty well to the logged values. The Appendix A presents all the recorded video snapshots versus QGIS application.

Video snapshot	timestamp	Impact area UI distance (m)	Impact area log distance (m)
Video shot 1 – show icon	1440593944000	96	87
Video shot 1 – dismiss icon	1440593970000	117	124
Video shot 2 – show icon	1440594072000	121	121
Video shot 2 – dismiss icon	1440594105000	99	106
Video shot 3 – show icon	1440594265000	100	100
Video shot 3 – dismiss icon	1440594311000	106	114
Video shot 4 – show icon	1440594401000	101	102
Video shot 4 – dismiss icon	1440594443000	97	103
Video shot 5 – show icon	1440594581000	95	94
Video shot 5 – dismiss icon	1440594609000	111	111

However, there was **a delay when displaying the icon on the mobile user interface**. A slow user interface update behaviour can be seen from the video also. From the log files it can be estimated that **the delay is more than two seconds**, see also Appendix A where the excerpts of the log files are presented and timestamps highlighted. At higher speeds, this causes problems, when analysing the driver's behaviour during the impact assessment phase. Figure 12 depicts the situation when entering an impact area. **We recommend checking that the logs would contain accurately the actual moment when a user is being warned.**

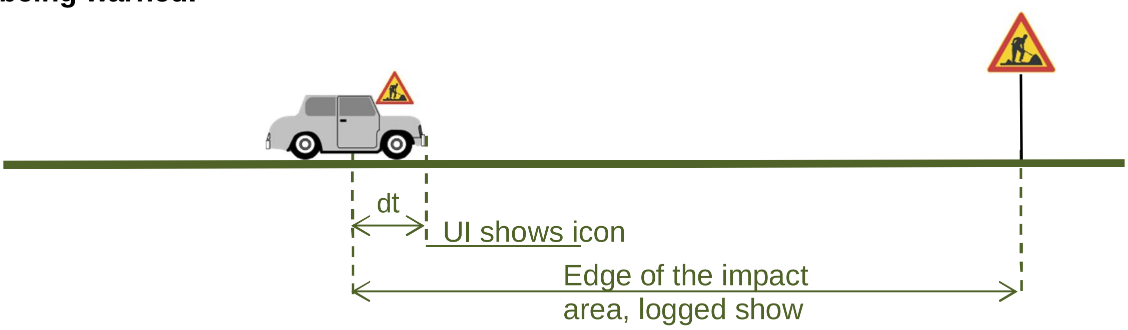


Figure 12. "Show icon" timings

Regarding the UI operation otherwise, the dynamics seemed fine, HERE e.g. demonstrated fluent switch between two warnings on a map. Also the logged heading and speed values were correct.

Test users concluded that sending messages with the system was easy and fast, after first attempt.

4. Timings

This chapter summarises the delays in the information processing and transmission. It also addresses time synchronisation of mobile phones.

Regarding the turnaround time, i.e. mobile phone receiving an acknowledgement from HERE servers (short loop), including various message processing steps, the average in tests was 1.28 s, ranging between 1.10–1.42 s. Of this turnaround time, in average 0.7 s (0.65–0.75 s) consists of internal processing by HERE. The remaining 0.58 seconds contains message parsing and UI activities in the mobile handset, along with mobile phone network transmission delays. Considering the other delays at play, differences between e.g. 3G and 4G network transmission times would not play a large role.

Receiving a confirmation from the long loop, via Infotripla, averaged at 3.64 (3.1–4.0) seconds.

HERE internal operations from receiving a DATEX message from Infotripla to sending a DENM to mobile phones took in average 1.43 s. Infotripla's internal processing time was in average 0.98 s (between FCD receive and DATEX send).

Infotripla–HERE transmission time was as small as 0.07 s, which was expected for Internet transmissions.

Figure 13. depicts the idea of the short and long loops and Figure 14 figure shows a worked out full timeline from scenario 3B to illustrate the magnitude of different delays in the process.

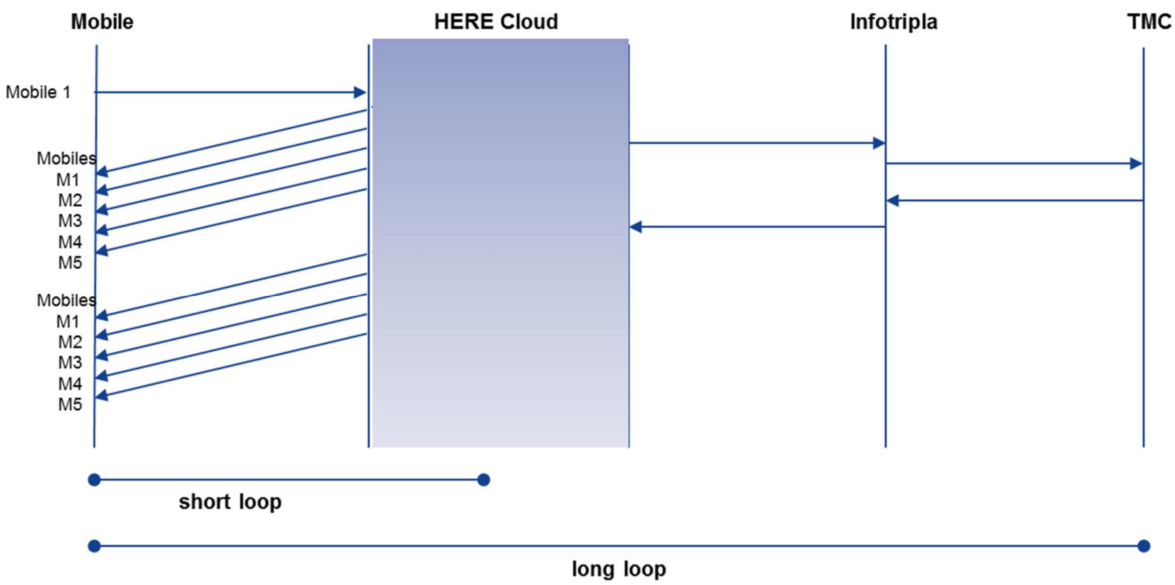


Figure 13 Short loop and long loop sequences

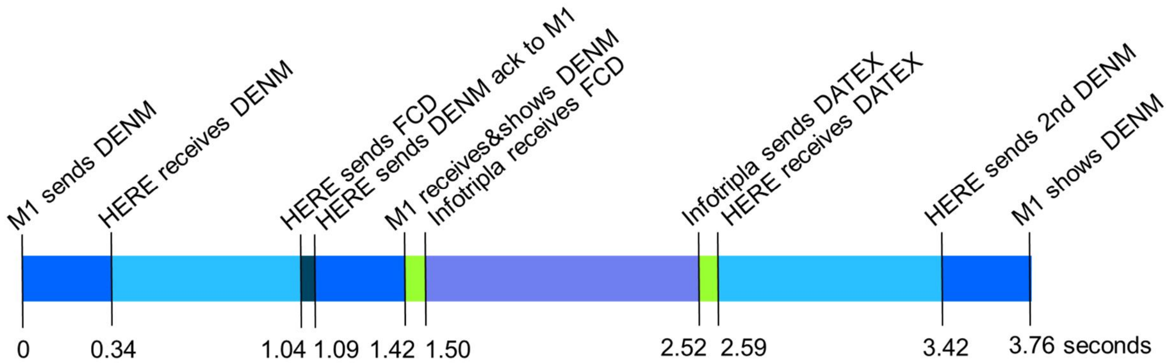


Figure 14. Timeline for scenario 3B.

Average clock error in mobile-initiated scenarios for M1: Assuming an average latency of 0.29 s from the moment of DENM send to displaying and logging a warning on the mobile phone, measurements for M1 phone show that it had a clock error of ~1.17 s compared to server timing. Due to short duration of tests, this difference remained reasonably stable throughout demonstrations.

5. Issues and recommendations

Time synchronization of mobile phones

In the tests, the mobile phones had time synchronization errors of around ±1 second to correct network time. When the errors remain in this range, they have only small effects on system performance, considering that the messages are targeted for drivers. However, generally mobile phone OS time synchronisation, without additional software, could be off even by ±20 seconds.

When a user sends a message, it's recommended to timestamp it with GPS time (error around 0.5 seconds in normal applications). Also, when receiving a message, its timestamps should be first compared to phone's GPS time. Comparison to GPS should keep the differences below one second.

Network Time Protocol (NTP), hardware-level GPS and other technologies that can keep the mobile phone time accurate to milliseconds are not necessarily required, considering the message types that are transferred in this project.

ActionID definition in DENM messages

As a minor note, ActionID in messages had not been used according to the DENM standard:

```
ActionID ::= SEQUENCE {
    originatingStationID StationID,
    sequenceNumber SequenceNumber
}
SequenceNumber ::= INTEGER (0..65535)
```

Expiry times of DENM messages in mobile phones

The expiry timestamps of DENM messages seemed to vary more than expected, about a second. Although it has practically no effect on users, we recommend checking the expiry method for possible implementation bugs. See details from Scenario 2A analysis.

relevanceTrafficDirection definition in DENM messages

As another minor note, the DENM standard defines an optional parameter relevanceTrafficDirection. That could be useful logged value for the impact assessment.

```
ManagementContainer ::= SEQUENCE {
actionID ActionID,
detectionTime TimestampIts,
referenceTime TimestampIts,
termination Termination OPTIONAL,
eventPosition ReferencePosition,
relevanceDistance RelevanceDistance OPTIONAL,
relevanceTrafficDirection RelevanceTrafficDirection OPTIONAL,
validityDuration ValidityDuration DEFAULT defaultValidity,
transmissionInterval TransmissionInterval OPTIONAL,
stationType StationType,
}
```

User interface log timing

Based on video recordings, there is a 2-second time difference between the moment when a log line is timestamped and when a warning is actually shown to the driver. This difference should be made minimal for not affecting the impact assessment.

GPS quality not logged

Generally when assessing situations where e.g. a user has received a false warning, the quality of GPS coordinates plays a big role. When a GPS fix is based on three satellites only, errors in position grow easily to 50 meters or more. With four or more satellites, GPS generally achieves a good accuracy, although large errors can still happen e.g. due to nearby high buildings at urban canyons. For impact assessment, we request logging the number of satellites as a rough indication of quality. Example with Java:

```
GPS quality logging locationManager = (LocationManager)
getSystemService(Context.LOCATION_SERVICE);
      locationManager.getGpsStatus(null).getSatellites();
```

Data log cleaning

Mobile phones log multiple empty DENM messages, with zero coordinates, even though there are no such messages sent by servers. Cleaning these fake log lines is required.

1440594611556 MOBILE DENM RECEIVED 5005 0 0 0 2 0 600 0 0

Infotripla's logging of "repeated" DATEX messages is to be cleaned as well. The parts of logging that save sender ID as "TEST" instead of a numeric value "2000", should be harmonized to use a number.

GPS coordinate rounding

Infotripla currently rounds up the GPS coordinates of the original message.

6. Further development targeting large-scale user tests

Controlled testing of prototype systems is generally rather different to running large-scale user tests. Topics such as high battery consumption and crashing software become different level of issues in user tests. Considering traffic information systems running in mobile phones, past field operational tests show that in the case that users need to start an application every time they start driving, a large percentage of them will eventually drop out of the study, stop using the SW. Since long-time usage has not yet been thoroughly addressed in the prototype system, we recommend a couple of development meetings to be held for reviewing the most viable options regarding

- Balancing battery consumption during large scale tests: The application should be operational at the test area and collect detailed log data when driving on E18 road. Otherwise it should stress the mobile phone's resources as little as possible. For example an automated startup using vehicle Bluetooth or running the SW "in background", but being able to wake it up in case of a warning and similar topics are to be discussed.

- HMI design for driver warnings: Audio warnings usually result in high short-term safety impacts but tend to disturb drivers in a long run, leading them to stop using the system. The HMI implementation should resemble a likely product implementation. In addition, showing confirmed vs unconfirmed warnings from other road users could be clarified. Details such as how the warnings work when a driver is e.g. sitting in a queue for a long time – or turns his system on while the warning has already been issued – can figure a technical discussion as well.

- Data collection during large-scale user tests: Considerations on using reference data (e.g. loop data for average speeds) and extra sensors such as radar or video to support a more detailed assessment of system's impacts. Extra sensors are not likely to be used with large user groups, but possibly a few vehicles could have higher instrumentation to support the main tests. Reference data can be needed for estimating e.g. how many incidents were detected by the tested system, establishing a ground truth. Further, a reference group is needed for comparing driver behaviour with and without the system. Automating log data collection from mobile phones as well as tacking which users still participate in tests are common field operational test procedures.

- Openness of collected data and formulation of data sharing agreements. Participants should preferably sign a consent form, widely releasing collected data for scientific research (according to FOT-Net Data Sharing Framework, www.fot-net.eu). The data collected by NordicWay will form a valuable resource for further research work, if just preparations are made in project agreements.

Since numerous development steps have been planned before large-scale user trials are to begin, VTT recommends a further checkpoint before starting large recruitments. A common method is to have a small group of users testing the system during the months up to the large trials, providing valuable feedback for final fixes and ensuring that the user experience is up to par.

7. Results

This table presents a summary of the scenario tests that were made, considering the recommendations that have been collected to Chapter 5.

SCENARIO	VALIDATION
• 2A: TMC-initiated temporary slippery road	PASS
• 2B: TMC-initiated obstacle on roadway	PASS
• 2D: TMC-initiated short-term roadworks	PASS
• 2E: TMC-initiated unprotected accident	PASS
• 2F: TMC-initiated exceptional weather conditions	PASS
• 3B: Mobile-initiated obstacle on roadway	PASS
• 3C: Mobile-initiated unprotected accident	PASS
• 3E: Mobile-initiated reduced visibility	PASS
• 4: TMC-initiated dynamic scenario	PASS

A proof of concept was to meet the following requirements set by the NordicWay consortium:

ITEM	VALIDATION
• Delivery of traffic-related safety messages in accordance to ITS Directive via 3G/4G LTE network	PASS
• Multi-cell and multi-operator support	NOT TESTED
• Consumer application in a smartphone	PASS
• End-to-end from road (mobile application / user input) to TMC	PASS
• Map based user interface for TMC staff (provided by Infotripla)	PASS
• Mobile application allowing for entry and display of traffic-related safety events on a map	PASS
• Displayed alerts for drivers that are in the area of impact region of an event	PASS
• Delivery of mobile-sourced traffic safety events to TMC	PASS
• Delivery of TMC sourced traffic safety events to mobile applications	PASS

• 6 traffic safety event message types to be supported:	
o Animal, people, obstacles, debris on the road (user display / user entry)	PASS / PASS
o Temporary slippery road (user display / -)	PASS
o Unprotected accident area (user display / user entry)	PASS / PASS
o Short-term road works (user display / -)	PASS
o Reduced visibility (user display / user entry)	PASS / PASS
o Exceptional weather conditions (user display / -)	PASS
• Logging of traffic safety event messages at the mobile (with timestamp and GPS location) and time-aligned logs within the cloud for post-test analysis	PASS
• 10 users in a controlled LTE environment to demonstrate traffic-related safety message delivery and logging capabilities while supporting analysis of system message flow and latencies	TESTED WITH 8 USERS The demonstrations were carried out with 8 phones, providing enough data for technical assessment of the demonstration phase. The system was implemented to operate in any network. The measurements were made in Sonera 4G LTE network. In the future, LTE and e.g. use of base station servers (Liquid technology) may allow for more features and slightly lower latencies.
• GPS heading, degrees clockwise from North	PASS
• GPS speed, Km/h	PASS
• GPS latitude, -90º - +90º	PASS
• GPS longitude, -180º - +180º	PASS

Finally, comparing the performance of the system against EIP criteria (Table 1), we note that:

- Timeliness of the start/update/end of an event cannot yet be validated, as they require measurements from operational systems. The demonstrated system has the technical potential to reach EIP targets, e.g. detection of an event in less than five minutes.
- The latencies observed in the proof of concept, similarly, would not prevent a successful implementation, providing information to users within required three minutes. Information automatically detected or manually entered in the prototype system was broadcasted within a few seconds.
- Since the demonstration is using GPS for positioning, EIP requirements on kilometre-level accuracy for the location of an event raise no problems. Further, cell-based positioning would reach these goals as well. Good positioning accuracy can reduce false warnings for users not affected by an event.
- Requirements for error rate depend on the information that users input. Filtering of possibly erroneous messages were not yet demonstrated in the prototype. These features are being implemented for large-scale pilot and will figure a test setup later.
- Similarly, the capability to cover e.g. 80% of all occurring events can only be addressed in a large-scale demonstration with suitable reference measurement systems in place.

8. Conclusions

Analysis of data logs collected during the demonstration day confirmed that the information system performed consistently, as several invited participants had already witnessed.

Technical assessment raised up a few topics to address especially during further development of the system, before entering large-scale user trials. Mainly these were:

- Further development of dynamic subscription areas and map matching for delivering correct warning messages to users
- Balanced battery consumption for long-time use of the mobile phone app
- Considerations for ensuring good evaluation data collection.

Development meetings on both the data collection and user experience are suggested.

Due to several development plans for the prototype system, VTT suggests a technical checkpoint before entering large-scale user tests. This is to ensure that the system performs well both from the end user and evaluation perspectives. Another suggestion is to use a small group of pilot users to test the system for a while and provide feedback, before the main recruitment phase.

The demonstrated proof of concept has potential for filling the several requirements set by the ITS Directive and EIP for upcoming traffic information services. Large-scale tests will enable further assessment of e.g. operational detection times of a traffic incident.

C-ITS deployment currently faces challenges related to user privacy and business models. Regarding these topics, mobile networks based implementation of C-ITS could have interesting advantages over direct vehicle-to-vehicle communication. The tests carried out in NordicWay are likely to raise interest internationally.

Appendix A

The following contains excerpts from the mobile 5005 log.

Video shot 1 – show icon

1440593941000 MOBILE LOC UPDATE 5005 60.18182693 24.82140069 29.204 91.4 111.44259868913
1440593942000 MOBILE LOC UPDATE 5005 60.18181985 24.82153769 28.8027 92.1 103.82909194208
1440593943000 MOBILE LOC UPDATE 5005 60.18181018 24.82168932 28.9102 92.6 95.376560731212
1440593941886 MOBILE ALERT SHOW 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440593944000 MOBILE LOC UPDATE 5005 60.18179647 24.82184833 28.872 94.3 86.462501704186
1440593945000 MOBILE LOC UPDATE 5005 60.18179012 24.82199748 29.1242 95.1 78.192527424404

Video shot 1 – dismiss icon

1440593968000 MOBILE LOC UPDATE 5005 60.18086863 24.82444221 28.4423 156.1 108.93446613568
1440593969000 MOBILE LOC UPDATE 5005 60.18080377 24.82449996 28.4408 156.1 116.74925017586
1440593970000 MOBILE LOC UPDATE 5005 60.18074005 24.82454441 29.088 159.2 124.0878466628
1440593968942 MOBILE ALERT DISMISS_AUTO 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440593971000 MOBILE LOC UPDATE 5005 60.18067061 24.82460235 29.4482 161.3 132.36883104989

Video shot 2 – show icon

1440594070000 MOBILE LOC UPDATE 5005 60.18068345 24.82472073 24.1207 343.6 134.57284758481
1440594071000 MOBILE LOC UPDATE 5005 60.18074601 24.82468663 25.4168 342.9 127.72541283939
1440594072000 MOBILE LOC UPDATE 5005 60.18081046 24.82465098 27.1455 341.9 120.69847214128
1440594070845 MOBILE ALERT SHOW 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594076000 MOBILE LOC UPDATE 5005 60.18105483 24.82442517 25.0722 335.3 91.431155609111

Video shot 2 – dismiss icon

1440594103000 MOBILE LOC UPDATE 5005 60.1818515 24.82178689 26.755 273.5 90.768502624145
1440594104000 MOBILE LOC UPDATE 5005 60.1818562 24.82164922 27.18 273.4 98.34935894078
1440594105000 MOBILE LOC UPDATE 5005 60.18186025 24.82151327 27.18 273.4 105.83133201748
1440594103799 MOBILE ALERT DISMISS_AUTO 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594106000 MOBILE LOC UPDATE 5005 60.18186104 24.82139863 27.5266 269.7 112.09855416326

Video shot 3 – show icon

1440594263000 MOBILE LOC UPDATE 5005 60.18183566 24.82139217 24.9489 90.2 112.03645825569
1440594264000 MOBILE LOC UPDATE 5005 60.18183137 24.82150732 23.4724 91.4 105.66407359777
1440594265000 MOBILE LOC UPDATE 5005 60.18183015 24.82161845 22.104 92 99.562324973448
1440594263887 MOBILE ALERT SHOW 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594266000 MOBILE LOC UPDATE 5005 60.18182694 24.82172555 21.4561 93 93.652974975134

Video shot 3 – dismiss icon

1440594309000 MOBILE LOC UPDATE 5005 60.1820479 24.82502171 27.2189 47 97.655722541682
1440594310000 MOBILE LOC UPDATE 5005 60.18209352 24.82513467 29.0912 49.7 105.42253375315
1440594311000 MOBILE LOC UPDATE 5005 60.18214463 24.82525643 29.0882 47.3 113.93111568965
1440594309894 MOBILE ALERT DISMISS_AUTO 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594312000 MOBILE LOC UPDATE 5005 60.18219531 24.82535483 29.6283 47.5 121.30862741239

Video shot 4 – show icon

1440594400000 MOBILE LOC UPDATE 5005 60.18262758 24.82364783 8.25351 219.7 104.04843756017
1440594400912 MOBILE ALERT SHOW 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594401000 MOBILE LOC UPDATE 5005 60.18260604 24.82362478 7.67028 212.7 101.51074558836

Video shot 4 – dismiss icon

1440594441000 MOBILE LOC UPDATE 5005 60.18183213 24.82180605 24.2931 272.6 89.348433180394
1440594442000 MOBILE LOC UPDATE 5005 60.18183766 24.82167551 24.9129 272.8 96.57080820464
1440594443000 MOBILE LOC UPDATE 5005 60.18183889 24.821556 25.8121 271.5 103.12089280083
1440594441879 MOBILE ALERT DISMISS_AUTO 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594444000 MOBILE LOC UPDATE 5005 60.18184061 24.82142677 25.812 271.5 110.21781109571

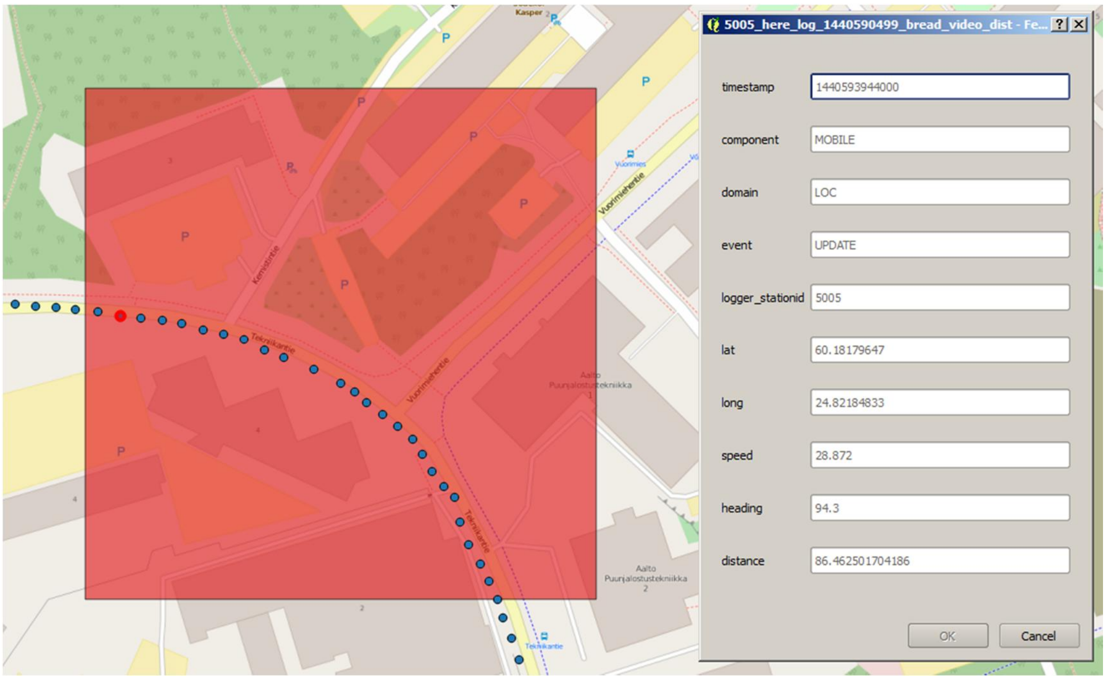
Video shot 5 – show icon

1440594579000 MOBILE LOC UPDATE 5005 60.18179297 24.82148547 19.8005 91.1 106.36124189003
1440594580000 MOBILE LOC UPDATE 5005 60.1817884 24.82158724 21.1732 92.8 100.71147014259
1440594581000 MOBILE LOC UPDATE 5005 60.1817828 24.82170261 22.7885 92.8 94.30215232107
1440594579886 MOBILE ALERT SHOW 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594582000 MOBILE LOC UPDATE 5005 60.18177802 24.82181037 23.5082 94.9 88.32051011062

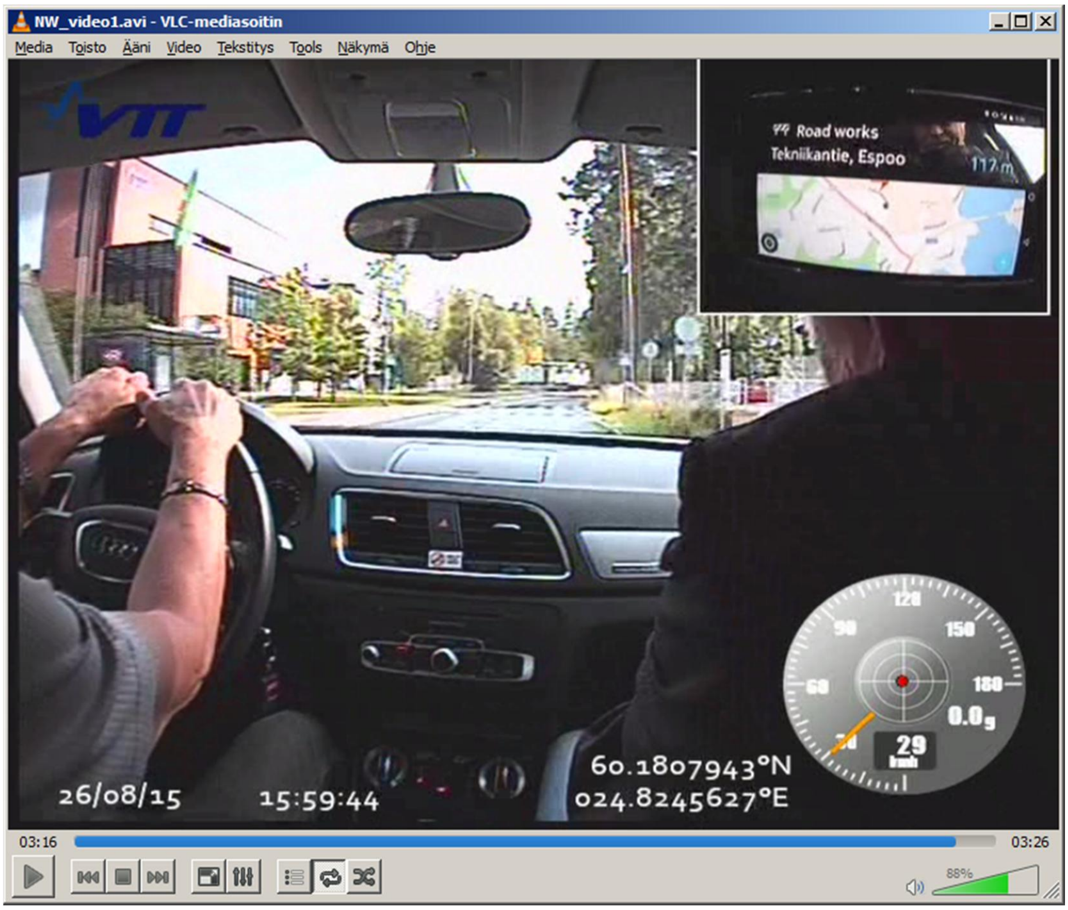
Video shot 5 – dismiss icon

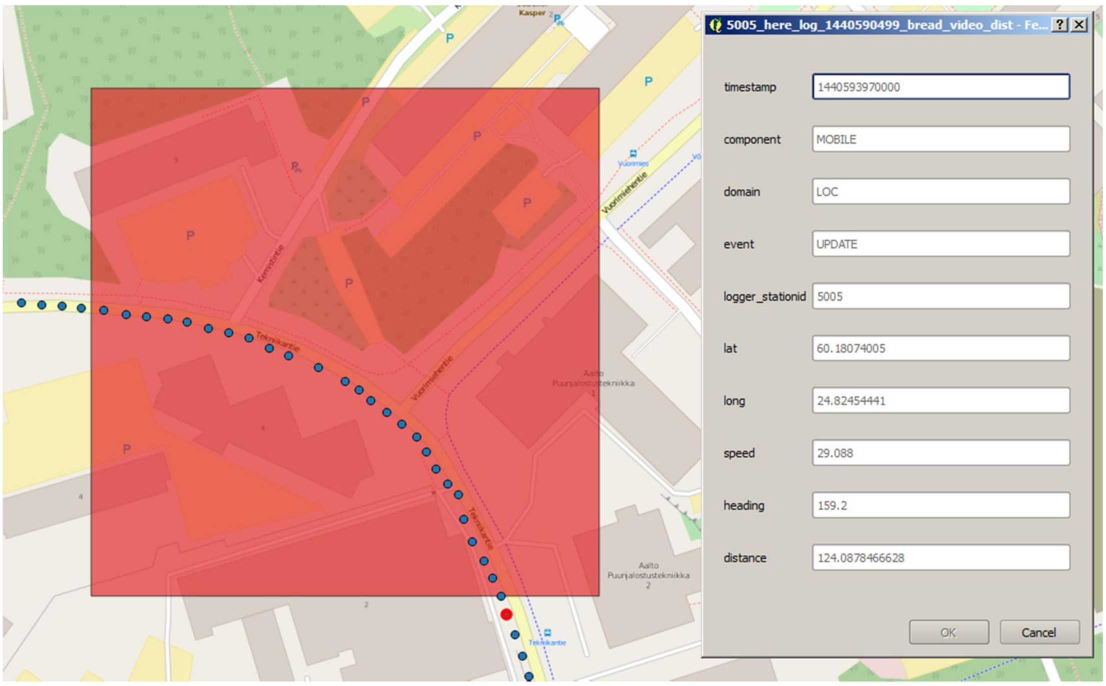
1440594608000 MOBILE LOC UPDATE 5005 60.18089472 24.82441456 28.9497 157.8 105.6640496669
1440594609000 MOBILE LOC UPDATE 5005 60.18085752 24.82447487 26.6879 159 110.94161711205
1440594608930 MOBILE ALERT DISMISS_AUTO 5005 1000 2000 33 3 1 1800 60.1817 24.8234
1440594611000 MOBILE LOC UPDATE 5005 60.18073977 24.82456916 25.7141 161.2 124.81788110022

Video shot 1 – show icon

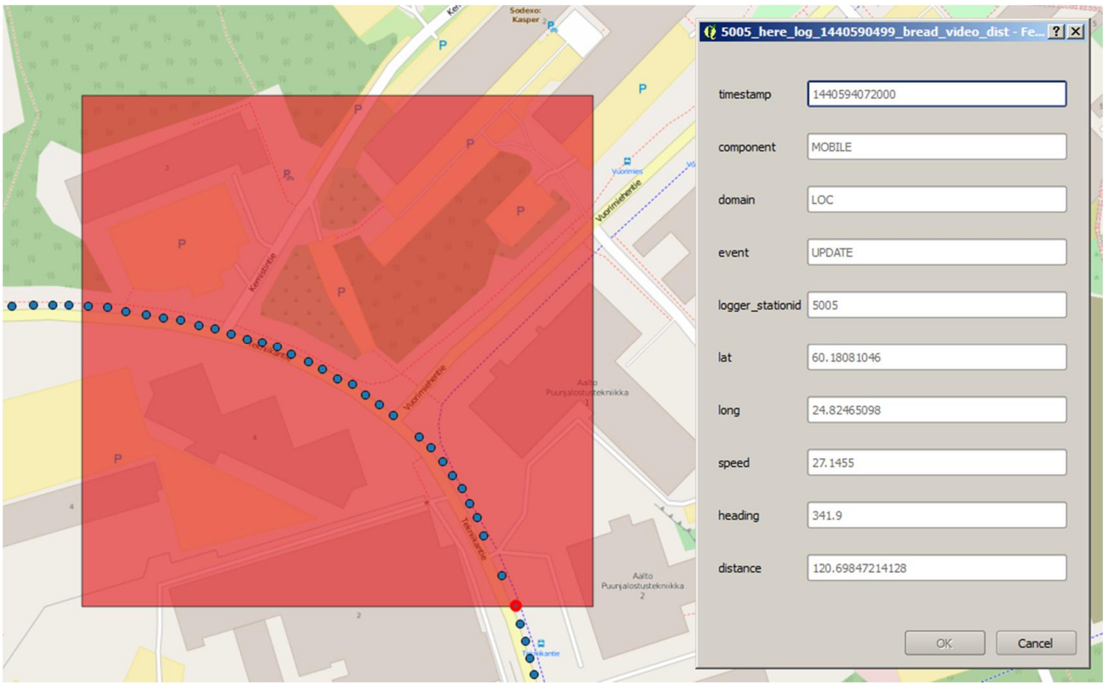


Video shot 1 – dismiss icon

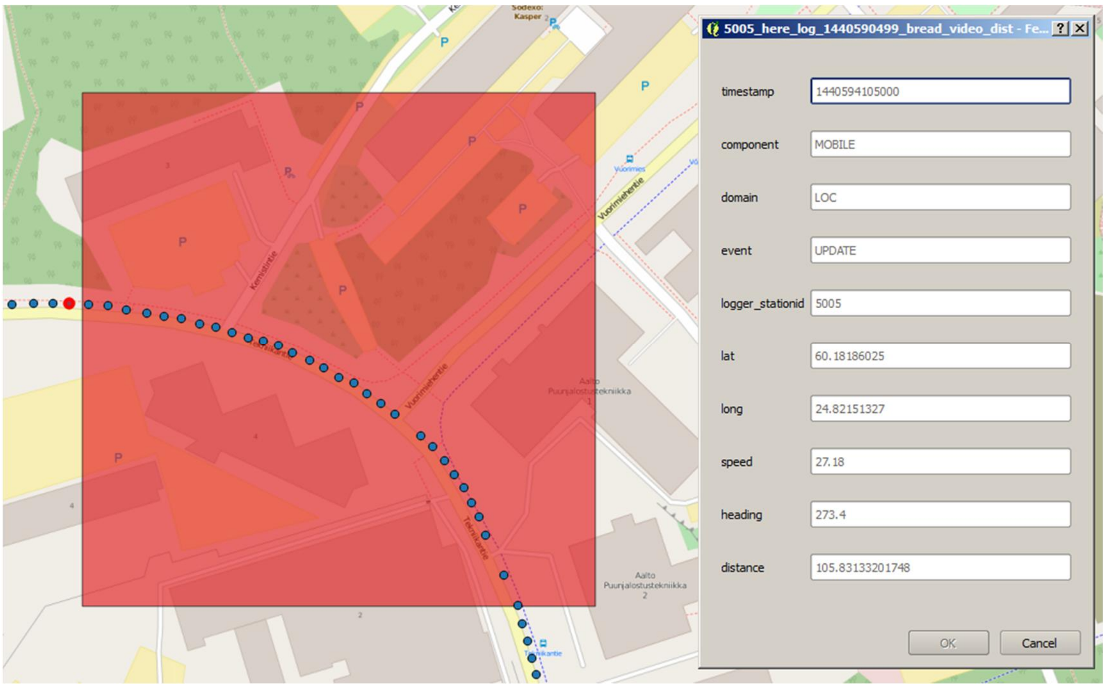




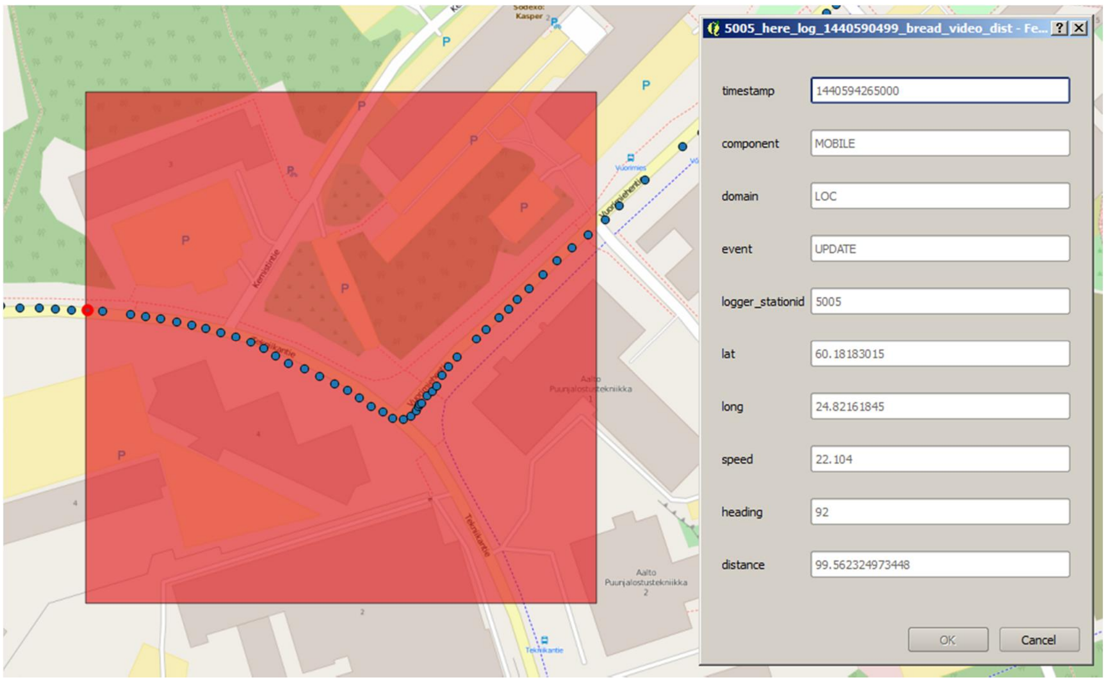
Video shot 2 – show icon



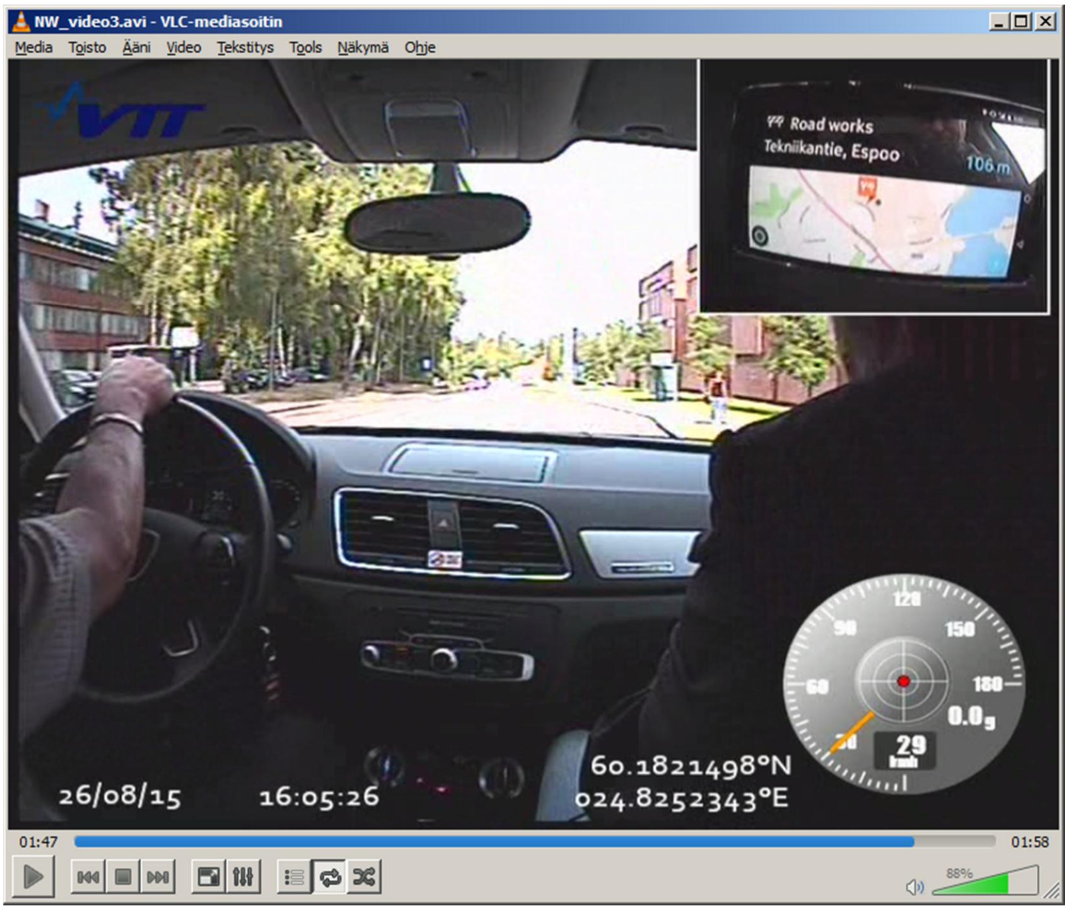
Video shot 2 – dismiss icon

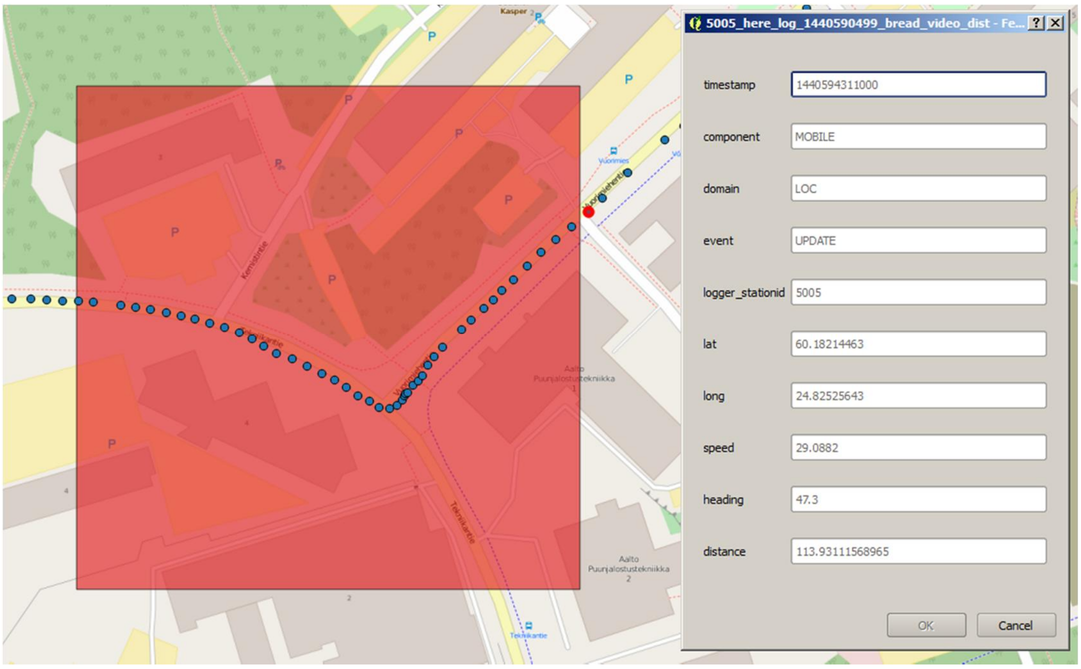


Video shot 3 – show icon

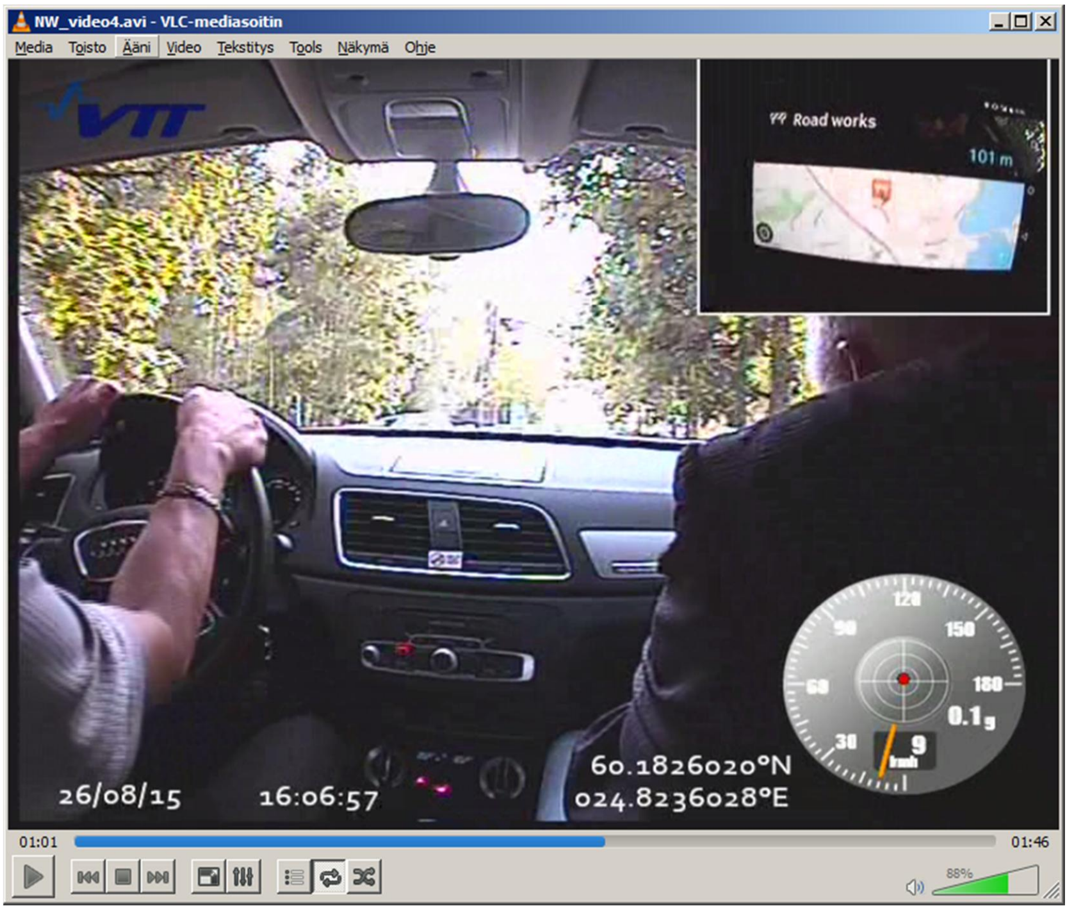


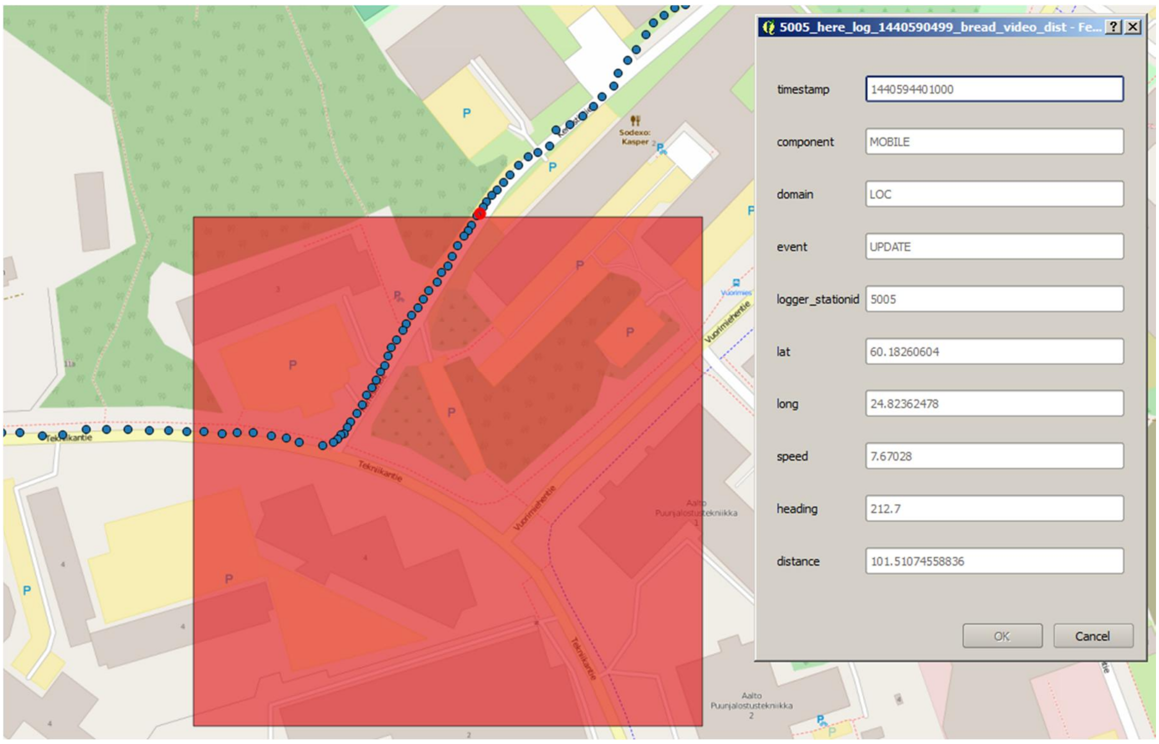
Video shot 3 – dismiss icon



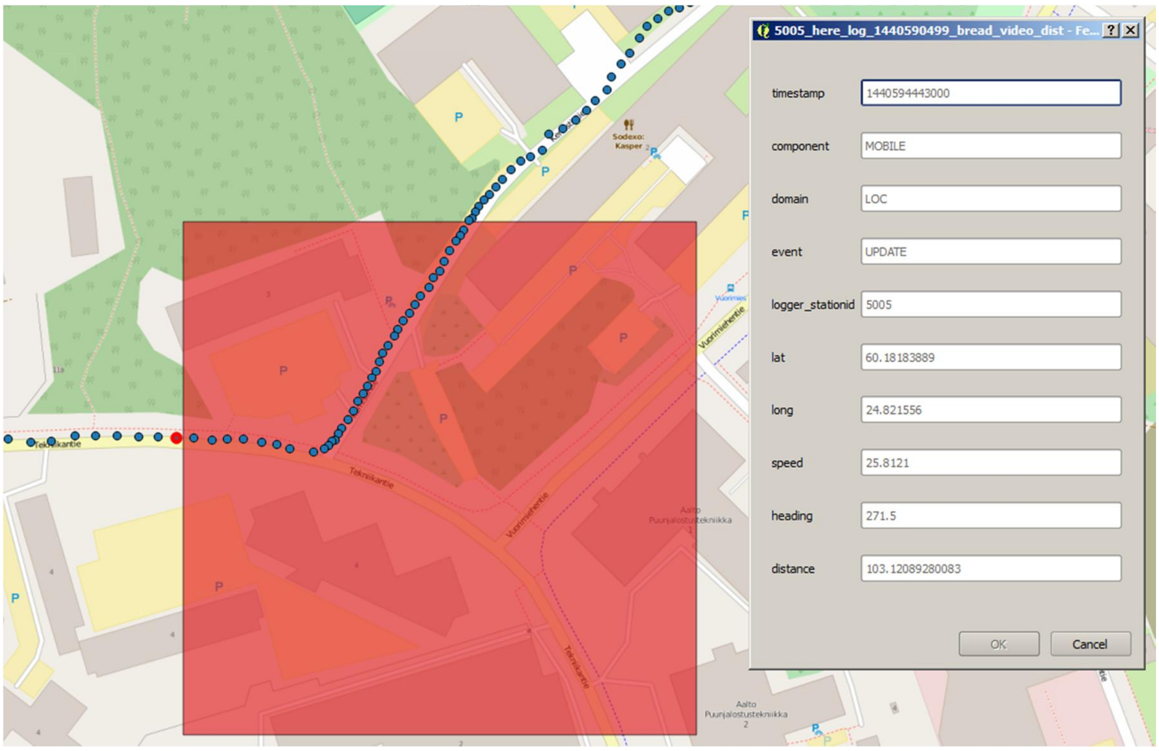


Video shot 4 – show icon

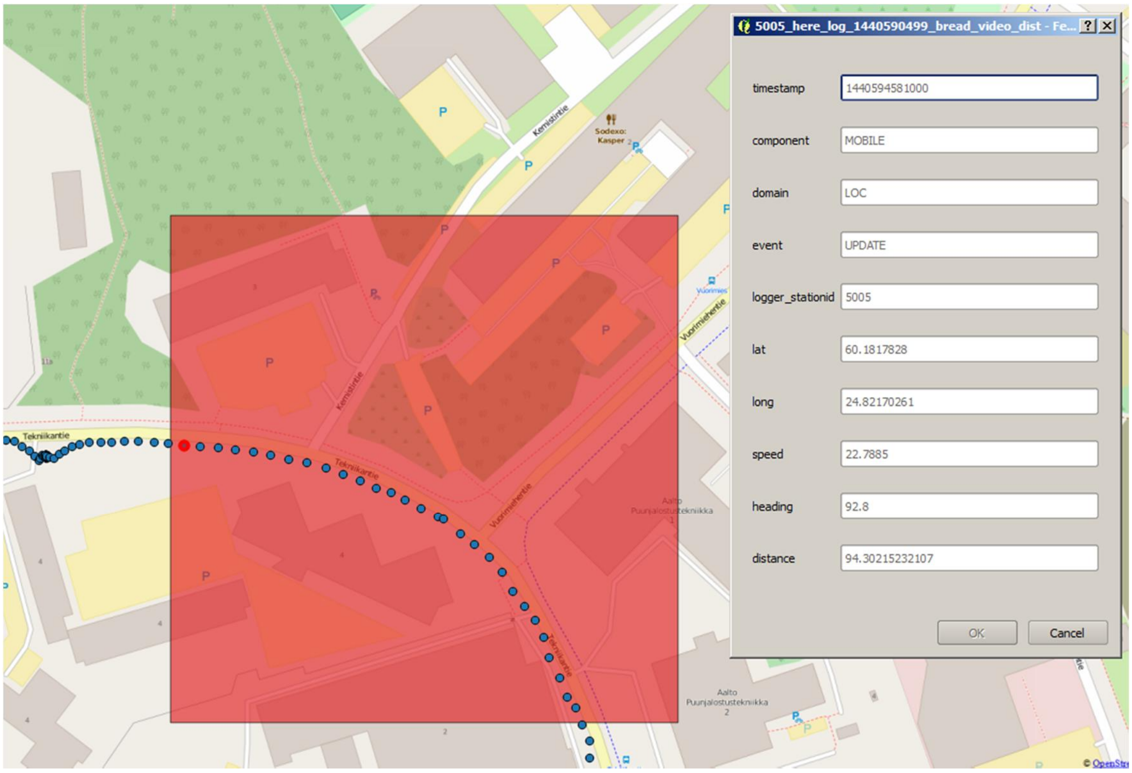




Video shot 4 – dismiss icon



Video shot 5 – show icon



Video shot 5 – dismiss icon