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ITS-enabled advanced road weather services and infrastructures for vehicle winter testing, professional traffic fleets and future automated driving

Timo Sukuvaara[1]*, Kari Mäenpää[1], Daria Stepanova[1], Sakari Kantomaa[1] and Virve Karsisto[1]

1. Finnish Meteorological Institute, Erik Palménin aukio 1, FI-00560 Helsinki, Finland

timo.sukuvaara@fmi.fi

Abstract

Intelligent Transport Systems (ITS) initiative focuses on providing technological approaches improving traffic safety and efficiency by advanced communication systems. Vehicular V2V and V2I communication with IEEE 802.11p, along with 4G/5G cellular networking are the key technological approaches for this communication entity. Along with other demands, ITS require more accurate weather forecasts and services tailored for specific road stretches. This would also increase traffic fluency and safety, as well as allowing automatic driving. For this the local observations originating from mobile vehicles and local road weather stations are required, along with real-time delivery of services. The Finnish Meteorological Institute (FMI) has studied the exploitation of vehicular data as input for its road weather forecasts model. We have set up a vehicle winter testing track, operational truck fleet and 5G pilot services palette, each one supporting the target of ITS-enabled road weather services in real-life scenario, concrete development environment.

Keywords:

IEEE 802.11p, 5G, road weather services

Introduction

The vehicular industry is nowadays facing huge evolution steps. The new challenges provided by the modern market trends consists of green technology, electrical/hydrogen vehicles, vehicular intelligence, online services and automatic vehicles, just listing the largest ones. Engine economy in general is somehow a challenge of its own, but for the rest of topics, cooperative communication presented by ITS presents the major role.

Seamless interoperability in highly mobile environments like VANET (Vehicular Ad Hoc Networking) is crucial while developing cooperative applications that can make full use of networking infrastructure. Cooperative applications for VANET require seamless communication between vehicle to infrastructure and vehicle to vehicle. IEEE 802.11p has been developed for this purpose, with European counterpart ITS-G5 tailored for European frequencies bands and channels by ETSI. In wide area communication the main problem is that the network coverage is low as roadside infrastructure is sparsely implemented.

On the other hand, the use of cellular networking as the communication media for vehicular transactions has been gaining more and more interest. Nowadays commonly used LTE (Long Term Evolution) cellular networking, also known as 4G communication, has been studied for this purpose. LTE does not natively sustain V2V communications, and especially when the vehicle density is high, beaconing signals of the vehicles can easily overload the network [1]. Another problem is response time for safety hazards and required instant messaging in V2V. One possible solution for this problem is bind VANET and cellular communication together into the hybrid communication system. VANET based communication is used whenever available, allowing instant accident warning messages, straightforward V2V communication and large data exchanges with roadside infrastructure (including road weather station information exploitation). When VANET is not available, supplemental cellular network ensures that the most important wide-area information is always exchanged. Hybrid communication scenario is carefully studied in [2].

Next generation of cellular networking, known as 5G, is tackling with these issues, and is expected to provide considerable improvements for these issues, among other advances like superior data capacity.

Reliable and efficient communication is very important aspect in autonomous driving vehicle, to assure safety and comfortability. As with general ITS, the same comparison between VANET and 5G remains active in this sector as well [3].

Road weather information is one of the most interesting and straightforward applications in ITS. Road weather information brings added travel convenience, but brings also essential increase into the traffic safety. Within autonomous driving, accurate and real-time road weather information is crucial element, when operating any kind of non-ideal weather conditions. The production of accurate road weather forecasts covering the full road network is a big challenge due to the lack of observations. Road weather stations are mainly located along major roads and are typically several kilometers apart. A growing number of available mobile observations are expected to be beneficial in solving the observation data void issue [4].

Road weather services exploiting traffic data allow for a more accurate real-time service generation directly to different traffic and transport actors. The next steps are to generate more extensive piloting of services in more controlled conditions and under real-life traffic conditions. Exploiting both VANET (IEEE 802.11p) and cellular networking (4G/5G) best features offer the best communication approach, as long as either one of them has not overtaken the superiority. FMI is presently building large-scale test environments for these purposes: the *Sod5G* project in a controlled vehicle winter testing area for both IEEE 802.11p VANET and 5G cellular networking, and the *Arctic Intelligent Trucks* project for operational vehicle fleet testing within a normal highway traffic environment under challenging weather conditions (with general 3G communication with hybrid IEEE 802.11p partially available). *Wirma* project studies road maintenance applications, while *5G-Safe* project introduces more demanding application scenarios for enhanced user experience and safety, obviously challenging the capacity and other advanced properties envisioned in 5G. Important communication safety features are analyzed in *CyberWI* and *SafeCOP* projects, the latter also introducing the cloud based data exchange for the vehicular networking entity. This paper introduces the ITS research and development infrastructure and research work of FMI, aiming to provide both attractive applications and services for the future ITS needs, as well as the testing and evaluation environments for these services and applications.

This paper is organized as follows. The next chapter introduces the FMI research infrastructures for ITS. The following chapter overviews the related ITS research activities. Finally, conclusions are drawn.

ITS-enabled advanced road weather infrastructures

The ITS research is nowadays targeting more and more into the operative systems, services and devices, expected to be ready for commercial vehicle fleets within certain period. Therefore, it is essential that for such kind of achievements it is possible to arrange straightforward testing in real-life conditions, in specific testing area, or within real traffic or merely in both. FMI has long experience of the development of advanced road weather services, but the operative testing has been so far conducted with FMI research vehicles, in some temporary arrangements. We have acknowledged, that in order to provide carefully configured, reproducible test measurements and analysis, more permanent environments and entities are required. To fulfill this deficiency, FMI is now building 5G and VANET testing environment with advanced road weather infrastructure into the vehicle winter testing site, along with mobile road weather observation instrumentation deployed into operative truck fleet of advanced communication capabilities to deliver observation data in real time as well as receiving real-time services. With these facilities, FMI can test and analyze the ITS and road weather services in controlled conditions and furthermore in operative real-life environment, and offer this “facility” to third parties as well.

The new EU ERDF funded Sod5G project will build a test environment for intelligent transport, road weather services and the 5G network in the Sodankylä airport area in Finnish Lapland. The main objective of this project is to build the 5G and VANET networks piloting environment to serve the needs of dedicated special multi-authority, intelligent traffic and vehicle winter testing. As a result, an accurate location-based road weather information and forecast service will be implemented throughout the test area road network, to be delivered in real-time through advanced 5G development network to authorities, vehicles, and the rest of the traffic actors.

The Sod5G test site is presented in Figure 1. The background of the figure on the left shows the whole airport area with a variety of test roads (with white lines). The right-hand side extraction of the figure shows the most important test drive track showcasing locations of the two road weather stations. Accurate road weather services for the test track are generated by combining (i) general meteorological road weather information for the area produced by FMI, (ii) road weather station (RWS) measurements in the area, and (iii) supplemental mobile data provided by test track vehicles. Both 5G cellular networking and IEEE 802.11p vehicular networking are employed in this scenario and the experiments have been conducted with both systems.

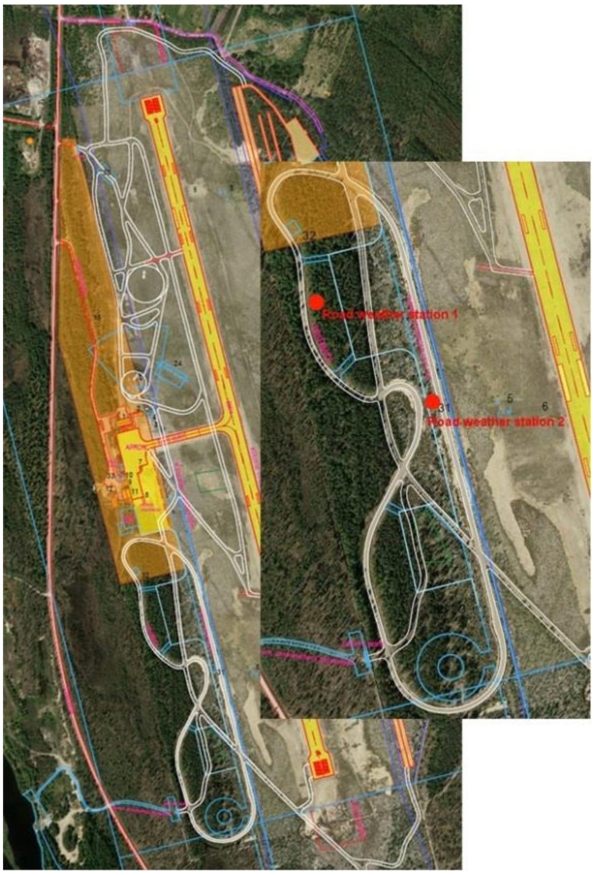

Figure 1 - Sod5G test track

In the pilot system, two vehicles are driving on the test track with embedded friction instrumentation. Surface friction data are collected during the pass of RWS with IEEE 802.11p, or continuously with 5G test network. Along with the vehicle data, also both RWS units collect weather data with their fixed friction instrumentation. Thereafter, the entire data are delivered to the test site road weather service computer. This computer combines these different data sources to form a specific test track road weather service and delivers information back to test track vehicles in real-time manner during each RWS pass.

The Intelligent Arctic Trucks project, also funded by the ERDF, comprises a 260km road stretch along which six heavy trucks will carry out measurements (Figure 2). The project started in September 2016, and the truck fleet with full instrumentation is ready for the winter of 2018-2019. The trucks form a mobile real-time test laboratory for studying and developing ITS and road weather applications. The project provides effective and accurate local road weather information in real-time with instrumentation installed on the trucks and produces road weather forecasts for the road stretch between Kevitsa and Kemi. The instrumentation consists of surface friction and temperature instruments (Teconer RCM411, RTS411), and a special vehicle telematics device (Sunit T7 and Sunit FD2 vehicle PCs and EEE Innovations devices) for achieving data from the vehicle CAN-bus. The data are collected from trucks using cellular 4G communication with cloud-based data entity for the storage of vehicular data, as well as the completed service data to be regularly delivered back to the trucks. The size of the friction measurement equipment alone means that it is not a feasible solution

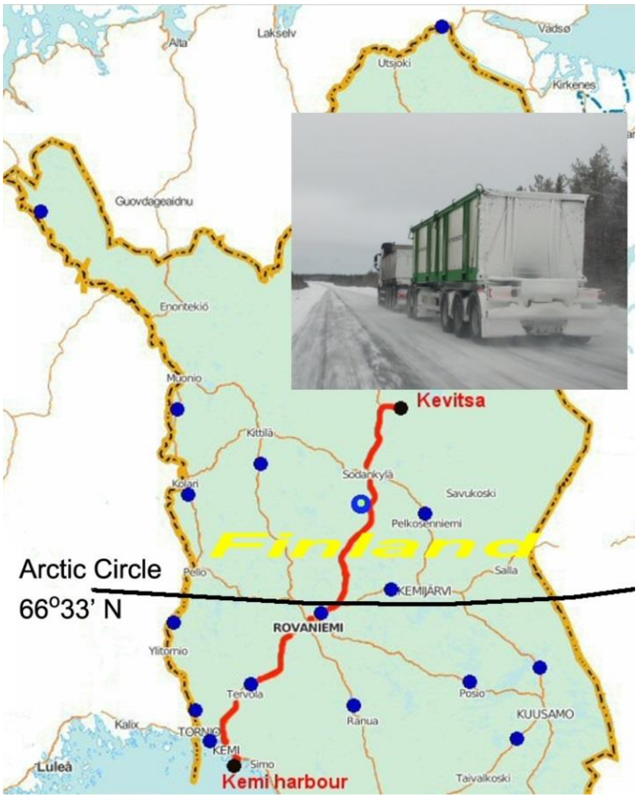

Figure 2 - Intelligent Arctic Trucks route and the existing RWS network. Blue dots are RWSs operated by the Finnish Transport Agency, and the interactive research RWS of FMI shown with an open blue dot

for all cars, but for example scheduled coaches or selected transport operators could provide data from certain main routes in the foreseeable future. The project also investigates how many vehicles are needed to produce sufficiently accurate data on the prevailing road conditions. Figure 3 shows two example analysis of road surface temperature along the route for 17th March 2017 7:00 a.m. local time. The panel on the left shows the starting temperatures when the road weather model did not use any mobile observations in the analysis and the surface temperatures are interpolated values from measurements made at road weather stations. The panel on the right shows the analysis where the mobile observations are included. As can be seen, these observations can have an effect of several degrees to the starting state of the model.

ITS-enabled advanced road weather services

The advanced field test facilities along with 5G test network and advanced ITS environment allow the research & design of advanced road weather and ITS services. For this purpose, FMI participates to Business Finland -funded 5G-Safe project, which develops advanced road weather and safety services for the vehicles, exploiting possibilities of 5G but at the same time offering serious communication capacity challenges for it as well. The services consist of accurate real-time road weather data and forecast for vehicle, friction, drifting snow and accident warnings for vehicles, the delivery of vehicle camera data between vehicles to offer first car front view for the following queue, in case of drifting snow. Furthermore, the similar services are tailored also for the road maintenance operator. The instrumentation used to collect the data for these services consists of optical friction measurement

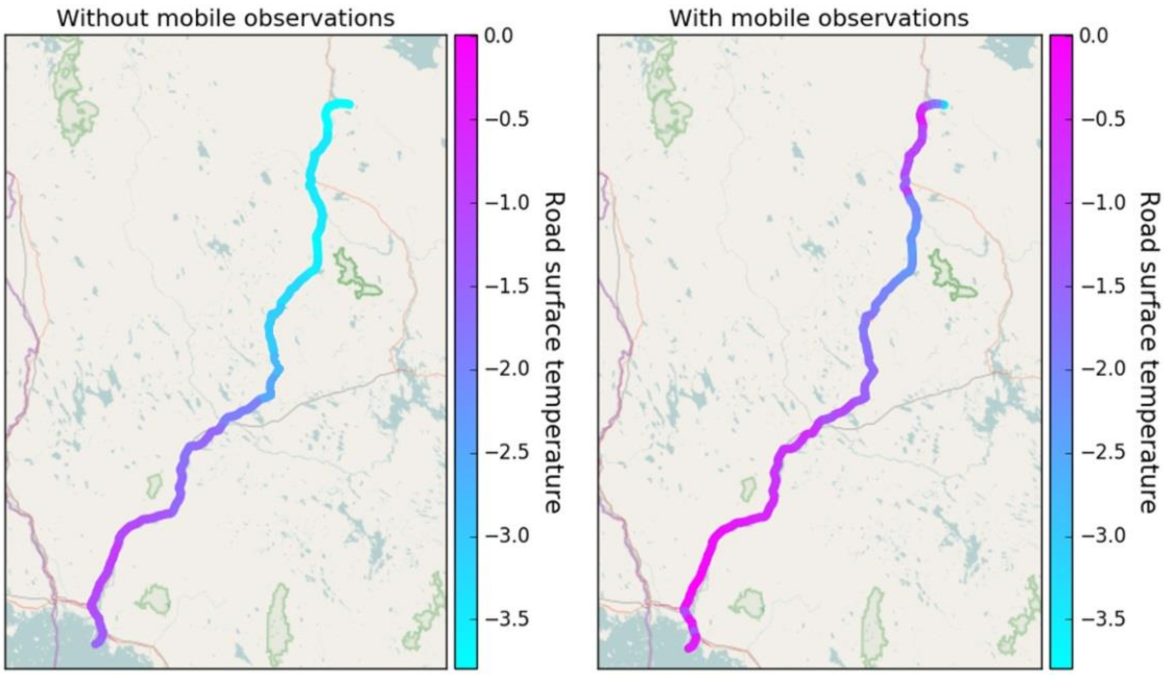

Figure 3 – Road surface temperature along the truck route in the road weather model before the start of the forecast. Left panel shows analysis without mobile observations and the right panel them included

device, vehicle telematics data, camera device and lidar device implemented into the vehicle. An example of image analysis is presented in the Figure 4, where the observation area has been narrowed to the road surface and vicinity, and observation of icy surface, pale surface and snow cover are successfully conducted. Other observed events are snowy traffic signs (need for cleaning) and drifting/running snow condition on the road, meaning simply that the visibility in the road is poor even if the weather is not bad. Parallel Interreg Wirma project is tailoring the road weather services for the road maintenance purposes.

Road weather services delivery directly to vehicles as well as collecting observation data directly from vehicles require a high level of security and trust. We must be able to ensure that the data transmissions and data handling procedures in the vehicles, service clouds and within the road weather service generation process are not disturbed or contaminated in any way. For this purpose, FMI is participating two projects providing security methodologies for our vehicular networking use cases. The EU ECSEL JU project SafeCOP introduces additional safety and trust for wireless communication with a specific runtime engine controlling the security and validity of each communication entity's internal operation, with supporting safety layer functionalities ensuring the general communication safety. These methodologies are employed especially in the road weather service cloud used in the Intelligent Arctic Trucks project introduced in the previous chapter and, more generally, in our vehicular communication entity. The Celtic Plus project CyberWI generates tailored safety features for pre-defined operational environments and FMI's RWS structures both in the Sod5G test truck scenario as well as in the interactive RWS along the route of the Intelligent Arctic Truck fleet.

Figure 4 – An example of vehicle camera image analysis

Conclusions

Within ITS research it is essential to be able to arrange straightforward testing of new services and applications of ITS and autonomous driving in real-life conditions, in specific testing area, or within real traffic. FMI has long experience of the development of advanced road weather services, but the operative testing has been so far limited. To fulfill this deficiency, FMI has now the 5G pilot- and VANET testing environment with advanced road weather infrastructure into the vehicle winter testing site, along with mobile road weather observation instrumentation deployed into operative truck fleet of advanced communication capabilities to deliver observation data in real time as well as receiving real-time services. With these facilities, FMI can test and analyze the ITS and road weather services first in controlled conditions and later on in operative real-life environment. This infrastructure is available for similar kind of testing and evaluation purposes for any existing or upcoming partner/co-operator of FMI.

Acknowledgements

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