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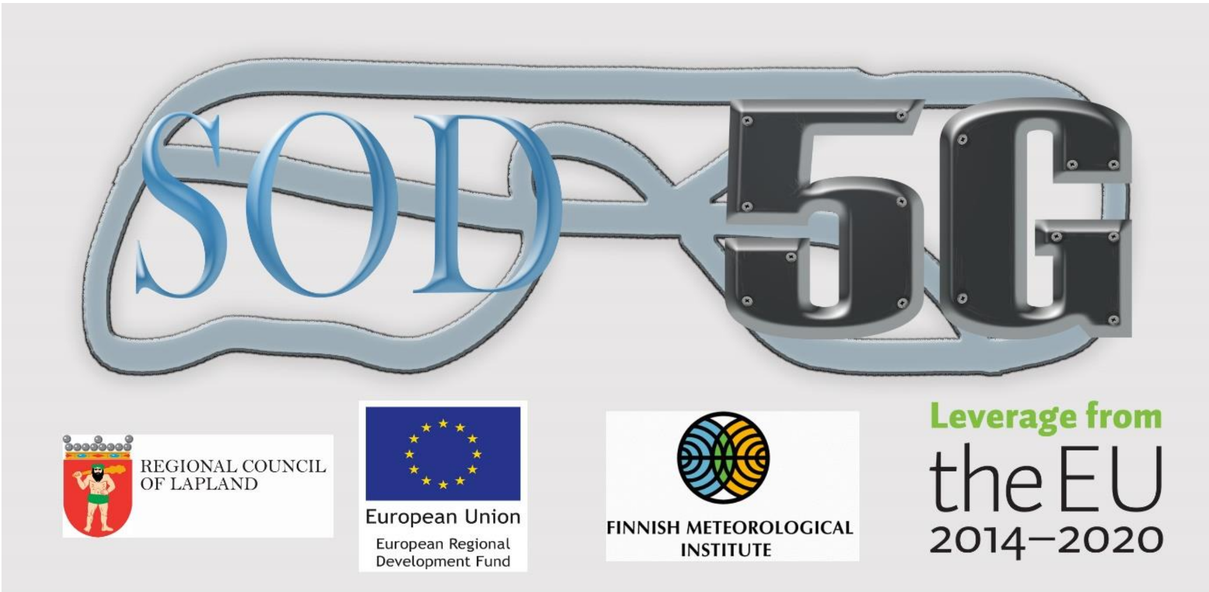

Sod5G - combined ITS-G5 and 5G test track for vehicle winter testing and advanced road weather services

Summary report 28.6.2019

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Abstract

The main objective of Sod5G project is to develop the 5G test network, road weather services and piloting environment for the dedicated special needs of multi-authority -, vehicle winter testing requirements and intelligent traffic. As the result of this project, forecast services and accurate location-based road weather information is implemented throughout the test area road network and entity, delivered through the advanced 5G test network to vehicles and the rest of the traffic actors in real time.

FMI is operating a vehicle winter testing track of 1.7 km long with advanced communication infrastructure within ITS-G5 and 5G test network, along with accurate road weather information and services supported by on-board weather measurements and road weather stations. It is located in Sodankylä, Northern Finland, where the long arctic winter period of more than half year provides us an opportunity to develop road weather services in (and for) severe weather conditions. This winter test track and environment provides favorable conditions for the development and improvement of advanced ITS safety services equally for autonomous, traditional and alternate energy vehicles, tailored road weather services for each special use case and accurate analysis of performance. Not to overlook the communication infrastructures and energy efficiency of traffic themselves, that are the critical entities in the development of ITS.

Introduction

The major challenges in modern traffic include vehicular intelligence, green technology, online services, automatic vehicles and alternative energy vehicles. Artificial intelligence and communication system are expected to play a crucial role in future traffic system developments.

Autonomous driving, enhanced driving safety as well as energy-efficient and low-carbon traffic solutions are the key entities in future traffic development system. Intelligent Transport Systems (ITS) provide numerous technological approaches to enhance the traffic efficiency and safety by advanced communication systems. Vehicular V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication with ITS-G5, along with 4G/5G cellular networking are the fundamental technological approaches in ITS. Advanced communication systems are critical enablers for autonomous vehicles in real-time support as well as in advanced safety features allowed by real-time weather warnings and accident or incident information.

Carbon-free or low-carbon solutions in vehicles and in traffic infrastructure are very critical elements when, e.g., European Union is setting aim to reduce the use of and ultimately phasing out fossil fuels in the following decades.

The Finnish Meteorological Institute (FMI) has a long history in the development of ITS-enabled road weather services and applications. Advancing safety has always been a main goal of FMI research, but now the merging trends of alternative energy solutions, automated driving, along with reduced carbon emissions in the traffic environment must be considered carefully as well.

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 needs seamless communication between V2I and V2V. The IEEE 802.11p has been developed for this purpose, with its European counterpart ITS-G5 tailored by ETSI for European frequency bands and channels.

Cellular communication systems provides the wide-area coverage by default, the missing element in VANET. 4G cellular networking with LTE-A (Long Term Evolution – Advanced) is a base for, e.g., vehicular cloud services offered by multiple vehicle manufacturers. LTE-A does not natively support direct vehicle-to-vehicle (V2V) communications, and especially when the vehicle density is high, beaconing signals of the vehicles can easily overload the network. Another critical thing is response time for safety hazards and required instant messaging in V2V. The probable solution for this issue is to combine VANET and cellular communication together into a hybrid communication system.

Next generation cellular networking, known as 5G, is dealing with these concerns, and is likely to offer considerable improvements for these issues, among other advances like ultra-low end-to-end delays and higher bandwidth.

Road weather services are another vital element of future driving. Autonomous vehicles relies on the accurate location information and all constraints related to its safety margins with respect to other traffic actors. They need very accurate road weather information to ensure safe driving in all critical situations. The production of accurate real time road weather forecasts covering the full road network is a big challenge owed to scarcity of observations. Road weather stations (RWS) 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.

Road weather services exploiting road traffic data allows more accurate instantaneous service generation straight to different transport and traffic actors. The following stage is to generate more extensive pilot services in more controlled conditions and under real-life traffic situations. Exploiting together ITS-G5 and cellular networking (4G/5G) features, offers the finest communication approach at hand. FMI has executed large-scale test environments for these purposes: the Sod5G controlled vehicle winter testing track for both ITS-G5 and 4G/5G cellular networking, and the Arctic Intelligent Trucks vehicle fleet for operational testing within a normal highway traffic environment under challenging weather conditions. For the Sod5G test environment was facilitated by 5G-Safe project with the introduction of demanding applications for enhanced user experience, safety, exploiting the enhanced capacity and mobile edge computing of upcoming 5G cellular architecture.

Infrastructure

FMI has long experience of the development of advanced road weather services. Based on this experience, FMI has built Sod5G - 5G and ITS-G5 testing environment with advanced road weather infrastructure into the institute's vehicle winter testing site in Sodankylä. The site is supplemented with mobile road weather observation in an operational truck fleet equipped with advanced communication capabilities to deliver observation data in real time as well as to receive near-real-time services. With these facilities, FMI can test and analyze the ITS and road weather services in controlled conditions and furthermore in operational real-life.

The EU ERDF (European Regional Development Fund) funded Sod5G test site is presented in Figure 1. The main track is 1.7 km long, supplemented with several "shortcuts" for different types of surface characteristics. The track has two fixed road weather stations, presented in the figure. The track surface under the snow is gravel, except the part of the track between road weather stations which has asphalt surface and under-surface pipelining across the road.

The communication infrastructure in the test track consists of several parallel communication entities. ITS-G5 communication is supported by Cohda Wireless MK5 transceivers embedded into the RWS infrastructures and FMI vehicles, allowing the testing of both V2V and V2I communication, presented in the Figure 2. RWS stations (Figure 3) are also equipped with traditional Wi-Fi hardware with IEEE 802.11n compatible devices, allowing for comparative measurements with Wi-Fi. The 5G test network consists of a single base station (Figure 4) located to the North of the track, just outside the area shown in Figure 1 (North is approximately to the left-hand side of the figure). With this one base station unit we can't offer constant quality of service throughout the track – in the rightmost part of the track the signal strength is very low, in snowy conditions below the threshold. However, this allows us to test communication in fading signal conditions as well. If continuous communication is required, we can use the shortcuts of the track. The 5G test network is supplying an LTE-A communication system with 5G communication architecture components and service modules through 5GTNF- open innovation ecosystem for 5G technology and service development, coordinated by VTT.

Accurate road weather services for the test track are generated by combining 1) general meteorological road weather information for the area produced by FMI, 2) road weather station (RWS) measurements in the area, and 3) supplemental mobile friction data provided by the vehicles on the test track. Both 5G cellular networking test system and ITS-G5 vehicular networking are employed in this scenario and the experiments have been conducted with both systems.

Figure 1. Sod5G test track. The Road Weather Stations are marked as RWS1 and RWS2.

Figure 2. Cohda Wireless MK5 transceiver.

In the pilot system, two vehicles are driving on the test track with embedded friction instrumentation. Surface friction data are transmitted during the pass of an RWS with ITS-G5, or continuously with the 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.


Figure 3. Road weather station in the Sod5G test track.

Figure 4. 5G test network base station antenna and the test track.

The Intelligent Arctic Trucks project, also funded by the ERDF, comprises a 260 km road stretch along which equipment attached to 12 heavy trucks carry out different environmental measurements (Figure 5). The trucks form a mobile real-time test laboratory for studying and developing ITS and road weather applications. Based on synthesis of the on-board measurements and the FMI meteorological services, effective and accurate local road weather information is composed for the road stretch between Kevitsa and Kemi. The instrumentation consists of surface friction and temperature instruments (Teconer RCM411, RTS411) viewed in the Figure 6, as well as several vehicle front cameras collecting both video and image data from the vehicle front. The friction instrument is also used in the Sod5G test track mobile friction measurements. Furthermore, special vehicle telematics devices (Sunit FD2 vehicle PCs and an E3 Grip telematic device) are used for retrieving data from the vehicle CAN-bus.

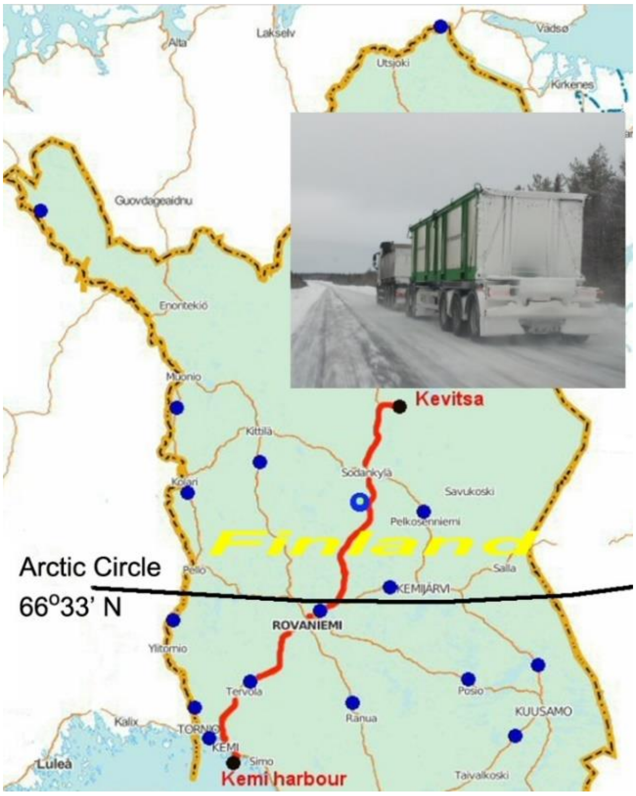

Figure 5. Intelligent Arctic Trucks route and the existing RWS network. The filled blue dots are RWSs operated by Traficom (the Finnish Transport and Communications Agency) the interactive research RWS of FMI is marked with an open blue dot

Figure 6. Teconer RCM411 and RTS411 instruments (used both in Intelligent Arctic Trucks and Sod5G mobile friction measurements).

ITS-enabled advanced road weather services

The field test amenities along with the advanced ITS-G5 and state of the art 5G test network allows the research, design and testing of a advance road weather and ITS services. The initial 5G-enabled pilot road weather services were developed in the 5G-Safe project (funded by Business Finland). 5G allows more robust data exchange with vehicles and road weather stations, providing more sophisticated traffic weather services. FMI provides three different road weather services especially tailored to benefit autonomous vehicles were introduced, shown in Figure 7. Autonomous vehicles can chose the best route based on 1) weather forecast information of each route, 2) current road weather-related alerts on the route and 3) existing safety-related alerts on the route. All of these pilot services were executed and generated by exploiting the 5G test network in real-time collection of observation data and warnings, eventually delivered to the vehicles in near-real-time by the 5G test network. Moreover, the V2V communication in the 5G test network and the ITS-G5 was tested with special "see-through" application, tailored to deliver vehicle camera data from the front of a vehicle queue during the poor visibility conditions, allowing to make precautionary measures for unexpected traffic anomalies. See-through application is extremely sensitive to the transmission delay and also possesses juridical questions, hence it is not set for the operational traffic environments yet. Nonetheless, the set of pilot services tailored for 5G and autonomous driving are accessible on the test track, along with C-ITS so called "day 1 services", which have been executed and tested on our winter test track at concept level and tests can be further extended in near future.

Vehicles receives the road weather services as well as collecting observation data directly from vehicles needs a high level of security and encryption. We should also ensure the security of data transmissions and data handling techniques in the vehicles, service clouds as well as within the road weather service generation process are not disturbed or contaminated in any way. For this purpose, FMI is participating in two projects providing security techniques and approaches for our vehicular communication use cases. The EU ECSEL JU SafeCOP introduces additional safety layer for wireless communication with a specific runtime engine regulating the security and validity of each communication entity.

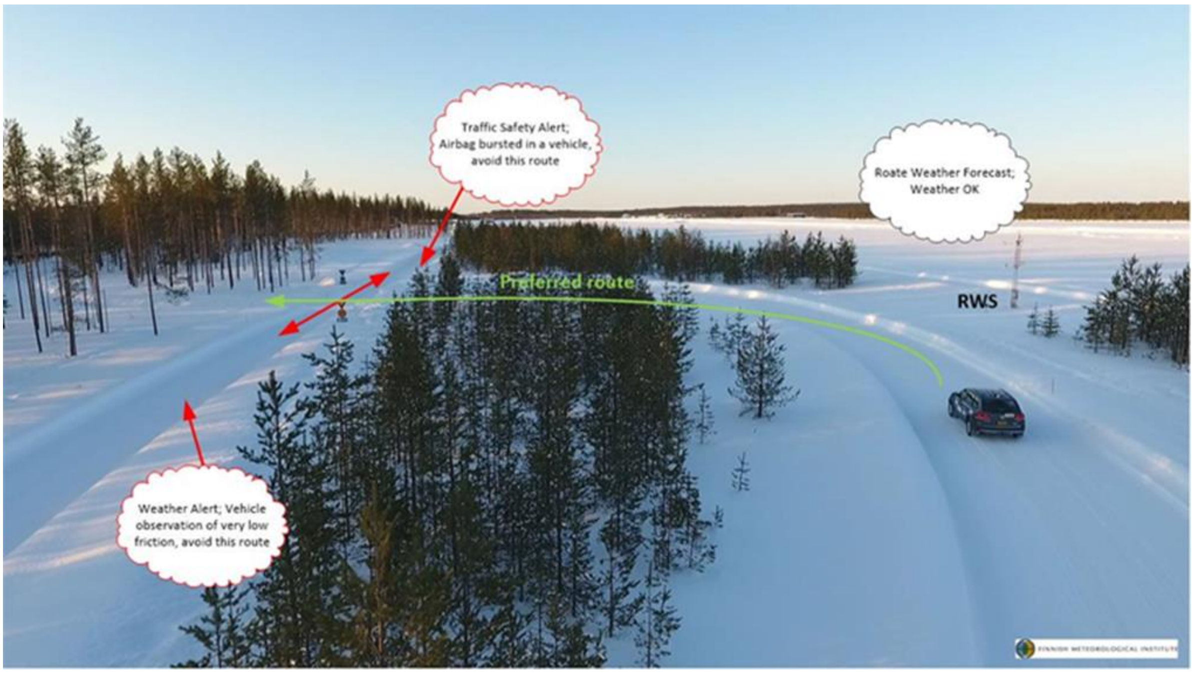

Figure 7. Pilot road weather services tailored for autonomous vehicles and 5G

Internal operation, having safety layer functionalities certifying the general communication safety. These techniques and approaches are employed especially in the road weather service cloud used in our vehicular communication entity and Intelligent Arctic Trucks. The Celtic Plus project CyberWI is another project that provides tailored safety features for pre-defined operational environments and FMI's RWS structures both in the interactive RWS along the route of the Intelligent Arctic Truck fleet as well as on the Sod5G winter test track.

Test track evaluation

The general operability has been demonstrated in the operation of the track infrastructure. Several pilot services have been generated and successfully operated within the track. We have also conducted more specific analysis of the ITS-G5 based V2V and V2I information sharing, for performance evaluation purposes. The general environment-of-operation is as follows. The RWS provides road weather information based on its observations. The road friction data, along with possible accident information is collected by vehicles in the test track. The RWS collects the observation information from the vehicles passing by (using V2I communications), to be used in these services. The RWS delivers the combined weather information to the vehicle (V2I). The vehicles encountering forward this RWS data to the other vehicle (V2V) thus spreading the RWS data and extending the RWS range.
In our field measurements, two vehicles were driving in the test track, two RWSs acting as the V2I counterparts. Communication between the vehicles and the RWSs was conducted with Cohda Wireless MK5 transceivers, compatible with ITS-G5. SUNIT F-series vehicle PC was the user interface (UI) in vehicles, Android tablets being an optional solution. In-vehicle communication, the data is collected solely from the external road condition monitoring measurement instrument installed in the vehicle. In these measurements we used Teconer RCM 411 devices with road temperature, -state and -friction data.
In the first stage, the vehicles collected RWS data in V2V and V2I communication mode, while driving on the test track. RWS delivered the up to date road weather information to the vehicles, while passing. Furthermore, encountering vehicles exchanged their latest road weather information received from RWS. The resulting connectivity is presented in Figure 8. The yellow marks are pointing the locations where the packets were received by a vehicle from a RWS in V2I scenario and from another vehicle in V2V scenario. The connectivity tests consisted of 10 passes vehicles driving both in the same and opposite directions.
In the second stage we evaluated the general performance of the communication, in terms of data throughput and delay. We conducted 10 measurement drives for V2I communication using the ITS-G5 network, the operational 4G network and the 5G test network. In the ITS-G5 scenario, the RWS was sending a standard road weather station message continuously and the test vehicle captured as many of those packets as possible. In cellular scenarios the

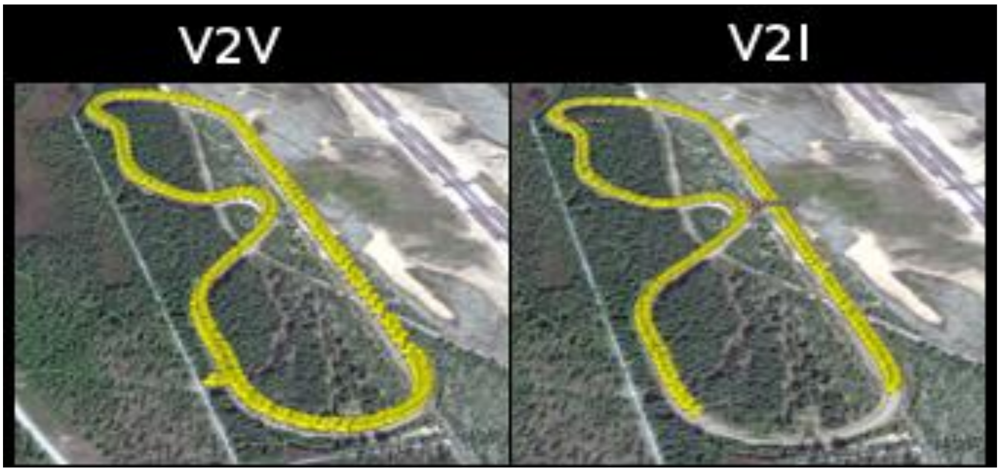

Figure 8. Test track ITS-G5 connectivity

same data were delivered through the cellular network. In each scenario the test vehicle was randomly driving along the test track. As a result, we got an estimate of general performance within the test track, presented in Table 1. The latency of ITS-G5 is significantly better compared to cellular systems. However, edge computing features and higher carrier frequency would benefit 5G test network performance (e.g., reduce latency) significantly. The share of lost packets was particularly high in cellular systems, due to relatively long initialization time included to the measurements. When connected, cellular network packet loss rate decreases dramatically.

Table 1. Performance measurements in the test track.

Description	ITS-G5	4G Cellular Network, V2I	LTE-A cellular test network, V2I
Measurements	26	45	44
Latency	0.18s	0.83s	0.65s
Lost packets	10%	75%	80%
Average throughput	1.46 Mbit/s	2.58 Mbit/s	2.66 Mbit/s

The rest of the performance evaluation results are presented in our related conference papers, authored by Muhammad Naeem Tahir, Kari Mäenpää and Timo Sukuvaara. These papers can be requested from the author of this summary report.

Conclusions

FMI has long experience in the development of advanced road weather services. With Sod5G infrastructure, the research work and the development of services can be conducted in the 5G pilot- and ITS-G5 testing environment with advanced road weather infrastructure at the FMI vehicle winter testing site. The mobile road weather observation instrumentation deployed with an operational truck fleet equipped with advanced, low-latency communications capabilities allows both the delivery of observational data in near-real time as well as receiving road weather services. The FMI test site is located in the Northern Finland, at Sodankylä, allowing for testing of arctic winter conditions for nearly half of the year. With these facilities, FMI can test and analyse the ITS and road weather services. This infrastructure is available for similar kind of testing and evaluation purposes for any existing or upcoming partner/co-operator of FMI as well.

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