

Connected vehicle safety network and road weather forecasting – The WiSafeCar project

Timo Sukuvaara and Pertti Nurmi

Finnish Meteorological Institute,
Erik Palménin aukio 1
Helsinki, Finland

Corresponding author's E-mail: timo.sukuvaara@fmi.fi

ABSTRACT

Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications are novelty key technological approaches to improve road transport efficiency and safety. The European WiSafeCar project focused on developing an intelligent hybrid wireless traffic safety network between vehicles and infrastructure. Vehicle based sensors and observations were exploited to generate intelligent real-time services on a service platform. WiSafeCar considers both the urban environment and rural areas, where no high-density telecommunication base station network is available. Traffic safety is enhanced by providing accurate and timely information about accidents and adverse weather. The application provides a platform for true bi-directional Internet-like networking tailored for connected vehicles.

In order to exploit platform capabilities and to analyze system capacity, several pilot services were developed. Accident warnings and various kinds of incident warnings as well as some driver convenience services were among the 10 initiated services. The most unique and specific application for the Finnish environment is the wintertime road weather service. Input generator for this service is the road weather forecasting system of the Finnish Meteorological Institute (FMI). The application provides detailed and customized, local en-route information on potential adverse weather conditions and events like road surface slipperiness and poor visibility in the form of real-time observations and short-range forecasts.

The communication platform designed for the project was based on IEEE 802.11p and 3G communication protocols. A pilot system was developed to showcase the platform and the operability of its services. A public pilot was established in Tampere in January 2012, where the services were demonstrated in a real operational environment. Additional IEEE 802.11p communication field measurements and large-scale simulations have ultimately validated our general impression that the WiSafeCar platform is a potential solution for a comprehensive future vehicular communication entity.

Keywords: Vehicular networking, road weather service, WiSafeCar.

1 INTRODUCTION

The WiSafeCar project [1] focused on building a comprehensive, secure and reliable solution for V2I (Vehicle to Infrastructure) and V2V (Vehicle to Vehicle) communications. The main objective was to generate true V2I and V2V communications based on the car-to-car communication standards developed by the European Committee for Standardization (CEN) and the European Telecommunications Standards Institute (ETSI). The WiSafeCar platform consists of vehicles equipped with on-board vehicle computers having vehicular networking capabilities (IEEE 802.11p and 3G), access point-like roadside units delivering vehicle data downlink and uplink, and the linking point within the fixed network, acting as the interface of platform vehicles (or users) and independent services coordinated and linked by the linking point. The ultimate goal was to create an intelligent, seamless communication platform and mechanism for vehicles, which can exploit the generated services, partially based on their own observations of traffic and weather conditions.

FMI was especially focusing on the road weather service, specially tailored for the Finnish wintertime environment. Road weather and related traffic safety issues are the most straightforward beneficial applications for the vehicular networking entity, therefore representing both scientific and commercial key topics. This paper gives an overview of the WiSafeCar communication system, including information about our innovative wireless road weather service.

2 THE WISAFECAR PLATFORM

The WiSafeCar platform is designed to provide an infrastructure to a wide community of commercial and governmental traffic and safety services and operators. The platform itself is the key element, but the services created into the platform have a crucial role as well. On the one hand, they generate different ways to use and exploit the platform, proving its efficiency. On the other hand, the services are the business card of the platform to the consumers. In order to make the consumers interested to purchase the platform and, furthermore, the vehicle industry to integrate the platform equipment into the vehicles, we must have certain specific key services interesting enough for the consumers. We have designed some key services to prove the applicability, usefulness and necessity of the platform. These are to be updated during the project. We vision the platform a “killer-application”, even with low deployment rate, raising public interest and, consequently, commercial success. This would lead into large scale deployment and generation of a wide spectrum of independent services. We have defined a set of preliminary services which can be divided into roughly three categories based on the above principles: (i) accident and incident warnings, (ii) driving convenience info services, (iii) road weather alerts. Our special focus here is on category (iii).

A general view of the platform is presented in Figure 1. The platform consists of vehicles, roadside units acting as system base stations and local weather stations, with the host systems as a linking point beyond the base station network, linking data transfer between regular Internet and the WiSafeCar network. We follow the IEEE standardization activity for the V2V communication environment, named as WAVE (IEEE 802.11p) [2]. The underlying technology in this standardization work is called Dedicated Short-Range Communication (DSRC) presented in the IEEE 1609 standard [3], which is essentially the IEEE 802.11a standard adjusted for low overhead operations. The primary purpose of the DSRC is to enhance public safety applications, to save lives and to improve traffic flow by vehicle-to-vehicle and infrastructure-to-vehicle communications. The vehicles form a VANET (vehicular area networking) network, compatible with IEEE 802.11p standard. They do not have continuous connectivity but operate in an ad-hoc manner with each other whenever possible, typically when two cars pass each other. A vehicle will get up-to-date traffic platform service data always when passing the vicinity of a roadside unit through the linking point located in the fixed network. The roadside unit acts as an interface between the fixed and wireless IEEE 802.11p networks. The vehicle also transmits data to/from the linking point over the lower capacity 3G network, whenever the IEEE 802.11p based connection to a roadside unit is not available. We have an option to use GPRS data transfer for an alternative emergency connection if also the 3G signal reception turns weak. The system can pass data from/to a mobile user with reduced operability in the platform. This paper focuses on vehicle oriented operation and, therefore, mobile user capabilities are not considered in detail.

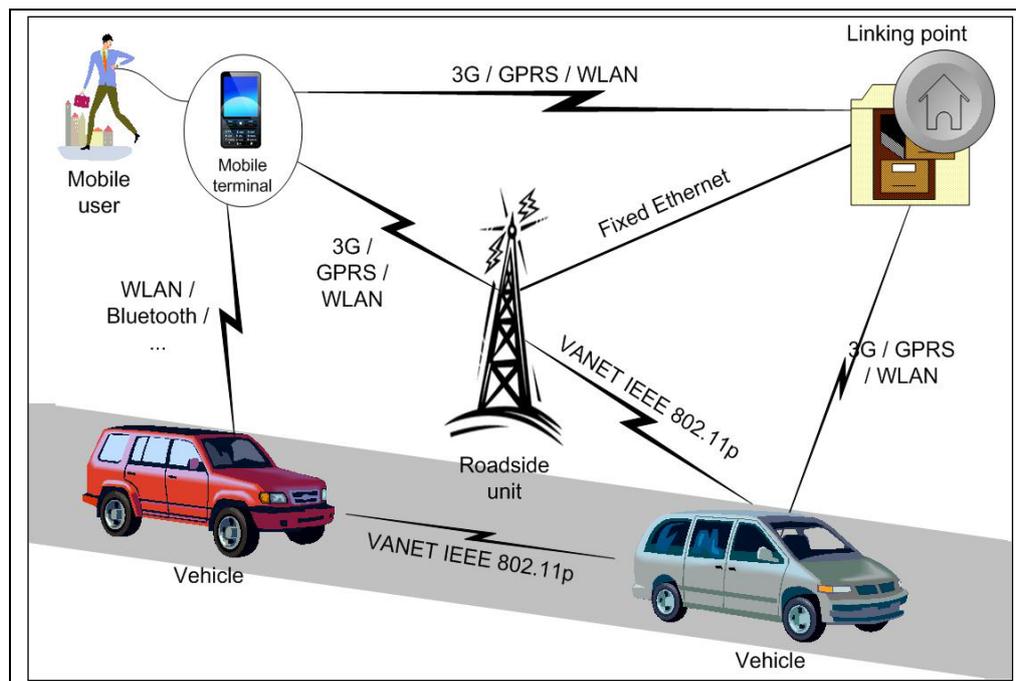


Figure 1. The WiSafeCar platform.

The communication entity in Figure 1 has four main characters; vehicle(s), the roadside unit, the linking point and a mobile user. The linking point is one entity above the platform, hosting the vehicles through the roadside unit network. Vehicles use IEEE 802.11p based networking to communicate with each other but mainly for communicating with a roadside unit whenever in the vicinity of one. The vehicle receives up-to-date real-time service data but, as an exchange, also delivers its own observation data gathered from the vehicle sensors and systems to further update the service data. The roadside unit delivers this data to the linking point through fixed connection together with its own advanced data set gathered from its own weather station and variety of traffic sensors. As an alternative option for critical data delivery in the position outside the range of IEEE 802.11p network we use 3G, providing complete coverage in the urban areas. For rural area operations, we have as final alternative the GPRS communication if even 3G fails.

3 ROAD WEATHER SERVICE

Road weather conditions have a great influence on traffic safety in the Nordic countries. Therefore, we have included services relating to en-route road weather observing and forecasting as a pivotal component in our service palette. The road weather application is a derivative of the Finnish Meteorological Institute's (FMI) road weather forecast model. The model is a one-dimensional energy balance model which calculates the vertical heat transfer in the ground and at the ground-atmosphere interface and takes also into account special conditions prevailing at the road surface [4]. The effects of the atmosphere, turbulence as well as traffic volumes on the road are considered. The underlying horizontal resolution of the model is a sparse five km meaning that the model cannot essentially resolve meteorological features beyond this spatial scale. Therefore, we aim at enhancing the spatial scale with the use of novelty sub-grid analysis techniques and additional weather data collected from platform vehicles, roadside units and other potential sources. The horizontal resolution was previously 10 km and this is the first time when the more accurate resolution is applied.

Modern vehicles are able to collect a lot of weather data and weather related parameters while on the move as demonstrated in Figure 2, and such information can be used as weather observations or additional information [5]. Windshield wipers can reveal if it is raining, fog lights are detectors of low visibility due to fog, heavy rain or snowfall, ABS and ESP provide information about slipperiness and, almost by default, present cars measure the air temperature. The output of a road weather model can potentially be adjusted utilizing car measurements. For example if the road weather model shows no slipperiness at a specific location but if cars are sliding, that location can be marked as a slippery place. However, the reliability and representativeness of the new observation types must be taken into account and assimilation of such data is one of the biggest future challenges in road weather modelling.

There are two kinds of weather related information that are delivered to the drivers in the WiSafeCar pilot: warnings against slipperiness and heavy precipitation. Warnings are produced only if the driving conditions are very bad. Slipperiness increases traffic accident risk dramatically. If slipperiness and low visibility (often due to heavy precipitation) occur at the same time the traffic accident risk is several times higher than during dry and clear weather. A heavy precipitation warning can also be issued during the warm season. Under heavy rainfall the visibility is low but also the risk for hydroplaning is high. The potential slipperiness warning is based on the new innovative statistical-numerical road surface friction forecasting model recently developed at FMI [6, 7].

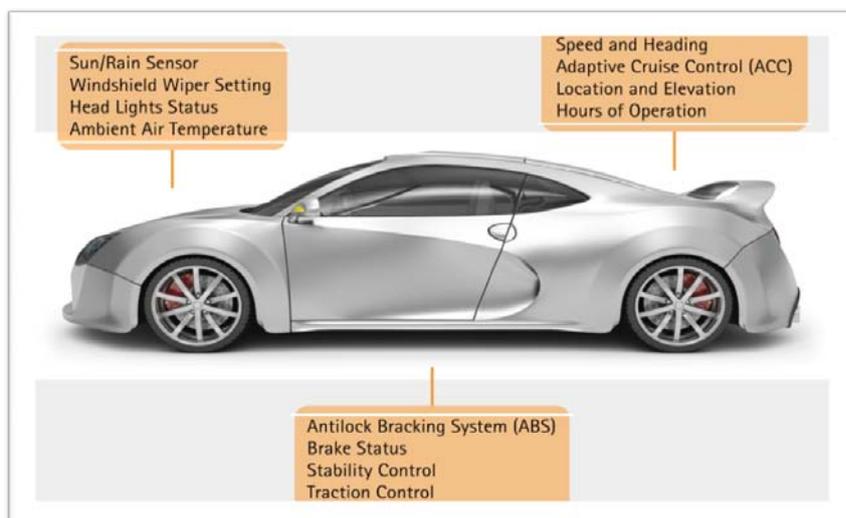


Figure 2. Weather related properties observed by a vehicle.

4 THE PILOT SYSTEM

Based on the project architecture and the results of field measurements, we defined the set of pilot services for the platform shown in Table 1. The services collect the data and then formulate the concluding condition from one or multiple sources. Internal data sources are WiSafeCar specific, originating typically from either vehicle or advanced roadside units. External data sources are independent of our system and, on the other hand, are commonly used already in most of the cases. External data is provided through the linking point. By combining these different sources we expect to reach the most effective reaction for different types of events and incidents.

Table 1: WiSafeCar pilot services.

Service	Overview	Internal Data Sources		External Data Sources (via Linking Point)
		Vehicle	Roadside Unit	
Accident warning	Accident in road interpreted	Airbag burst, GPS, emergency lights on	-	Accident info from authorities
Incident warning (BCW)	Exceptionally bad weather conditions interpreted or observed	Temperature, GPS	Road surface condition sensors, temperature, rain intensity, humidity, wind	Weather radars, weather stations etc., authorities
Incident warning (SRW)	Slippery road conditions observed in specific spot	Road surface condition sensors, gyroscope, GPS	Road surface condition sensors, temperature, rain intensity, humidity, wind	Weather radars, weather stations etc., authorities
Incident warning (AOV)	Indication of approaching emergency vehicle	Vehicle-to-vehicle information through VANET	-	-
Incident warning (RWW)	Indication of roadwork ahead	-	Infrastructure-to-vehicle information through VANET	-
Local road weather (RWS)	Local weather information and forecast to the location of vehicle	Temperature, road surface condition sensors, GPS	Road surface condition sensors, temperature, rain intensity, humidity, wind	Weather radars, weather stations etc.
Route weather	Weather information and forecast to the vehicle route options	Temperature, road surface condition, GPS	Road surface condition sensors, temperature, rain intensity, humidity, wind	Weather radars, weather stations etc.

The system was piloted in off-line operation since the autumn of 2011 in the Tampere region in Finland. Five pilot vehicles were equipped with measurements for temperature, wipers on/off, emergency lights on/off, fog lights on/off, ABS (Anti-lock Braking System), ESC (Electronic stability control), high beam on/off and 3D-accelerations. For the public pilot, conducted on 25 January 2012, the online services of road weather warnings, accident and incident warnings and approaching emergency vehicle warnings were delivered to four pilot vehicles and one advanced road side unit. Figures 3 and 4 show a pilot vehicle routing in the pilot service area. The services were delivered to vehicles via dedicated screens. The user interface was not fine-tuned but presented the service data as text information or as warning signs on a map as seen in Figure 4. Services were provided both in short range (IEEE 802.11p) and long range (3G) communication in such manner that the short range IEEE 802.11p network was used whenever available, and in other times the system relied on the 3G network.

The services of the pilot system operated as expected. The service data was transferred between vehicles instantly with IEEE 802.11p and within seconds when using 3G, having the data travel through the network oriented service core. All in all, the pilot was successful, showing the service sketch in real-life operation with decent response times. It was concluded that there are no foreseeable obstacles for large-scale operational use of the system to improve traffic safety and convenience.



Figure 3. WiSafeCar pilot vehicle in operation.



Figure 4. WiSafeCar pilot vehicle screen displays.

5 CONCLUSIONS

Real-time wireless traffic service platform for vehicles is generally recognized as an eminent area of R&D within ITS. Significant weather conditions affecting traffic are rarely included in application development, despite the undisputed increasing frequency of adverse, extreme and high-impact weather phenomena throughout the world. Only in the very recent works the weather has started to play more visible role, but still merely arranged by automatic singular devices rather than via expert meteorological systems. The WiSafeCar approach includes the weather component in an effort to establish a framework to meet with all relevant challenges facing the development of a functional real-time wireless traffic service platform. Furthermore, our weather service is a combination of FMI meteorological system supported by vehicular measurements, rather than just independent weather measurements. Our vision is that in the future of road weather systems must be trustable and reliable, and therefore link between road weather service and other meteorological data available is crucial.

6 REFERENCES

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