Intelligent Road Weather Forecasting in the CARLINK Platform

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ABSTRACT

The objective of the international R&D project CARLINK (Wireless Traffic Service Platform for Linking Cars) is to develop an intelligent wireless traffic service platform between cars, supported with wireless transceivers along the roads. Over ten partner institutes and companies representing three countries, Finland, Luxembourg and Spain, participate in this three-year (2006-08) research undertaking. Each participating country has its own site-specific application. The Finnish application relates to real-time observing and very short-range forecasting of local road weather to address and ease wintertime road traffic operations under adverse weather conditions, thus enhancing traffic safety. The other partners develop services for public transportation (Luxembourg) and urban traffic management (Spain). The road weather application is exclusively managed by Finnish Meteorological Institute (FMI).

Keywords: Road weather observing, modelling and forecasting, wireless data transfer, car-to-car communication

1. INTRODUCTION

There are large amounts of observed weather information available at fixed road weather observing sites which are typically located along the main highways in Finland. However, the spatial distribution of these stations is still not sufficient to provide enough details of the intermittent and variable weather conditions, especially during wintertime. Finnish Meteorological Institute (FMI) runs an operational road weather forecast model during the cold season of the year. This one point energy balance model produces a.o. air and surface temperature forecasts and also defines the condition of the road surface (e.g. snow-covered, icy, frosty, wet, dry). The operational model uses as its input data from the road weather observing sites.

Modern cars are equipped with an increasing number of diverse observing systems which can measure weather related parameters like the ambient temperature and the road surface friction based on car wheel rotation. Such data can be aggregated practically continuously in the data terminal equipment of the cars. It is the idea in CARLINK to collect some of these instantaneous, up-to-date data from cruising vehicles, further delivered to other vehicles, and eventually to be fed in the road weather model, in support of the more conventional observations. Consequently, the CARLINK framework is expected to provide a more detailed spatial and temporal analysis of prevailing and expected road weather than previously. A system test and demonstration will take place during autumn/winter 2008 along a pre-specified road stretch on the E18 highway in Finland.

There are diverse technical solutions available for car-to-car communication, most commonly applying bilateral communication protocols between two vehicles, or broadcasting information from one vehicle or infrastructure to vehicles in the surrounding area. The CARLINK approach is to adapt an intelligent hybrid wireless traffic service platform supported with wireless transceivers acting as access points along the roads (for more details, see [4]). Communication between cars is arranged in an ad-hoc manner together with wireless base station connection to the background network. Various wireless local area network technologies and ad hoc networking technologies are integrated (WLAN, WiMAX, cellular networks). The integration is necessary to guarantee sufficient coverage and data transmission ability and speed within the various application areas (along highways, minor roads and urban streets). The coverage will be tested under adverse weather conditions by utilizing both conventional surface weather and more specific road weather observations and by applying the local road weather model of FMI.

The CARLINK wireless traffic service platform is designed to provide a basis for a wide range of commercial and governmental traffic and safety services. Likewise the Finnish road weather application, the other applications, such as accident or traffic jam information, can be integrated into a similar telecommunication framework. These will be investigated by the Luxembourgish and Spanish partners of the project. The present paper will, however, not cover them.

2. CARLINK PLATFORM TECHNICAL OVERVIEW

The CARLINK platform boasts a wireless ad-hoc type communication entity with connectivity to the backbone network via base stations and consists of three modules: (i) Traffic Service Central Unit (TSCU), (ii) Traffic Service Base Stations (TSBS), and (iii) Mobile End Users (MEU) (see Figure 1). The TSCU hosts a network of TSBSs along the roads. Our pilot platform uses the IEEE 802.11g-based WiFi network as the radio protocol in the TSBS. However, the platform can host practically any radio communication protocol available. The Mobile End User (MEU), located in a given vehicle, will transfer platform data every time when passing a TSBS (as well as with an encountering vehicle). The MEUs form a wireless network. They do not have continuous connectivity but operate in ad-hoc manner with each other, typically when two cars are passing each other. The data gathered from vehicles are delivered to specific weather and incident/emergency services beyond the TSCU. The updated service data are geographically spread by the TSCU to appropriate TSBSs. Potential critical warnings are delivered without delay via an additional GPRS-based backbone connection, directly from the TSCU to MEUs. This means that any extraordinary weather conditions (like dangerously slippery roads, black ice) or accidents, when having been observed by the first arriving vehicle, will generate a notice to be delivered to encountering vehicles over the platform.

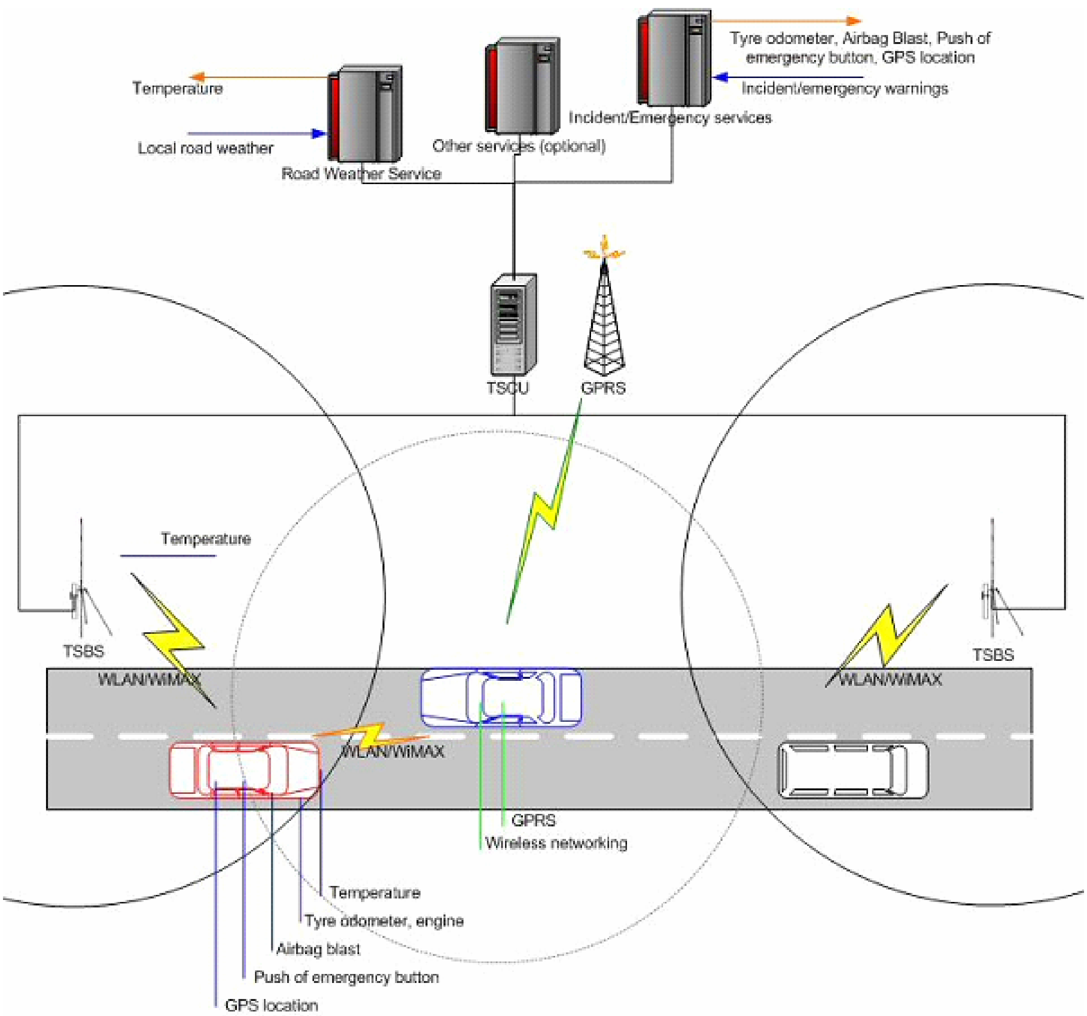

Figure 1. CARLINK system structure.

The TSCU is on the top of the platform with connections to the underlying service cores, the local traffic weather service and the incident/emergency warning service. The TSCU covers user management and, as a central unit of the system, maintains interdependencies between all platform elements. It also stores all of the data gathered within the platform and forwards all appropriate data both to the road weather service and to the incident/emergency warning service. In the present configuration temperature observations from the cars are assumed to be the only road weather data but it is the purpose to exploit other temperature information at a later stage.

The incident/emergency warning service parameters are an airbag blast, a push of the emergency button inside the car, a tire odometer and an engine status, all of them including the GPS location of the observed issue. The road weather service core covers a weather forecast model generating operational local road weather forecasts. The model is supplemented with temperature observations of the cars and their GPS locations. The resulting local road weather information is delivered to the TSCU which further forwards this data to the vehicles over the CARLINK platform. Similarly, the incident/emergency warning service collects vehicle data to build up a warnings database. Depending on the significance of the warning the TSCU selects the appropriate path for its delivery. The most critical warnings (e.g. location of an accident) are delivered through the GPRS connection as rapidly as possible, while the more informative-like warnings can be distributed through the base stations.

The network of TSBSs under the TSCU (Figure 1) acts mainly as a data transmitter from the TSCU to the MEUs and vice versa. The TSBS itself is also collecting weather data and delivering it to the TSCU. The MEUs in the vehicles are the actual users of the CARLINK platform. They are collecting raw platform data along the roads, delivering data to the TSCU and its underlying service cores and, finally, exploiting the weather and warning information. As seen in Figure 1, the parameters gathered from the vehicle are: temperature, combined tire odometer and car gyroscope information, airbag blast, push of emergency button, and the GPS location of each individual data source.

3. CARLINK ROAD WEATHER APPLICATION

FMI boasts a long history and excellent know-how in road weather modeling and forecasting research and operational service implementation. A description of FMI's road weather modeling activities is given in [2]. Further reasoning for choosing road weather as the use case application within CARLINK was founded on the earlier ColdSpots project ([1] and [3]), where localized road weather behaviour was studied in detail. It was found that fixed road weather stations are not sufficient to define intermittent and variable wintertime road weather conditions.

FMI's road weather model (see Figure 2 and [2]) is a one-dimensional energy balance model which calculates vertical heat transfer in the ground and at the ground-atmosphere interface, taking into account the special conditions prevailing at the road surface and inside the ground below. The model also accounts for the effect of traffic volume on the road. Output from a Numerical Weather Prediction (NWP) model is typically used as a forcing at the upper boundary. This input provides also the horizontal coupling between individual computational points of the model. The basic horizontal resolution of FMI's present road weather model is as sparse as 10 km which means that in principle the model cannot resolve meteorological features beyond this spatial scale. This is of course a severe limitation to local-scale road weather forecasting.

The main body of calculations relate to conditions within the ground, where the vertical temperature distribution is solved to a depth of down to c. six meters. For this purpose, the ground is divided into 15 layers of varying thickness, with the thinnest ones (2-10 cm) closest to the ground surface, where the temperature changes are most pronounced. The model atmosphere is considered as a forcing factor having an effect on the ground surface through a number of variables like ambient temperature, relative humidity, wind speed, short- and long-wave radiation, and precipitation. The values of these variables can be inferred from observations or from a forecast, i.e. the model does not make a distinction as to the source of the input data. The heat balance at the ground surface is solved on the basis of these variables and taking into account such additional factors as sensible and latent heat fluxes as well as atmospheric stability. The effect of melting and freezing is also included in the energy balance.

An additional forcing at the surface is the traffic volume, which causes not only increased turbulence but also mechanical wear of e.g. snow, ice or frost that prevails on the surface. A spatially constant traffic effect is assumed in the model, and during night time a smaller traffic factor is used. Further to calculating the ground and road surface temperatures, the model performs a road condition interpretation. Eight different forms of road surface description are used: dry, damp, wet, frost (deposit), dry snow, wet snow, partly icy, and icy. The model furthermore combines information about the road conditions, storage sizes and certain weather parameters to produce a three-valued traffic condition index describing the traffic conditions in more general terms. They are: normal, bad, and very bad, and this same classification is used for traffic condition warnings issued by FMI.

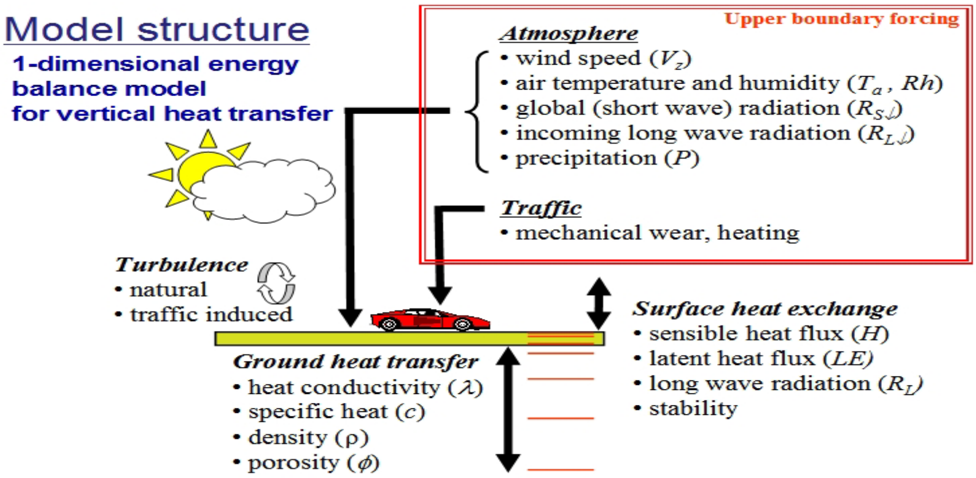

Figure 2. Schematic of the road weather model.

It was noted earlier that fixed road weather stations, although much more densely distributed than conventional meteorological (synoptic) observation sites, cannot adequately reveal detailed local small-scale meteorological features. This holds true especially during wintertime and strongly affects the applicability of present (road) weather models for local forecasting. Figure 3 shows an illustrative example. The lower part of the figure shows a 30 km road stretch along the major E18 highway in Finland and, as an indication of the scale, a superimposed 10 * 10 km horizontal grid mesh. The upper part of the figure shows the observed road surface temperature variations along this 30 km stretch (represented by the red curve) on a given date, made with a high-quality optical device attached to the car driving thru the route. The blue symbols, on the other hand, indicate temperature measurements with the car's own temperature sensor. Typically these thermometers are located in the side mirror or under the wing of the car and do not measure road surface temperature per se. In this particular situation, however, the correspondence is actually astonishingly good. The reason is that we are in quite extreme weather conditions when the air above the surface was quite stable. What is noteworthy, though, is that the temperature variations were as big as 10 degrees within a distance of a few kilometres. For example in such situations additional car measurements might be useful to complement road weather model output.

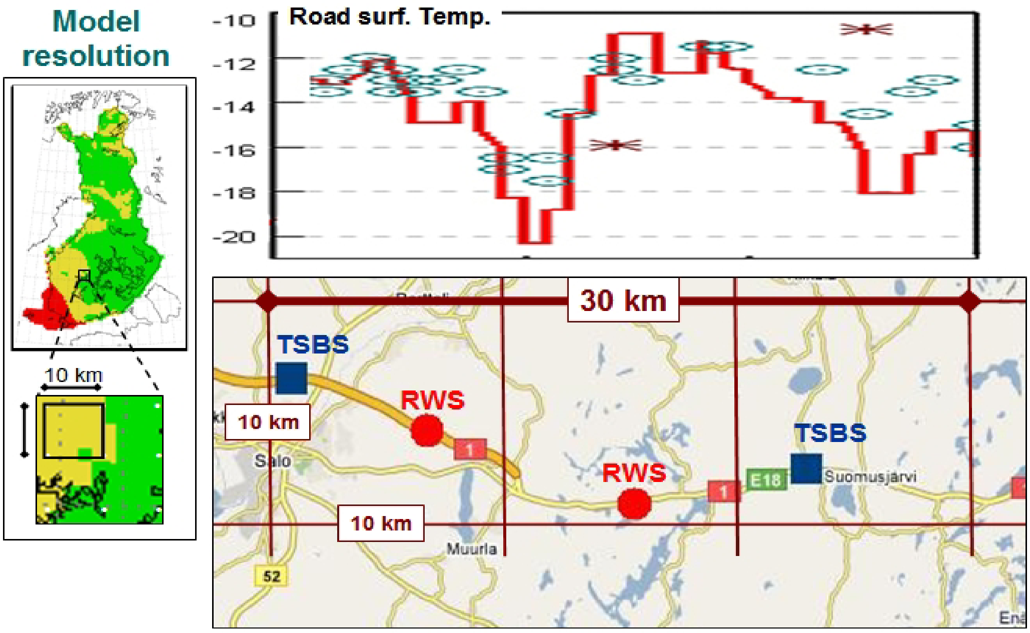

Figure 3. Road surface temperature observations along a 30 km stretch (see text for more details).

4. UPCOMING CARLINK PLATFORM DEMONSTRATIONS

The ultimate goal of the CARLINK concept is to build an intelligent wireless communication platform for vehicles in which they will deliver weather observations to the platform core and to the road weather analysis/forecasting system of FMI. This information is further delivered to vehicles as analyzed information about local road weather and as potential warnings against incident en route. The CARLINK solution will be extensively tested during autumn/winter 2008 on a pre-defined test route along highway E18 at the outskirts of Turku in Finland (Figure 4). Test cars will be cruising back and forth along this route and various functions of the CARLINK platform will be tested and demonstrated. These will include a.o. vehicle-observed data evaluation, base station distance optimization, user interface evaluation, as well as connection time, thruput and service update analysis.

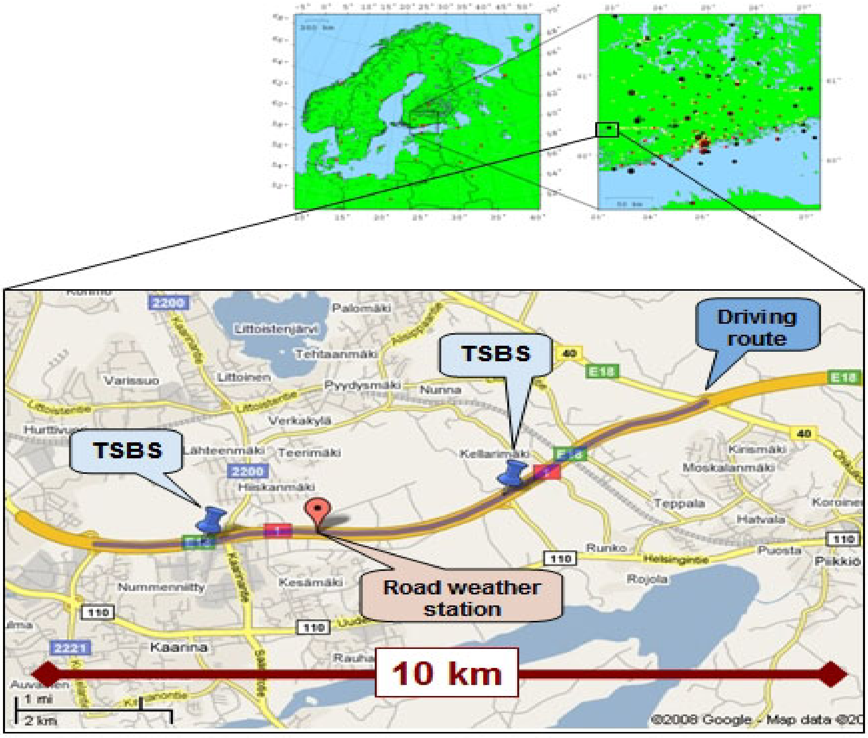

Figure 4. CARLINK test site demonstration.

4. REFERENCES

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