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

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Project objectives

✓ EU Eureka-program Celtic-cluster Call 6 project in 2009-2012 (Finland, Luxembourg and Korea)
✓ Comprehensive, secure and reliable solution for V2I (Vehicle to Infrastructure) and V2V (Vehicle to Vehicle) communications
✓ 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)
  ▪ Vehicles equipped with on-board vehicle computers & vehicular networking capabilities (IEEE 802.11p and 3G)
  ▪ Access point-like roadside units
  ▪ The linking point within the fixed network, acting as the interface between vehicles and the independent services
<table>
<thead>
<tr>
<th>Service</th>
<th>Overview</th>
<th>Internal Data Sources</th>
<th>External Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident warning</td>
<td>Accident in road interpreted, warning spreaded to the accident vicinity area</td>
<td>Airbag burst, abnormal GPS location, emergency lights on</td>
<td>Accident info from The Traffic Information Centre or authorities</td>
</tr>
<tr>
<td>Incident warning, bad conditions</td>
<td>Exceptionally bad weather conditions interpreted or observed</td>
<td>Temperature, GPS, ESP activation, ABS activation, friction, surface sensors</td>
<td>Road surface condition sensors, temperature, rain intensity, humidity, wind</td>
</tr>
<tr>
<td>Incident warning, slippery road</td>
<td>Slippery road conditions observed in specific spot</td>
<td>Surface sensors, angular speed /acceleration, GPS, ESP, ABS, friction</td>
<td>Road surface condition sensors, temperature, rain intensity, humidity, wind</td>
</tr>
<tr>
<td>Incident warning, vehicle abnormal behaviour</td>
<td>Abnormal behaviour (sliding, sudden breaking) of vehicle observed, reason not clear but may cause hazard</td>
<td>Gyroscope, GPS</td>
<td>The Traffic Information Centre</td>
</tr>
<tr>
<td>Incident warning, approaching emergency vehicle</td>
<td>Indication of approaching emergency vehicle</td>
<td>Vehicle-to-vehicle information through VANET</td>
<td>-</td>
</tr>
<tr>
<td>Incident warning, Roadwork/Intersection</td>
<td>Indication of roadwork ahead</td>
<td>-</td>
<td>Infrastructure-to-vehicle information through VANET</td>
</tr>
<tr>
<td>Road weather</td>
<td>Local weather information and forecast to the location of vehicle and vicinity ahead, using speed and bearing of vehicle</td>
<td>Temperature, road surface condition sensors, GPS, friction</td>
<td>Road surface condition sensors, temperature, rain intensity, humidity, wind</td>
</tr>
<tr>
<td>Traffic jam info</td>
<td>Information about traffic jams and congestion, re-routing</td>
<td>-</td>
<td>Traffic amount estimation</td>
</tr>
<tr>
<td>Route planner</td>
<td>Planning route to expected destination</td>
<td>-</td>
<td>Traffic amount estimation</td>
</tr>
<tr>
<td>Parking places</td>
<td>Real-time parking place availability info</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Vehicle data generation

- Temperature
- Camera
- ABS/ESP
- Gyroscope
- Critical temp. change
- Windshield wiper
- Hazardous location
- Fog Lights On
- Airbag
- Emergency lights
- Location
  - time
  - speed
- Slippery
- Car Swerving
- Ice/Slippery
- Rain
- Danger
- Low Visibility
- Accident
- Special Event (instantly)
- Temperature (pre-defined interval, sorted data)
Road weather model

✓ One dimensional energy balance model which takes into account the special conditions at the road surface and inside underlying ground, as well as traffic density effects
✓ Output from a Numerical Weather Prediction (NWP) model is used as upper boundary
✓ 5 km horizontal resolution of the NWP model cannot resolve meteorological features beyond this spatial scale
  ▪ Model spatial scale can be enhanced with novelty sub-grid analysis techniques and additional weather data collected from platform vehicles, roadside units and other potential sources.

Model structure

1-dimensional energy balance model
for vertical heat transfer

Atmosphere
- wind speed \( (V_z) \)
- air temperature and humidity \( (T_a, R_h) \)
- global (short wave) radiation \( (R_{S,a}) \)
- incoming long wave radiation \( (R_{L,a}) \)
- precipitation \( (P) \)

Upper boundary forcing

Traffic
- mechanical wear, heating

Surface heat exchange
- sensible heat flux \( (H) \)
- latent heat flux \( (LE) \)
- long wave radiation \( (R_{L}) \)
- stability

Ground heat transfer
- heat conductivity \( (\lambda) \)
- specific heat \( (c) \)
- density \( (\rho) \)
- porosity \( (\phi) \)

Turbulence
- natural
- traffic induced
Road weather model operation

- To produce road weather forecasts with higher spatial resolution we divide road stretches into a number of segments (scale from a few kilometres down to metre-scale, depending on the available computer resources).
- Model results are further interpolated from regular grid to the centre of each road segment, and a Road Weather Model (RWM) simulations is further done for each of the road segments.
- By default, the input to the RWM are forecasts of a 3D NWP model; however RWM accuracy can be improved by using local weather and traffic observations.
- Final results of the system are the forecasts of road weather and road surface conditions at selected points/segments.
Friction forecasting

✓ An innovative state-of-the-art statistical-numerical road surface friction forecasting technique has been recently developed at FMI
  ▪ Detailed pre-information of potential slipperiness on the roads
  ▪ A decrease in road surface friction is a highly significant negative factor affecting driving conditions
  ▪ The application produces short-range (up to 6 hours) forecasts of friction as absolute values (between 0 and 1), addressed as critical threshold values
✓ Friction forecasting was tested during WiSafeCar pilots
Supporting field measurements

✓ Sunit vehicle-pc:s integrated or installed to vehicles, with NEC LinkBird-MX radio tranceivers (IEEE 802.11p capable) installed to 1-4 test vehicles
✓ Data transmission capacity and general connectivity analysed in different scenarios
✓ The vehicle-to-infrastructure:
  • Average throughput during connection 1.5 Mbps with 100 km/h
  • Link is accessible on average 35 seconds with 100 km/h
✓ The vehicle-to-vehicle:
  • With 100 km/h, the average connection time is more than 20 s
  • The data speed remains approximately same, regardless of the vehicle speed
✓ The vehicle-to-vehicle via relaying vehicle
  • Average throughput dropped to around 1.0 Mbps
  • Semi-regular length of communication period, reason unknown
Pilot system

✓ Project pilot conducted in Finland in January 2012
  • 4 special equipped vehicles to accurate service tests, with one road side unit and large fleet of vehicles collecting platform data
  • Pilot services (including weather services) operated through pilot platform installation
  • Pilot services and overall system performance estimation
### The summary of results and preliminary deployment estimation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Bypass speed (km/h)</th>
<th>Goodput time (sec)</th>
<th>Avg. Throughput when connection (Mbps)</th>
<th>Avg. Throughput during session (Mbps)</th>
<th>Connection availability %</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2I</td>
<td>70</td>
<td>42,437</td>
<td>1.519</td>
<td>0.627</td>
<td>41,257</td>
</tr>
<tr>
<td>V2I</td>
<td>80</td>
<td>38,442</td>
<td>1.527</td>
<td>0.652</td>
<td>42,713</td>
</tr>
<tr>
<td>V2I</td>
<td>90</td>
<td>33,280</td>
<td>1.531</td>
<td>0.637</td>
<td>41,600</td>
</tr>
<tr>
<td>V2I</td>
<td>100</td>
<td>30,320</td>
<td>1.530</td>
<td>0.644</td>
<td>42,111</td>
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<tr>
<td>V2V</td>
<td>70</td>
<td>24,044</td>
<td>1.453</td>
<td>0.679</td>
<td>46,751</td>
</tr>
<tr>
<td>V2V</td>
<td>80</td>
<td>22,508</td>
<td>1.519</td>
<td>0.760</td>
<td>50,018</td>
</tr>
<tr>
<td>V2V</td>
<td>90</td>
<td>18,793</td>
<td>1.461</td>
<td>0.686</td>
<td>46,983</td>
</tr>
<tr>
<td>V2V</td>
<td>100</td>
<td>16,875</td>
<td>1.513</td>
<td>0.709</td>
<td>46,875</td>
</tr>
<tr>
<td>V2V2V</td>
<td>60-80</td>
<td>36,121</td>
<td>0.950</td>
<td>0.860</td>
<td>81,379</td>
</tr>
</tbody>
</table>
Summary

- An intelligent wireless traffic service platform between cars supported with wireless roadside base stations
- Combined communication structure ensures operation also in early deployment phase or in rural areas, where base station density is low
- Set of example serviced created to exploit platform capabilities and provide enhancements for traffic safety
- Basic operability verified via simulations, field measurements and system deployment
- Considerable amount of traffic fatalities can be avoided with operative system with real time weather and accident info