LOW-COST COOPERATIVE ROAD WEATHER MONITORING STATION

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ABSTRACT

New concept of Cooperative Road Weather Monitoring Station is presented in the paper. Cooperative systems in Traffic & Transportation (Intelligent Transportation systems) are based on communication between vehicles and infrastructure (Roads equipment). It is well-known V2X Technology. The exchange of data between the vehicles and infrastructure is imperceptible by drivers until a potentially dangerous situation is detected, at which moment the drivers concerned will receive an alert. The sensors for temperatures of the air, road surface and road structure, wind speed and direction, humidity, intensity and the state of precipitation, visibility (and other options) are connected to the road weather monitoring station. Road weather information are analyzed and assigned to some road condition categories by the Local processing unit. Some recommendations of speed limits and other possible warnings to driver (Emergency warning system for vehicles) are sent via DSRC (Dedicated short-range communications) to vehicles on the road. Also, the speed limits and possible warnings can sent to variable message signs near the road weather monitoring station.

1. INTRODUCTION

Intelligent Transport Systems (ITS) can be defined as holistic, control, information and communication upgrade to classical transport and traffic systems enabling significant improvement in the performance, traffic flow, efficiency of passenger and goods transportation, safety and security of transport, reduction of pollution etc., [1]. The quality of implementing Intelligent Transport System is primarily based on harmonization and possible integration of individual solutions into integrated systems. The achievement of that is related to design of the basic system organization, the so-called ITS Architecture and definitions of the necessary standards by official organisations. The new paradigm of ITS is Cooperative approach. Cooperative systems are systems by which a vehicle communicates wirelessly with another vehicle (V2V communication) or with roadside infrastructure (V2I communication or I2V communication) with the ultimate aim of achieving benefits for many areas of traffic management and road safety. The development of cooperative systems, based on an exchange of information and communication between vehicles and with the road infrastructure, is currently developing rapidly, [2].
Road Weather Information Systems (RWIS) are essential for traffic because ambient conditions have considerable influence on safety, functionality and efficiency of road traffic.

Therefore, the monitoring system has to be set-up on the elements that enable fast exchange of information and good response. In this sense, Road Weather Information Systems are also very important part of Intelligent Transportation Systems. Today is very actually some R&D in area of use Cooperative approach for these applications. Another way of this approach is the acquisition of road and weather condition information from DSRC equipped public agency vehicles and to transmit this data via roadside infrastructure to a central RWIS server.
The basic features of the cooperative systems in traffic and transportation are described in Section 2. General description of modern Road Weather Monitoring Station is given in Section 3. In Section 4 an overview of road weather information set for driver is given. Some technical characteristics of communication module are given in Section 5. The concluding remarks and some recommendations for the future of cooperative approach in road weather monitoring are given at the end of this paper.

2. COOPERATIVE SYSTEMS IN TRAFFIC AND TRANSPORTATION

Cooperative Systems are important component of the intelligent transportation system architecture. It enables a driver (or its vehicle) to communicate with roadside equipment or other drivers (or their vehicles. As a result, this information can help improve the road traffic safety and efficiency. The general architecture of cooperative system network is presented on Figure 1.

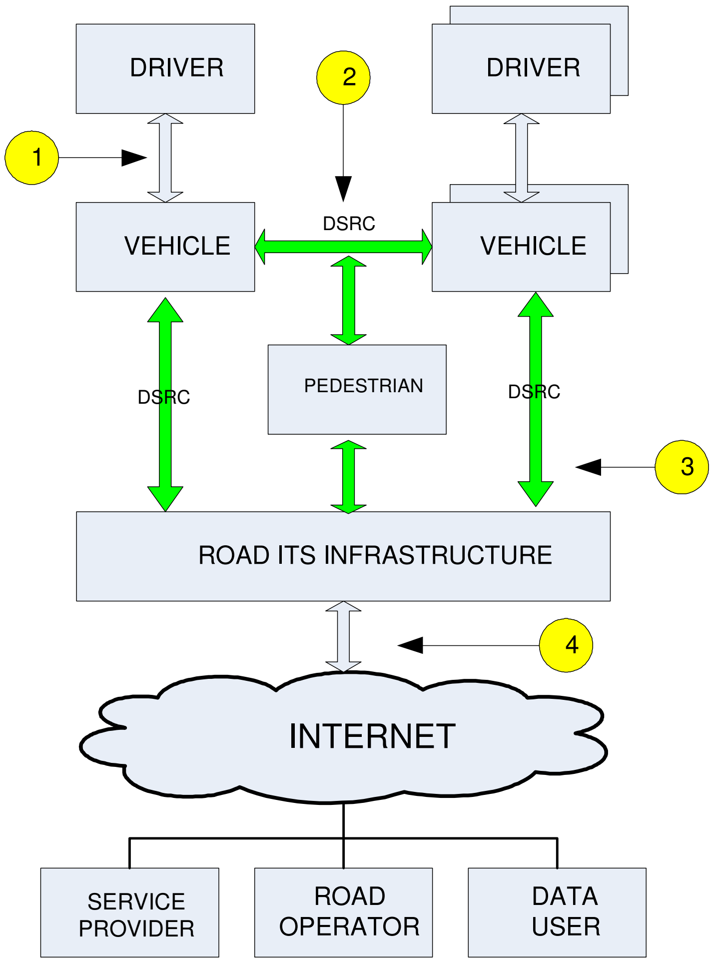

Figure 1 - General Concept of Cooperative Systems

Cooperative system networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and stationary nodes called Road Side Units (RSU) attached to infrastructure that will be deployed along the roads. Also, there are some ideas for movable pedestrian equipment, especially for Vulnerable Road User (VRU). Both OBU and RSU devices have wireless/wired communications capabilities. OBUs communicate with each other and with the RSUs in ad hoc manner. There are mainly two types of communications scenarios in vehicular networks: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R), [3]. The RSUs can also communicate with each other and with other networks like the internet by its users (service providers, road operators, other traffic data users) as shown in Figure 1.

3. ROAD WEATHER MONITORING STATION

Road weather monitoring station consists of multiple sensors that collect data of atmospheric conditions such as air temperature, visibility, air pressure, wind speed and direction, relative air humidity, quantity and type of precipitation. Also the station collects data of road conditions such as surface temperature, temperature beneath the surface. Also it can detect a difference between dry, wet or ice covered surface and it can measure water film thickness.

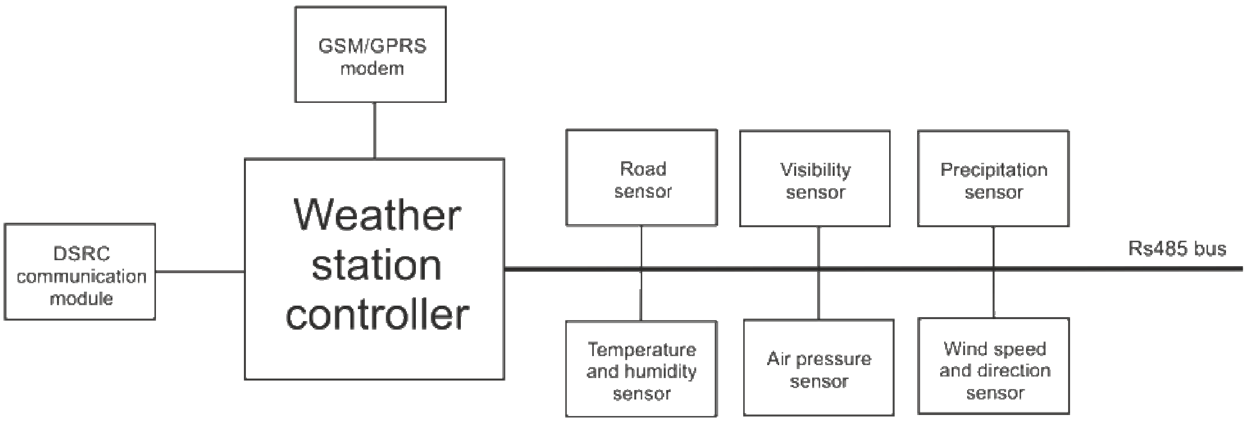

Figure 2 - Weather station block diagram

The central component of the weather station is the controller to which are sensors connected. The main task of the controller is to collect data from the sensor, log the data locally and send a data to the central weather server in regular intervals. For connecting sensors there are several different ports available. These ports can be configured as 2-wire RS485 or RS232 ports. There are also available ports for connecting sensors with current output (4-20mA) and voltage output (0-5V). Whole system can be powered from the local power grid but in the absence of the mains power connection it can be powered from the batteries that are charged via solar panels. In that case the controller is equipped with power monitoring board which monitors several crucial parameters of the system such as battery voltage, charging current, load current etc. If the batteries got over discharge the controller sends a warning message to the central server and in that case the maintenance service can react and change the discharged battery on the site. In order to the controller to send the data to the server it must be equipped with some kind of communication module. This communication module can be connected directly to dedicated local, in most cases optical, network that is connected to the monitoring center. In the other cases where local network is not available communication module could be a GSM/GPRS (or faster 3G, LTE) module. In the last case if we have more than a few

weather stations and other smart traffic infrastructure we can have a dedicated short range communication between them and in the end one of them (could be a weather station, but it can be a separate dedicated device) has a direct connection to the monitoring center.
In the beginning of the last section are listed weather and road conditions that can be measured with this weather station. In the following section is going to be described configuration and types of the sensors which are used to measure these conditions. For measurement of these conditions will be described five different devices.
First device is for measurement of air temperature and relative humidity. For the air temperature is usually used some kind of resistance temperature detectors with positive (PTC) or negative temperature coefficient (NTC). Also there is available some semiconductor type of temperature sensors, but they usually have a slightly worse characteristics than the resistive types.
For the humidity in this case is used capacitive MEMS (microelectromechanical system) sensor. Both of these sensors (temperature and humidity) are connected to the electronics for attenuation and conditioning. Later on these prepared signals are sent to AD converter and later prepared for the output. As mentioned the output can be digital (RS485, RS232) or analog (current output, voltage output). Same technology (MEMS) is used for air pressure sensor.
Wind speed and wind direction can be measured with electromechanical sensors such as cup anemometer and wind wane or just with ultrasonic sensor. Cup anemometer has a three or four cups that transform wind into rotation of the axle on which end is mounted relative encoder. Depending on wind speed there is more or less pulses for controller to count and there is connection between wind speed and frequency of the pulses. Wind wane has a similar principle as cup anemometer but instead of relative encoder it has absolute 5-bit gray code encoder. In this case controller just need to readout the value of the absolute encoder. On the other hand the ultrasonic sensor is more reliable in the winter conditions because there is no moving parts which can froze in the low temperatures. It uses in the measurement two pairs of ultrasonic transceivers: one for the x axis and another for the y axis. Disadvantage of this kind of sensor is lower accuracy in the condition of extensive precipitations.
Precipitation sensor can also be very simple like tipping bucket but also complicated like Doppler radar. Tipping bucket is accurate way to measure rain but it cannot recognize the difference between snow and rain. Also there is a problem with freezing during the winter so it is not maintenance free. Doppler radar can recognize snow from rain and there are fewer problems with the freezing during the winter but in some condition on the road can sometime give a false measurement especially when is mounted incorrectly.
The data from visibility sensor is crucial for detecting the road conditions because the reduced visibility can produce all sorts of dangerous scenarios in traffic. Visibility sensors are using a forward scattered light procedure for estimating visual range of human eye. Sensor contains receiver and transmitter, usually an infrared diode and photo transistor on the other side. The transmitter and receiver are not turned to each other directly but they are turned for a certain angle in relation to horizontal line. After the fog is formed in the front of the sensor reflected light beams from the transmitter are detected by receiver. The amount of the reflected light beams is inversely proportional to visibility measurements. The more beams are reflected the worse are the road conditions. Usually the measurement range is 10 to 2000 meters [4] but there is on the market products for measurements up to 35000 meters [5].
The road sensor is like the visibility sensor very important for measuring road conditions. Also this sensor will be the theme of the future studies so here is going to be explained some principles that are used for building prototype. The goal of the research is to achieve the similar or better results than the sensors developed in the past and improve the algorithms for detecting the road conditions. Road sensor can be divided in two functional

units. The first one is for temperature measurement. It can have one or several temperature sensors: one for the surface temperature and the others are for measurement of temperature beneath the surface. The temperature beneath surface can be useful because it can be indicator when or how long is going to be ice on the road. For example in conditions of low temperatures the ice can form very quickly on the surface but is the temperature beneath surface is over the freezing temperature it will melt faster when the outside temperature rises. The temperature sensors and the measurement principle is the same as was described for the air temperature sensor so additional explanations are not necessary. Second functional unit are the modules for detecting road conditions. For this purposes the sensor measures conductivity and capacity on the road surface. With conductivity measurements the sensor can detect the liquids on the road surface and detect a certain amounts of chemicals in the liquids. Capacity is measured at two different frequencies f and f/2 and the data is used to improve the results which sensor acquired with conductivity measurements. The goal with fusion of this two sensors, temperature sensor and learning algorithms will be to detect road conditions such as dry, wet, ice, black ice. Also it could be estimated water film thickness and chemical concentration. In this first stage in the prototype will be integrated micro radar for detection of water film thickness for comparing estimated results with measured results.

4. ROAD WEATHER INFORMATION SET FOR DRIVER

Road weather information collected from weather station is sent to central data acquisition server and the data is also stored locally at the weather station. Data on the weather station is processed locally and information about possible bad weather is sent to oncoming vehicles to avoid vehicles entering a bad weather area at high speed or without winter equipment [1]. To make it possible to send data to the vehicle weather station is equipped with some short range communication module. Also the protocol between vehicles and infrastructure needs to be developed and maybe the most important part is presentation of the data to driver. Communication module will have separate section further in this paper so here is going to be presented more about presentation of the collected data.

The goal is to present data to driver clearly and on time. There is two ways to present data to driver. The first one is concise and simple and its task is to warn the driver fastest way possible that driver can undertake necessary actions without endangering the other members in traffic. Proposed appearance of the weather warning icon is shown on the Figure 3.

Figure 3 - Proposal for weather warning icon, [3]

It is also possible to show some sort of text warning near the weather warning icon to emphasize the type of weather and the distance to the bad weather area. The warning could be presented on car console, near other informational icons, on screen of the trip computer or on the head-up display (HUD). Also it can be implemented some discrete sound indicators that will ensure that driver notices the weather warning icon. The second type of presentation is extended. This type of presentation presents full data from weather station. The driver can choose from the menu in the car trip computer is going to be presented on the screen. After the driver notices weather warning icon and see extended information about the weather can decide to change a route or adapt to new weather conditions. Use case diagram for road weather exchange information procedure is presented on Figure 4.

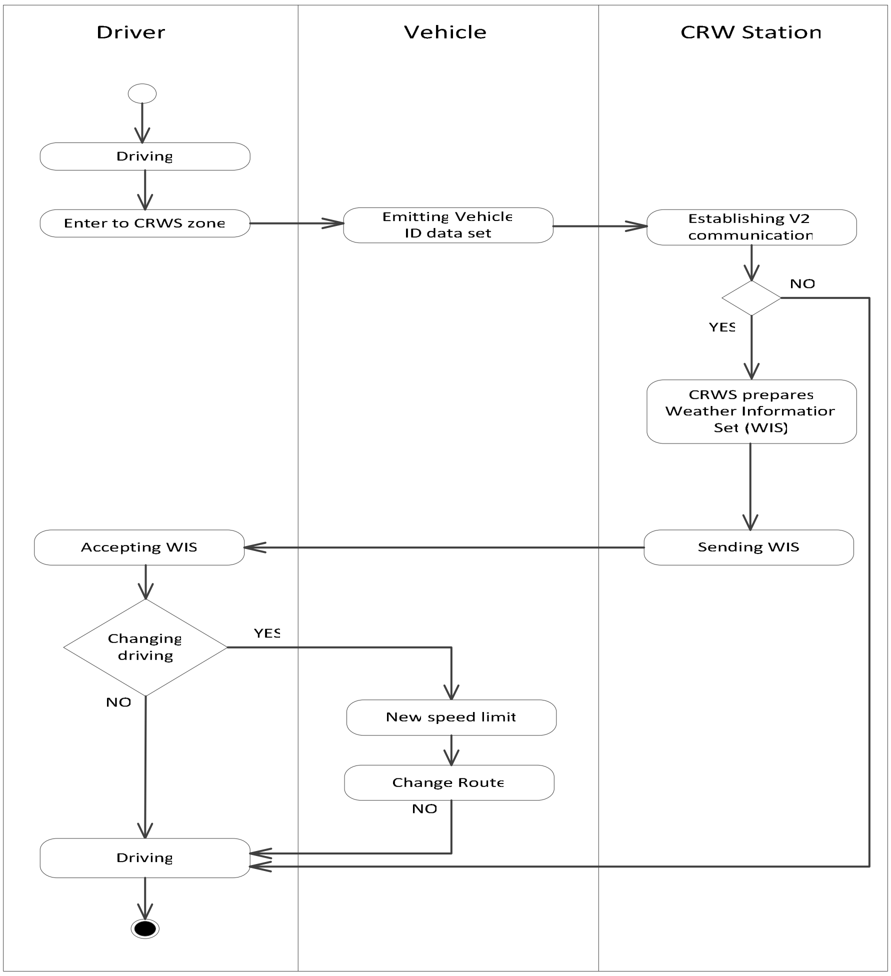

Figure 4 – Use case diagram

5. COMMUNICATION MODULE

As mentioned before weather station must have some sort of DSRC module for communication with approaching vehicles. This DSRC network must meet some requirements that are specific for the vehicular environments such as fast reconnection, high interference environment, impact of weather conditions to range of the network. For that purpose the IEEE 802.11 standard body made an addition to existing 802.11 standards to meet these requirements. The full name of the new standard is 802.11p WAVE (Wireless Access in Vehicular Environments) [6]. This network is going to operate at 5.9GHz so for the foundation is taken IEEE 802.11a because this standard already operates at 5GHz so there is small amount of changes in the physical level of this

standard. Another difference between these two standards is that IEEE 802.11p allocates 10MHz channel while IEEE 802.11a has 20MHz wide channel. In the proposition of the standard 802.11p has allocated seven of 10MHz channels where the two channels at the ends of the spectrum are used for special uses. The channel in the middle of the spectrum is used as control channel and the rest of the channels are used for general purpose.
Communication module will include IEEE 802.11p integrated transceiver connected with a general purpose microprocessor for data processing and communication with the other systems in the vehicle. For that purpose communication module must be equipped with bus connection capability like CAN, LIN or FlexRay transceiver. When connected the communication module can show as previously described the data from weather station.

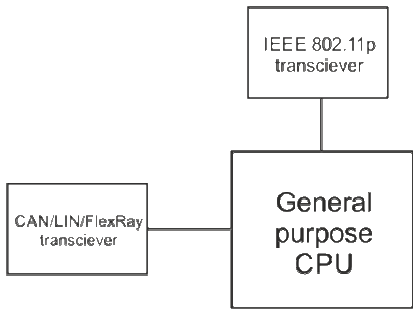

Figure 5 - Communication module block diagram

6. CONCLUSION

New cooperative approach for Intelligent transport systems development provides multiple opportunities in the development of new road weather equipments and system. Various useful information can be generated and transmitted between the roadside equipment and the vehicle. Many of today's complex pavement condition systems in the vehicle can be significantly simplified by transfer selected information from the road weather station to the vehicle. Significant research will be guided in the area of information presentation problem to the driver in the vehicle. Here we expect solutions from simple warnings to complex Advanced Driver Assistance Systems (ADAS).

7. ACKNOWLEDGMENTS

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