Traffic Regulations Monitoring Using VSNs

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Abstract — **Traffic regulations represent formal control of motor vehicle traffic worldwide. Their violations are one of the key reasons for traffic accidents causing human losses and material damages. Therefore, the monitoring of traffic regulations can substantially increase the traffic safety and provide intelligent traffic management. Recent developments in vehicular communications, as well as the production of high performance sensors, led to novel ideas in the corresponding area. This paper shows an applicative solution for traffic regulations monitoring using a Vehicular Sensor Network (VSN). The solution is tested on a small testbed realized with SunSPOTs and several other sensors available off-the-shelf.**

Keywords — **VANET, VSN, Sensors, Traffic regulations monitoring, SunSPOT.**

I. Introduction

Traffic accidents cause losses of thousands of lives and huge material damages every year. One of the key reasons for majority of traffic accidents are the violations of traffic regulations. Therefore, having an efficient way to detect violations will yield reductions of traffic accidents and enable intelligent traffic management.

Recent advances in telecommunications, computing and sensor technology emerged the vehicular environment as an attractive research field for the communications community. They led to a definition of an entirely new communicating paradigm, i.e. vehicular communications, which can increase passenger safety and provide "smarter" road and regulations monitoring.

In the past decade, the wireless ad–hoc networking has been established as a candidate technology for networking vehicles. Its characteristics support self-organization among dynamic and autonomous devices (in this case vehicles). In the near future, Vehicular Ad–hoc NETworks (VANETs) will provide means for development of a large variety of vehicular applications ranging from transport automation systems to entertainment and comfort based applications [1].

An extension of VANETs exploiting the usage of various sensors that sense road and vehicle phenomena and send sensor data to relevant entities (e.g. users, institutions etc.) represents the Vehicular Sensor Networks (VSNs). VSNs greatly affect the emerging traffic regulations monitoring issues [2, 3]. For example, the most prominent tool for monitoring the use of road regulations nowadays (besides traffic police) is video surveillance. Many countries' transportation departments have implemented video cameras on the roads (especially city crossroads) which are usually a part of a Closed-Circuit Television (CCTV) network [4, 5]. Even though the extensive usage of CCTV for traffic regulations monitoring proved to lead to a decrease of traffic violation, its possibilities are limited. VSNs allow ubiquitous road sensing and enable more diverse applications and regulations policing.

This paper proposes a traffic regulations monitoring solution based on a VSN. The solution encompasses several sensor technologies to provide efficient data gathering from the vehicular environment and to disseminate the gathered information to relevant authorities. The whole approach is tested on a custom built VSN testbed with components already available on the market.

The paper is organized as follows. Section II briefly discusses some of the main VSN challenges that greatly affect the possibilities to realistically create a VSN application. Section III elaborates on a novel application for traffic regulations monitoring named Smart Road Monitoring (SRM) and the testbed created as a proof-of-concept. Finally, section IV concludes the paper and gives some possible future guidelines.

II. VSNs' Implementation Challenges and Constraints

In order to have a real world implementation of a VSN based application, a number of technical issues need to be resolved. The vehicular environment is very specific in its nature. It is characterized with high and spatially structured mobility of nodes that leads to a very dynamic topology of the network [6]. This dynamic topology invokes a variety of technical issues such as establishing a fully functional routing algorithm, maintaining end–to–end connectivity and scalability etc [7, 8]. Contrary to the constraints the mobility produces, power consumption is not a crucial issue at the vehicle since the battery provides sufficient energy [9]. This empowers designers with the ability to use more resource demanding protocols and techniques.

According to the previously stated constraints, each VSN application needs to resolve these challenges. Depending on the application characteristics, a different design philosophy (that deals only with the constraints being imposed in front of the application being developed) can be used. The following section will elaborate on a VSN based application for efficient traffic regulations monitoring called Smart Road Monitoring (SRM). The SRM application combines ad–hoc networking with a

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fixed infrastructure to enable detection of traffic violations and provide appropriate notifications.

III. SMART ROAD MONITORING (SRM)

According to the VSNs' specifics mentioned above, this section proposes a traffic regulations monitoring system. The system has 2 key features:

- real–time monitoring on the obedience of road regulations and
- driver and authorities notification of rule violations and dangerous situations.

The system features are enabled with the deployment of processing and communication equipment in vehicles and alongside roads. Additionally, sensors are mounted in vehicles for sensing the vehicles' behavior and the surrounding environment. The current version of the SRM application supports monitoring of 3 road regulations, i.e.

- speeding,
- stopping on a STOP sign and
- driving in the wrong direction on a one-way street.

Also, a pre-crash signalization is enabled.

The SRM application operates on the assumption that all three regulations are located on a single crossroad. Subsequently, a testbed for proof-of-concept was developed that relies on this assumption.

A. System Architecture

The architecture enabling the SRM application consists of four different entities, Fig. 1:

- Vehicle node (VN),
- Roadside Node (RSN),
- Data Center (DC) and
- Authorities (AU).

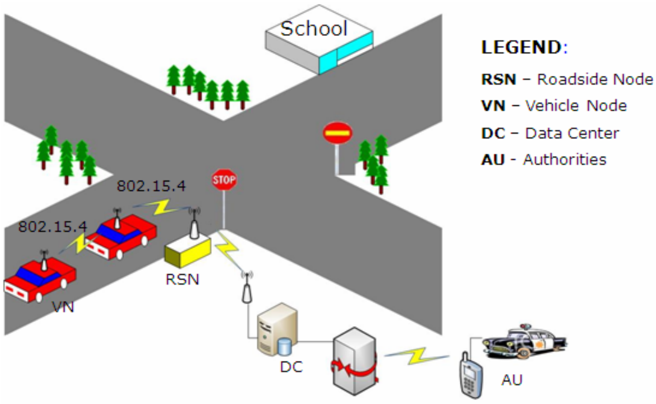

Fig. 1. System architecture

The vehicle along with the appropriate mounted equipment represents the VN. It is used to sense the environment. The RSN is a processing and communication unit located by the road. It can communicate with both the VN and the DC, relaying the data received from the VN to the DC. The data gathered from the nodes is stored in the Data Center (DC). When traffic violations occur, data is sent to the authorities. The authorities can have access to this data through the DC. Communication between two VNs is also possible.

B. Communication Protocol

Although VSNs are not typically concerned with power consumption, the usage of a RSN enforces the SRM concept to focus the processing and most of the "broadcasting" at the VN.

The VN constantly broadcasts its ID. When the RSN "hears" the VN, it returns the road regulations for the specific area. The VN collects the data through the sensors and determines whether a violation has occurred according to the regulations received from the RSN. The decisions are sent to the DC through the RSN. The authorities can be notified with an alarm message in cases of violations.

Two VNs can communicate between each other, resulting in a notification for the driver in case of a hazardous situation. A message sequence chart of the communication protocol is shown in Fig. 2.

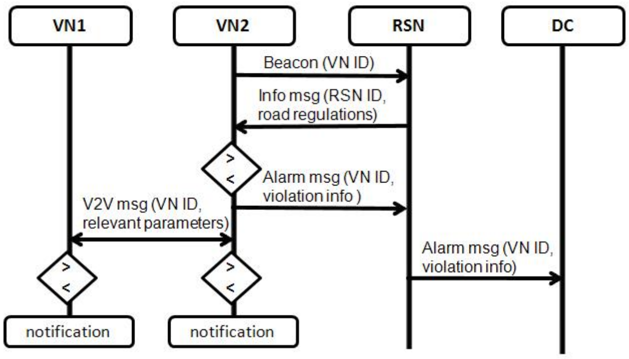

Fig. 2. Communication protocol

Having defined the system architecture and the basic communication protocol in usage, following subsections will give more insight into the equipment necessary for testbed realization of the SRM application along with some results.

C. Equipment

In order to demonstrate a proof-of-concept of the SRM application, a small testbed using toy vehicles equipped with a SunSPOT device [10, 11] was created. The SunSPOTs perform all the processing and serve as communication units. They work on IEEE 802.15.4 at the physical and data link layers. Additionally, a LV-MaxSonar EZ4 distance sensor [12] and a ServoTek E-Series tachometer [13] are connected to the SunSPOTs. The distance sensor is positioned at the toy vehicles' front and it measures the distance to objects in front of it (vehicles). The tachometer is mounted on the right rear wheel and is used for determining the vehicles' speed. A simple circuit is triggered depending on the vehicles' motion status (whether the vehicle is moving or not). A HP Server is used to represent the DC. Moreover, sending SMS messages to the authorities is enabled through a GSM/GPRS Gateway.

D. Programming the Equipment

The intelligence in the whole system is introduced through the SunSPOTs. SunSPOTs are easily programmable devices in JAVA based on a Squawk virtual machine. Two separate MIDlets form the basis of the testbed, one for the VN and another one for the RSN. At the DC, a host application is used to gather the decisions received from the RSN, which are later stored in a SQL Server database. The data stored in the database can be monitored through a Graphical User Interface (GUI).

E. Implementation Issues

The characteristics of the specific testbed environment generally produce two main problems: localization and sensor measurements reliability. Key feature in the scenario is providing information for the vehicles position in every moment due to the difference of the applied traffic regulations in different areas. In order to accomplish this, 2 algorithms for regulations violations and localization are created, one more suitable for the testbed and another one for implementation with real vehicles. The first algorithm assumes that the vehicle can be aware of the moment when it has reached the previous crossroad. With the ability to measure the length of the trajectory, whether it has turned right or left, the vehicle can have a relatively precise picture of its current location. When the vehicle will reach the next crossroad the device placed as a RSN will refresh this location information. In a real setting a simpler solution is possible. By using RSSI (Radio Signal Strength Identifier) the transition between approaching and distancing from the RSN positioned at the crossroad can be determined, thus detecting when the vehicle has reached the crossroad.

Sensor networks are usually susceptive to the accuracy of raw sensor data. By tracking a certain large enough amount of sensor data samples in a small enough time interval, we try to avoid errors, thus resulting in increased reliability.

F. Results

The realized testbed proves that the design of the Smart Road Monitoring (SRM) application for road regulations monitoring is feasible. The entire communication protocol can be properly carried out resulting in the detection of regulation violations. An output taken directly from the VN that shows the decisions regarding the road regulations is shown in Fig. 3.

Fig. 3. VN output – traffic regulations monitoring

Combining the information about the relative distance to the front vehicle and the speed of the two vehicles allows determining a dangerous situation. The testbed uses LEDs on the SunSPOT as a notification utility. Such a pre-crash signalization is shown on Fig. 4.

Fig. 4. VN output – pre crash signalization

At the DC, a GUI can be used for monitoring the decisions stored in the data base. The GUI is shown on Fig. 5.

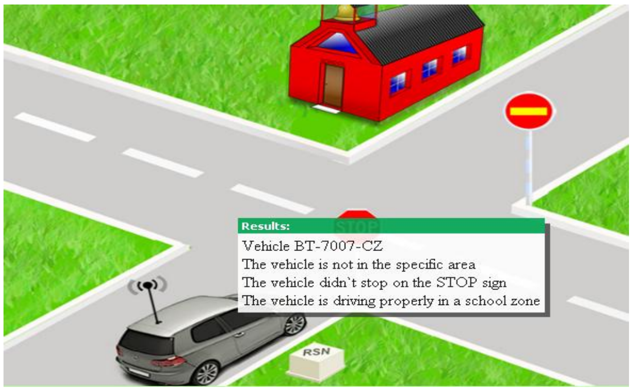

Fig. 5. GUI

At the GUI, tracing of the vehicles' speed is implemented, Fig. 6.

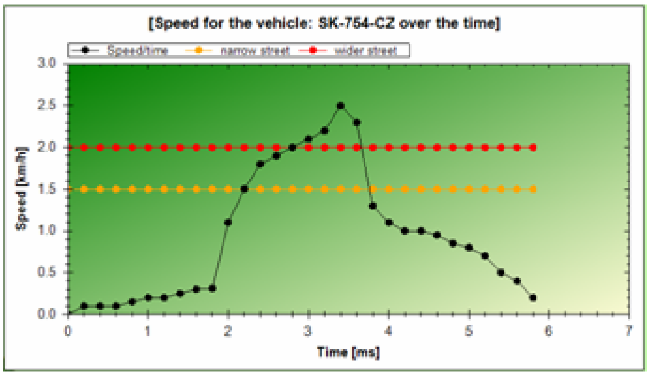

Fig. 6. Tracing the vehicle' speed at the GUI

Currently two means of authorities' notifications are implemented, i.e. SMS message and an e-mail. Despite the fair amount of unreliability, SMS messages and e-mails are sufficient at this stage of the implementation since only eventual notification is needed and promptness is not a requirement. The generated SMS message is shown on Fig. 7 and the e-mail is shown on Fig. 8.

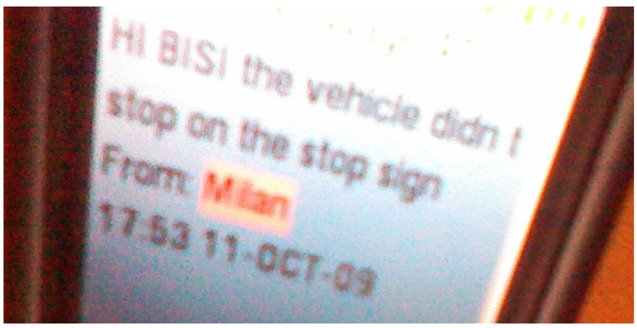

Fig. 7. SMS notification


Notification from Smart Road Monitoring at Thu Sep 03 12:21:45 CEST 2009
From: "notify@prosense.mk" <notify@prosense.mk> Add to Contacts
To: biserabbe@yahoo.com; druid0101@gmail.com

There is a notification from the Smart Road Monitoring system
The vehicle with Registration: SK-754-EF
has not stopped on a STOP sign!!!
This is an automated response from FEEIT's TC server for notification.

Fig. 8. E-mail notification

This section elaborated on the possible implementation of a traffic regulations monitoring system using a VSN. It discussed a novel, custom built, application (i.e. SRM) which was implemented on a laboratory testbed in order to provide proof-of-concept demonstration on the potentials of the whole concept. The presented results clearly show that the SRM can provide monitoring of road regulations and subsequent notifications. In order to make the SRM application practically implemental, more advanced alerting mechanisms can additionally be investigated.

IV. Conclusions and Future Work

Traffic regulations monitoring is an emerging research topic. It can be realized with traditional methods (e.g. CCTV) or rely on new communicating and sensing paradigms such as the VSNs. The overall idea is to enforce cooperative vehicle behavior that enables more efficient traffic regulations monitoring and notifications in case of certain violations.

This paper proposes the SRM application exploiting VSNs for monitoring the use of traffic regulations. The system consists of four main entities that exchange relevant data in a vehicular environment (i.e. VN, RSN, DC and AU). Adapting to the specific conditions that VSNs present, where power consumption can only be a constraint at the RSN (but not at the VN), a specific communication protocol was also designed. Additionally, a small testbed platform was created proving the feasibility of the SRM application. Successful detections of traffic regulation violations are represented through SMS messages and e-mails sent to the governing bodies for traffic violations.

Future work will include various enhancements of the basic SRM application. The whole concept can be used as a part of a larger road monitoring application where problems such as scalability, data dissemination and processing must be carefully addressed. For example, the VN to VN communication in a larger scenario would benefit more by employing IEEE 802.11p [14, 15] rather than IEEE 802.15.4. IEEE 802.11p allows for prioritizations of specific data, thus enabling real-time and prompt notifications. Additionally, localization techniques (e.g. GPS, RFID) can be implemented for tracking vehicles in larger areas (e.g. vehicles that have broken stricter regulations) [16, 17]. Also, a variety of sensors that would help determine possible violations for different traffic regulations can be added. It would all contribute to making the future roads truly "smart".

Acknowledgment

This work was funded by the EC FP7 ProSense project (http://www.prosense-project.eu). The authors would like to thank everyone involved.

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