Performance Evaluation of the IEEE 802.11p Protocol in a VSNET scenario

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Abstract: Vehicular sensor network (VSNET) is an emerging technology, which combines wireless communication offered by vehicular ad hoc networks (VANET) with sensing devices installed in vehicles. VSNET creates a huge opportunity to extend the road-side sensor infrastructure of existing traffic control systems. The efficient use of the wireless communication medium is one of the basic issues in VSNET applications development. The Intelligent Transportation Systems (ITSs) has also emerged as a key candidate that is benefited from the unique features and capabilities of VANET and Wireless Sensor Networks (WSNs). Currently, WSNs are beginning to be deployed in a rapidly manner. It is not unreasonable to expect that in 5-10 years that the world will be covered with wireless sensor networks with access to them via the Internet. This can be considered as the Internet becoming a physical network. The IEEE 802.11p Wireless Access in Vehicular Environment (WAVE) protocol providing for vehicle to infrastructure and vehicle-to-vehicle radio communication is currently under standardization. This paper provides a simulation study of the proposed IEEE 802.11p MAC protocol focusing on vehicle-to-infrastructure communication, and evaluates the performance of protocol under metrics such as throughput and packets rate of drop. To carry out the simulation process, an open source simulator tool is used for this study namely-NCTUns-6.0 (National Chiao Tung University Network Simulator).
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Key words: *VANET, VSNET, WSN, ITS, IEEE 802.11p, NCTUns-6.0 simulator.*

1. Introduction

The world is progressing at a very fast manner in almost all spheres of life and so is the case with wireless networks, which have become a widely spread type of communication technology and also a challenging scientific area for new fields of research. Many contributions in ad hoc networks, such as WSNs and VANETs, have been proposed **[1, 2]**. Both WSNs and VANETs are kind of ad hoc networks which can operate without any centralized or predefined management. The network organization is carried out by the nodes themselves, every node is capable to work as a sender, receiver or as a routing platform for forwarding packets. WSNs are an interesting alternative to other Technologies traditionally used for monitoring. Their use requires low installation and maintenance costs and enables the development of distributed collaborative applications, thus not limiting their functionality to the mere acquisition of data.

WSNs are usually composed of small, low-cost devices that communicate wirelessly and have the capabilities of processing, sensing and storing. The nodes often self-organize after being deployed in an ad hoc fashion. It is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives the user the ability to instrument, observe, and react to events and phenomena in specified environment. Due to their small size and weight it allows fast deployment in the monitored environment. In addition, it has some restrictions in comparison to other ad hoc networks, such as their limited memory, small transmission range, scarce energy, and low processing capacity. In addition, WSNs can be used in conjunction with other technologies making more complex applications possible. Such as VANET and the functions that can perform by these applications divided into four different categories:

(a) Traffic safety, (b) traffic law enforcement, (c) traffic control, and (d) smart parking applications **[2].**

VANET is a subclass of Mobile ad hoc networks which provides a distinguish approach toward Intelligent Transport System (ITS). Besides providing inter-vehicle communication; VANETs also provides communication between vehicles and Road Side Units (RSU). Such networks comprise of sensors and On Board Units (OBU) installed in the vehicle as well as the RSU. The data collected from the sensors on the vehicles can be displayed to the driver, sent to the RSU or even broadcasted to other vehicles depending on its nature and importance. The RSU distributes this data along with other data from the road sensors, current weather and traffic control centers to the vehicles. Also, it provides commercial services such as parking space booking, Internet access and gas payment **[3].**

VANET application can be categorized into following categories (a) VANET provide ubiquitous connectivity on the road to mobile users (b) It provides efficient vehicle to vehicle communications that delivers Intelligent Transport System. That system includes variety of applications like cooperative traffic monitoring, control of traffic flows, blind crossing and collision prevention. (c) Comfort application is the application to allow the passenger to communicate with other vehicles and with internet hosts, which impresses passengers comfort. Figure 1 illustrates the VANET System Architecture **[4].**

Vehicular sensor network (VSNET) **[5, 6]** is emerging as a new sensor network application for monitoring the physical world of urban environments, which is also a type of VANET **[7].** VSNET is a high speed mobile wireless sensor network containing set of smart vehicles which are equipped with different types of on-broad sensors and can communicate with each other or pre deployed road side units via wireless medium.

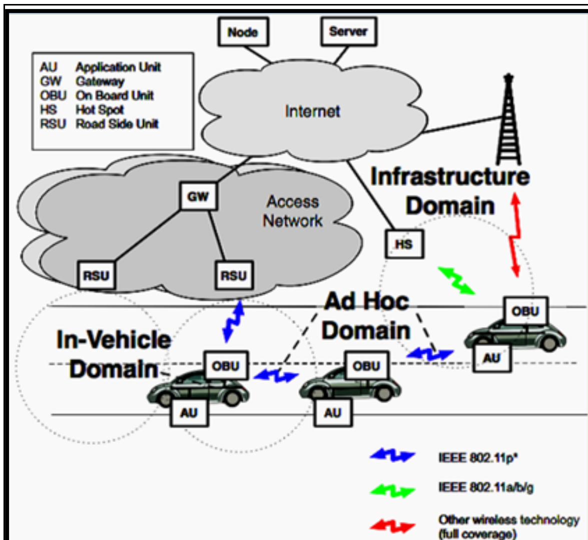

Figure 1. VANET System Architecture

VSNETs aim to provide ubiquitous, efficient sensing and networking capabilities for mobile users on the road and also support a variety of urban monitoring and safety applications. Because of the increasing popularity of mobile wireless devices and smart vehicles, in the near future, VSNETs will become one of the important components of the next generation of Internet and Internet of Things **[6].**

The IEEE 802.11p specification **[8]** is a standard protocol intended for future traffic systems in order to support safety and commercial non-safety applications for vehicular communication. The IEEE 802.11p protocol was specifically designed to operate in Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) settings, and makes use of spectrum band and channels allocated to the Dedicated Short Range Communications. The main aim of this standard is to provide support public safety applications that can save lives and improve traffic flow. It defines a new MAC layer operational mode for Wireless Accesses in Vehicular Environments (called the WAVE mode). The WAVE mode so far defines two basic service sets. One is the WAVE Basic Service Set (WBSS), which comprises a provider and several users and is mainly used for (RSUs) to communicate with the (OBU) **[9].** Currently, this kind of emerging network is being developed and evaluated. The IEEE802.11p protocol is selected for this study. The performance of this protocol is carried out using NCTUns-6.0 simulator tool **[10]** which provides various advantages over other simulators like VanetMobiSim**[11],** TraNs**[12],** SUMO**[13]** etc.

2. Related Work

Many researchers have evaluated the VANET MAC protocols by means of different performance metrics and using different simulators such as:

- The work presented I. C. Msadaa, P. Cataldi, and F. Filali, **[14]** compared the IEEE 802.11p and WiMAX technologies in a high way scenario. Two scenarios are proposed to study the impacts of the source data rate and vehicle speed on 802.11p/WiMAX. Subsequently, the coverage, average throughput, and end-to-end delay are evaluated for different vehicle speeds, traffic data rates, and network deployments. Finally, based on the simulation results, it is concluded that WiMAX offers large radio coverage and high data rates and that 802.11p is better suited to low traffic loads, where it offers very short latencies, even at high vehicle speeds. However, each of the simulation scenarios presented in this paper only considers one vehicle; hence, the access collisions among the vehicles are not considered.
- Packet delay in legacy IEEE 802.11p is analyzed in R. Khalaf, I. Rubin, [15]Two transmission scenarios are presented: single-hop and multi-hop. Theoretical curves are compared with simulated. Therefore, there are some differences from inter-vehicle communication. The received packets are acknowledged, which is not the case in WAVE, where information is broadcasted.

- The author in A. Böhm and M. Jonsson, [16] proposed a V2I communication solution by extending the IEEE 802.11p protocol. They introduced a collision-free MAC phase with an enhanced prioritization mechanism based on vehicle positions and the overall road traffic density. The author had evaluated protocol performance using Matlab.
- In another paper **[17],** an OMNeT++ simulator was used to evaluate the collision probability, throughput and delay of IEEE 802.11p. It shows that WAVE can prioritize messages, where, in dense and high load scenarios the throughput decreases while the delay is increasing significantly.
- The main design issues related to multi hop data delivery in 802.11p/WAVE-based vehicular ad hoc networks have been investigated in **[18].** Then, by leveraging on the capabilities of the 802.11p specifications, a set of solutions for deploying effective and efficient vehicle-to-roadside multi hop are proposed.
- The work in **[19],** evaluates the Medium Access Control (MAC) specification of the IEEE-802.11p using MATLAB simulations. It has evaluated channel access delay and probability of channel access in different VANET scenarios involving varying number of vehicles and the sensing range. It is observed that when it increases the number of vehicles from 100 to 200, channel access delay increases by approximately 20 ms and probability of channel access decreases by approximately 5%. Increase in number of vehicles also increases the chance of collision; hence vehicles get less chance to get access to the channel.

3.The Proposed VSNET FRAMEWORK

Both VANETs and WSNs are subject of ongoing research activities. However, the characteristics of VANETs and WSNs are very different. In the new concept of Sensor-Vehicular Networks both network types can benefit from the strengths of each other while compensating the weaknesses.

In VSNET there are two kinds of sensor nodes, some are embedded on the vehicles-vehicular nodes- and others are deployed in predetermined distances besides the highway road, known as Road Side Sensor nodes (RSS). The vehicular nodes are used to sense road conditions. Vehicular sensors are able to communicate with both static road side sensors and vehicular sensors. The RSS nodes are deployed beside the road. RSS nodes receive the data from mobile nodes and retransmit towards the server.

This paper will focus on the communication part between the Vehicular Sensor (VS) and the RSS.

- **Communication protocol for VSNET framework**:

There are two types of communications that should be considered in the VSNET framework as flow:

1) Communications (VS) 2 (RSS)
   - The VS detects RSS within its transmission range.
   - The VS sends a connection request to the RSS.
   - The RSS sends back an acknowledgement (ACK) to VS.
   - The VS sends to the RSS road information which was previously gathered from other VS or other RSS.
   - The RSS sends a packet including road information regarding the path along the destination of the passing VS which updates that information (if newer) regarding the states of the roads.
   - When the VS reach the border of the transmission range, the connection is ended.
2) (VS) -2-(VS) communications

   In the case of vehicles moving in the same direction (see Figure 2). Vehicles share information gathered from the RSS. This communication can be divided into the following steps (considering VS(B) is behind VS(A) in the same direction):
   - VS(B) is detected by VS(A) within its transmission range.
   - A connection request is sent from VS(A) to VS(B).
   - An ACK is sent by VS(B) to VS(A).
   - The VS(A) sends a packet to VS(B) regarding the state of the roads and traffic density of the road in the destination path of VS(B). Also the packet includes traffic information about the roads within other paths.
   - When the VS(A) reach the border of the transmission range of VS(B), the connection is ended.

In the same process, road information is spread backward through the group of vehicles. Therefore, every new vehicle in the group sends its own road information forward till the leader vehicle through the other relying vehicles in the group. This way, the leader gathers the whole road information of its group of vehicles and keeps always updated.

When the detected vehicle goes in opposite direction, the connection will only be established between the first vehicles of both groups. The communication between vehicle A and vehicle C can be describe as following:

- VS(C) is detected by VS(A) within its transmission range. VS (C) moves in opposite direction of VS(A).
- A connection request is sent from VS(A) to VS(C).
- An ACK in sent by VS(C) to VS(A).
- The VS(A) sends a packet to VS(C) regarding the state of the roads and traffic density of the road in the destination path of VS(C). Also the packet includes traffic information about the roads within other paths.
- When the VS(A) reach the border of the transmission range of VS(C), the connection is ended.

Finally, each group leader disseminates the new road information among the vehicles within its own group.

In order to analyze the performances of the proposed VSNET communication protocol scenario which illustrated in Figure 3, the paper used the NCTUns 6.0 network simulator [10].

The NCTUns is open source software that provides easy and efficient simulation results. NCTUns 6.0 is supported by the RED-HAT LINUX with the Fedora flavor v.12. This simulator is purely written in C++. NCTUns uses Linux TCP/IP protocol stack for packet passes. It supports both wired and wireless networks **[20].**

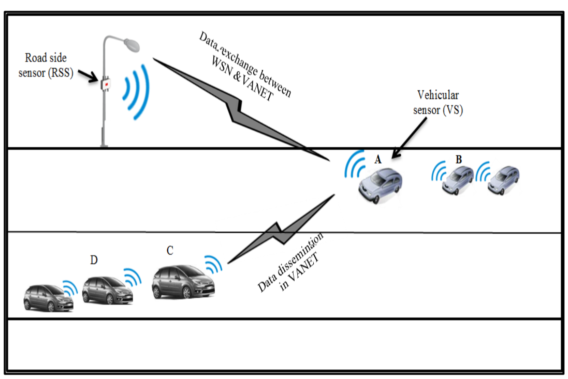

Figure 2. General VSNET framework

4.Simulation and Results

NCTUns simulates 80.211a, 802.11b, 802.11g and 802.11p protocols. Also, it simulates multiple wireless interfaces inside a sensor node including the 802.11p interface. The usability of this simulator for the ITS has been enhanced. NCTuns includes free space with a shadowing path loss model, Rayleigh and Ricean fading models **[20].** The NCTUns implements directional, bidirectional and rotating antenna types. The Signal to Noise Ratio calculation is cumulative and the signal strength is determined from the sender's and the receiver's perspective point. NCTUns implements block objects to introduce the hindering object between wireless signals.

The Wall object can completely block the wireless signal or can attenuate the signal with a specified value. The hindering object gives good simulation environment to observe the effects of multi hop wireless network simulation. During the simulation, each node is allowed to send either a UDP or TCP packet.

The topology is a rectangular road network with a RSU deployed at the road side. The road segment is 2km in length. Table 1 shows the configuration parameters used in the simulations.

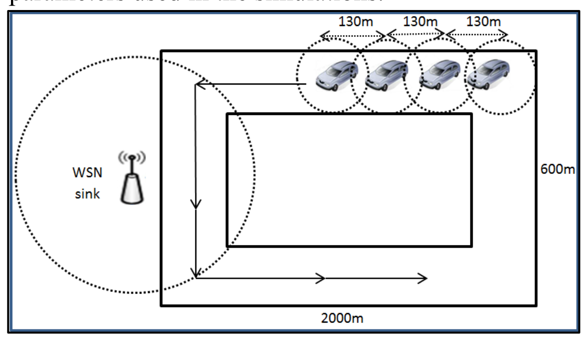

Figure 3. The proposed VSNET scenario

This paper verifies the efficiency and the performance of the IEEE 802.11p in proposed VSNET framework. The performance of the frameworks evaluated in a V2I communication environment using different vehicle speeds (60, 80, and 100 km/h) and different packet sizes (100, 500, and 1000 byte).

Table1. Simulation parameters of the VSNET scenario

Parameter	Value
Speed of the nodes	60, 80, 100 km/h
Number of road lanes	4(two in each direction)
Road length	2 Km
Data rate	3mbps
Antenna high of Mobile nodes in the VANET	1m
Antenna high of nodes in the WSN	2m
MAC	IEEE 802.11p
Number of Mobile nodes in the VANET	4 vehicles
Number of nodes in the WSN	1 sink node
Packet size	100,500,1000 bytes
Simulation time	100 sec

In order to evaluate the performance of IEEE 802.11p technology, the work carried out several simulations in the NCTUNs network simulator. The performance evaluation is done using two metrics; the throughput, and the packet loss rate sent from the source node to the receiver node.

The movement of all vehicles on the road is generated randomly by the simulator. In NCTUns, each vehicle can be specified with different auto-driving behaviors. A driving behavior is defined by a vehicle profile.

After vehicles' deployment, one can specify what kind of profile should be applied to the ITS vehicle. The vehicle profile tool included in NCTUns6.0 is used to define the behavior of vehicles. An overview of the information of different vehicle profiles used for the simulation is shown in Table 2.

Table 2. Different profiles per vehicle

	Prof.1	**Prof.2**	**Prof.3**	**Prof.4**	**Prof.5**
Maximum speed	20 k/h	60 k/h	70 k/h	80 k/h	100 k/h
Maximum acceleration	1 m/s	1.2m/s	1.25 m/s	1.34 m/s	4.5 m/s
Maximum deceleration	1.5 m/s	2 m/s	2.43 m/s	2.24 m/s	8.9 m/s

Packet loss is usual under wireless networks caused by bad quality of wireless channel, node failure, and/or congestion. In VSNET packet loss should be decreases as possible; in order to guarantee a good reliability of the system. Figure 4 shows the impact of speed in the rate of packet loss with different packet sizes. Results show that there is a decrease in the rate of packet loss when there is an increase in speed. That mean the used protocol gets an excellent level of reliability in this VSNET scenario.

On the other hand, the throughput refers to how much data can be transferred from one source node to distention in a given amount of time. The throughput is usually measured in bits per second (bit/s or bps), or in kilo bit per second (kbps). It is used here in the paper to measure the performance of the proposed VSNET communications.

Figure 5 shows the impact of speed in the throughput with different packet sizes. Results show that there is an increase in the throughput when there is an increase in speed. This enables proposed VSNET framework to get reliable results.

Consequently, it can be concluded that IEEE 802.11p protocol is feasible to be used in designing VSNET environments. So, it should get more researchers' attention in order to study and investigate its capabilities.

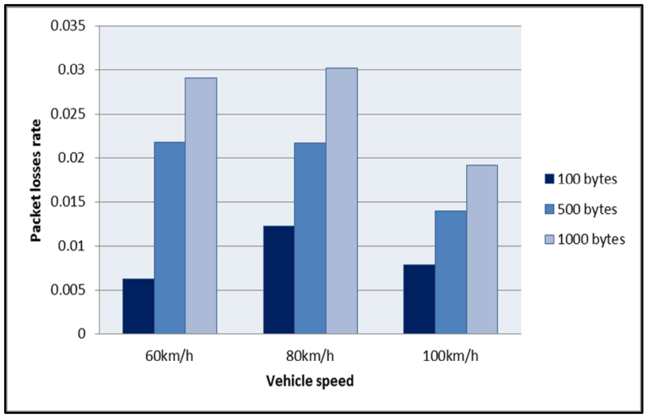

Figure 4. The impact of the vehicle speed on the packet loss rate.

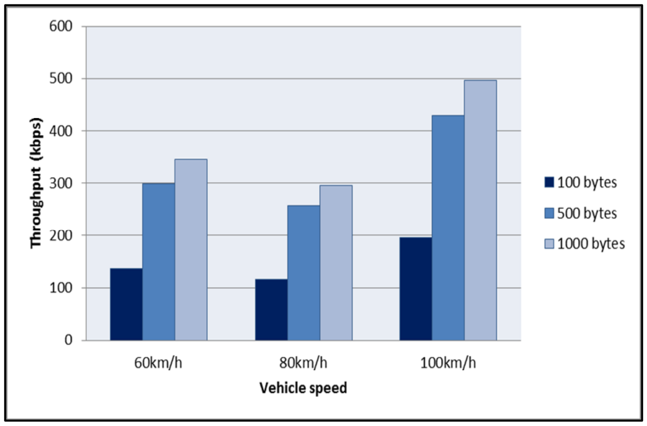

Figure 5. The impact of the vehicle speed on the throughput rate.

Conclusions and Future Work

VSNET is a promising wireless communication technology for improving highway safety and information services. This paper addresses the approach of Vehicular Sensor Network on the road to implement an efficient ITS, that increase the safety of road travel. The paper shows the performance of the IEEE 802.11p protocol in a VSNET framework. Simulation results show the performance of IEEE 802.11p protocol impacts with high speed vehicles such as: reducing the number of packet losses while increasing the system throughput along with the increase in the vehicle's speed. As a future work, the performance of IEEE 802.11p protocol may be tested with different VSNET scenarios, and under different conditions.

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