PLANNING V2X COMMUNICATION SYSTEM USING VANET ON OMNET++ SIMULATOR

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Abstract— Smart mobility is becoming an alternative technology of transportation development for today and the future. Today's developers use Intelligent Transportation Systems (ITS) to achieve traffic efficiency by minimizing traffic problems [1]. They care about equipping cars with some safety features as collision detection and lane change assist that depend on sensors like ultrasonic sensors, cameras, and Lidars to allow the vehicles to detect blind spots. The Vehicle-to-Everything (V2X) provides another level of safety by enabling vehicles to exchange information wirelessly, this technology allows vehicles to communicate with each other with coverage up to 300 meters, broadcast and receive Omni-directional messages covering all the space around it (360-degree awareness) even if other objects are blocking line-of-sight; giving it the ability to see around corners. Different communication systems and protocols such as 5G, Ad-Hoc Network, and the Dedicated Short-Range Communications can be used to implement the V2X system. This paper provides a detailed explanation of the used communication system and its fundamentals to improve the ITS, also it is discussing the used simulation platforms and their features.

Keywords— V2X, Smart Mobility, Ad-Hoc, Artery, VEINS, DSRC, OMNET, ITS, VANET.

I. INTRODUCTION

Since road traffic injuries are a major part of deaths globally, most of these accidents are usually because of the improper infrastructure of road, speeding, alcohol, or even any distractions for drivers, and with the evolving of vehicles and its technology including the AEB, barking assistance, navigation systems, and so many other features and of course making safety a key concern such as Blind-Spot Warning (BSW), rear cross-traffic alert and Lane-Departure Warning (LDP).

According to World Health Organization (WHO), Approximately 1.35 million people die in road crashes each year, on average 3,700 people lose their lives every day on the roads, and that's an additional 20-50 million suffer non-fatal injuries, often resulting in long-term disabilities, it also causes considerable economic losses to individuals, their families, and nations as a whole and cost most countries 3% of their gross domestic product[2].

Vehicular Ad-hoc Network (VANET) provides a communication path between vehicles; Vehicle-to-Vehicle (V2V) or between Vehicles-to-Infrastructure (V2I) by implementing wireless communication devices on the vehicles, considering too that also the Vehicle-to-Everything (V2X) technology aims to increase the safety on the road, provide more traffic efficiency and other services. V2X depends on exchanging information of vehicles periodically, this information includes the vehicle's location, velocity, and maybe other parameters as a destination; the ITS applications use the transmitted or received data to help the drivers to raise their awareness of the road.

II. VANET

A. *Communication protocol*

V2X technology provides data transmission between vehicles wirelessly, mainly this type of communications used to prevent accidents and allowing vehicles to transfer data about their position and their speed through an ad-hoc mesh network, or a decentralized connection system can be used, which may provide either a fully connected mesh topology or a partially connected mesh topology. Major standardization In the U.S., the IEEE 1609 Wireless Access in Vehicular Environments (WAVE) protocol stack builds on IEEE 802.11p WLAN operating on seven reserved channels in the 5.9 GHz frequency band. The WAVE protocol stack is designed to provide multi-channel operation (even for vehicles equipped with only a single radio), security, and lightweight application layer protocols. The charter of this committee is to promote technical activities in the field of vehicular networks.

B. *The physical Layer of VANET*

The radio system is operating in the GHz range, the Orthogonal Frequency Division Multiplexing (OFDM) Wi-Fi is adapted and used in this layer.

Interference, Noise, and Sensitivity considering the propagation phenomena and the reception at the antenna, a generic signal reaches the receiver and is ready for decoding. Intuitively, the stronger the signal and the lower the interference and noise are, the better the reception is. This is confirmed by two parameters characterizing the reception. The first one is the Signal to Interference and Noise Ratio (SINR) and is defined in Eq. (1). (reference)

write equation

$$\mathrm{SINR} = \frac{P_R}{\sum_i P_I^i + P_N} \quad (1)$$

P_R represents the power of the received signal (affected by attenuation, fading, and antenna phenomena); i is the …., P_I is the sum of the interfering signals in the target frequency (they may be simultaneous transmissions by other nodes or disturbs). P_N is the power of noise (or noise floor) coming from the environment that can be ascribed to the environmental thermal noise.

Channelization and Power Constraints: a specific band is allocated for vehicular communication for both of the safety and non-safety messages, a band of 75 MHz is reserved for the Dedicated Short-Range Communications (DSRC), from 5.850 to 5.925 GHz for the vehicular technology, In this spectrum, seven 10 MHz-wide communication channels are available (numbered with even numbers from 172 to 184): one Control Channel (CCH) and six Service Channels (SCHs). A guard band of 5 MHz is introduced in the lower portion of the DSRC band.

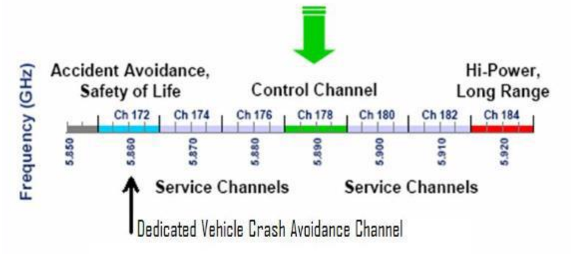

Figure 1: DSRC channel allocation

Channel 172 is reserved for the V2V safety communication; messages are being exchanged between vehicles also the Road Side Units (RSUs) to help in reducing/avoiding road accidents.

Channel 184 is used for public safety applications, and it's a high power long-distance communications, for example, the sent signal that facilitates the road for the emergency vehicles; For such operations, a higher transmit power (up to 40 dBm) is required to reach longer distances.

C. *The MAC Layer of VANET*

To make the vehicular environment satisfy our needs in the safe roads and other applications, the Medium Access Control (MAC) protocol must be reliable, efficient, and deliver the transmitted packets with a consideration of the rate, delay, throughput, and bandwidth utilization [3].

MAC protocol design should consider different types of messages in VANETs; there are three types of messages:

1. **Periodic messages**: The information needed to be broadcasted periodically as speed, position, and direction to the nearby vehicles.
2. **Event-driven messages**: This is the message that is responsible for the Emergency messages informing unsafe situations that have been detected. It has the highest priority among all the messages.
3. **Informational messages:** These types of messages are used to make the drivers more comfortable (Non-safety application messages); it's not a high-priority message.

Distributed Coordination Function (DCF) relies on the Carrier Sense Multiple Access with collession Avoidance (CSMA/CA) technique to reduce the collision probability among multiple stations accessing the medium. The CSMA basic idea is to listen before talk; a station must check the medium before transmission to determine whether it is busy or not.

The timing intervals are slot time, Short Interframe Space (SIFS), Distributed Interframe Space (DIFS), and Extended Interframe Space (EIFS). SIFS and slot time are the shortest intervals and the foundation of the others. In addition, there also exists an optional Point Coordination Function (PCF), which is not considered here.

When the MAC receives a request for transmission, the medium is checked by the physical and virtual CS mechanisms. If both of them indicate an idle medium for a period of DIFS or EIFS, the transmission is allowed to begin. DIFS is used after ordinary data frames and EIFS is used after the detection of an erroneous frame. The SIFS is used when a station needs to keep the medium for additional transmissions like an ACK or CTS/RTS exchange, and no other stations should be able to interfere [4].

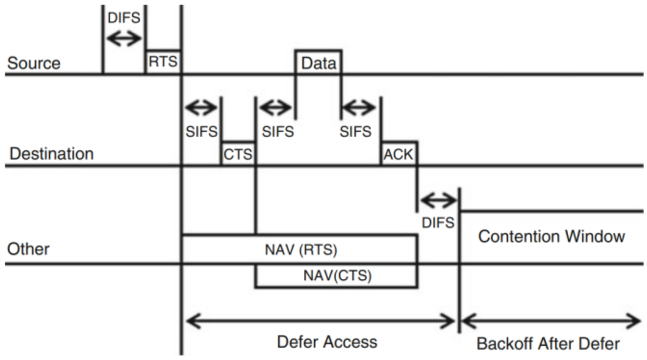

Figure 2: Virtual carrier sensing through RTS/CTS frame handshaking

III. TESTING

A. *Simulation Platform*

The IEEE 802.11p based simulator is composed of several simulation frameworks of different functionality; OMNET++ is an open-source simulator that is made for the research and development of networks. It's interfaced with other frameworks [5]:

INET is an open-source library containing various models to simulate communication networks and is specially written for the OMNeT++ environment.

VEINS is an open-source library consisting of numerous models specific to vehicular networking. For instance, it has an IEEE 802.11p model; that includes multi-channel operation, QoS channel access, and SNIR effects.

Artery corresponds to the application and facilities layers, which enable the generation of CAMs and DENMs. Moreover, its middleware provides common facilities to the multiple ITS-G5 services running on individual vehicles [6].

VANETZA implements the GeoNetworking (for routing) and BTP (for transport) protocols and supports ASN.1 message (CAM, DENM) [7].

B. *Architecture of Scenario*

The physical and medium access is introduced by INET Framework[1] that includes the model of 802.11, enables the Ad-hoc communication protocol, and provides 10MHz radio channel bandwidth with 5.9 GHz besides using the CSMA/CA.

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Network and Transport Layer is provided by VANETZA[2] to allow the routing of the packets to the desired destination which is handled by GeoNetworking using the DataRequest (to transmit the packet) and DataIndication (to receive the packet) and using Basic Transport Protocol (BTP) for the transportation; note that also the Decentralized Congestion Control (DCC) and the security is provided by VANETZA.

Facilities are used to provide service applications in the upper layer of the OSI model which is provided by the Artery framework; also Artery provides the middleware module which contains the service module (ITS application).

Mobility Moving network nodes are realized by the OMNeT++ mobility module that emits a continuously updated signal that contains the position of the GN router.

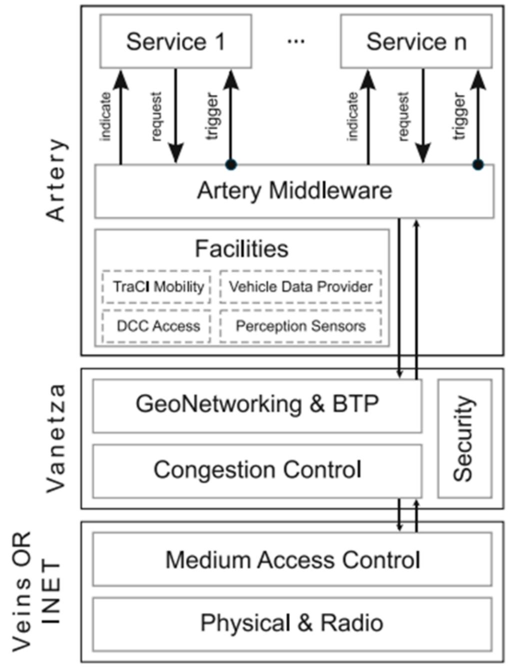

Figure 3: The Architecture Applied on Each Node

C. Scenario

The scenario is a test for the communication system of VANET between vehicles on a highway, the scenario starts with five vehicles on five busy lanes of a highway road, it happened that an emergency vehicle is passing and there are no empty lanes to pass through, the emergency vehicle will send a message through the network so any of the vehicles will empty a lane for the emergency vehicle.

There are two steps in this application:

1. A broadcast message is being **transmitted** from the emergency vehicle (node 6) about its destination and its current position.
2. **Receiving** the message by other vehicles (nodes 0–5) and react to that message from the emergency vehicle to issue a warning to the driver.

Figure 4: Emergency Scenario test I

The statistics of the radio medium can be seen in Figures 5 and 6, that show the received/sent Frames and SNIR.

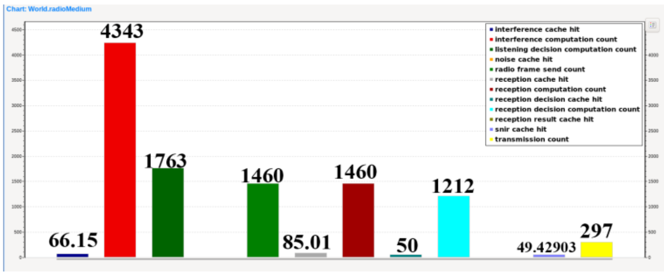

Figure 5: RadioMedium statistics I

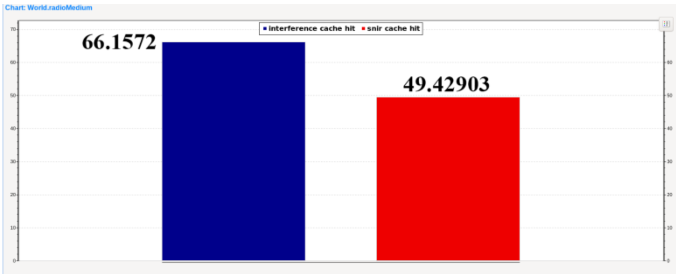

Figure 6: SNIR and Interference Statistics I

The scenario is adjusted to increase the number of vehicles to 9 vehicles (nodes 0 ... 8).

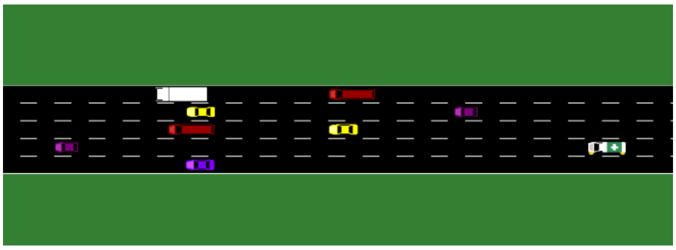

Figure 7: Emergency Scenario test II

by increasing the number of vehicles, the number of packets sent/received will increase, and the SNIR will decrease as a result of the increasing interference in the medium.

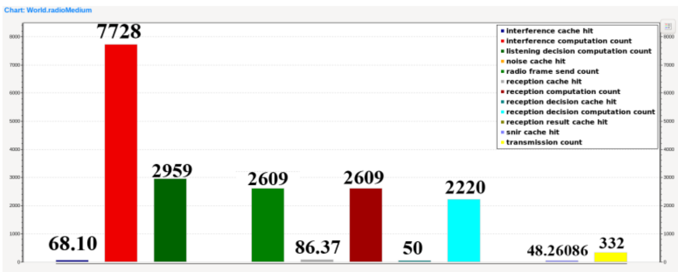

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Figure 8: Radio Medium statistics II

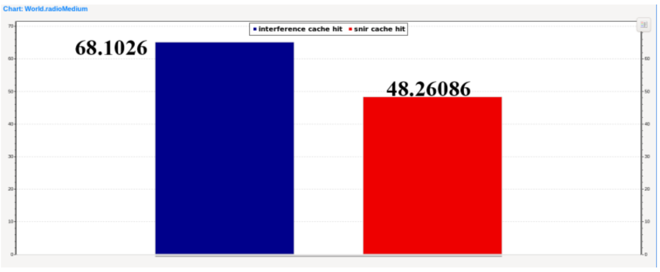

Figure 9: SNIR and Interference Statistics II

Table 1: Used Aspects for Emergency Scenario

Antenna	**Isotropic Antenna**
Frequency	**5.9e+09 Hz**
Bandwidth	**1e+07 Hz**
Transmitter	**Ieee80211ScalarTransmitter / OFDM**
Receiver	**Ieee80211ScalarReceiver**
Channel	**Ieee80211Channel, Ch=180**
RadioMedium	**Ieee80211ScalarRadioMedium**

IV. CONCLUSION

VANET is one of the new research field and hot topics of network communication; we have explained the factors and requirements that the VANET depends on, and after testing the communication system on OMNET++ and its framework, it has been discovered that whenever the traffic increase the SNIR decrease as a result of increasing the interference also it affects the delay, it should be solved using other protocols as 4G/5G.

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