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Research Article

VANETS Model: Vehicle-to-Vehicle, Infrastructure-to-Infrastructure and Vehicle-to-Infrastructure Communication using NS-3

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Abstract

Vehicular Ad-hoc Networks (VANETs) is a technology that uses moving vehicles as nodes in a network to create a mobile network. Vehicular communications like V-2-V , I-2-I and V-2-I with vertical handover decision process has to consider the speed limits and other real-time constraints such as lane-changes, emergency braking along with QoS (Quality of service) parameters such as delay, jitter, bandwidth, packet delivery rate and cost. The proposed work focuses on V2V, I2I and V2I communications.

Keywords: *Wi-Fi, WAVE, LTE, Road Side Unit (RSU), On-Board Unit (OBU), VANETS, V-to-V, I-to-I, V-to-I.*

1. Introduction

The recent advances in wireless networks have led to the introduction of a new form of networks called Vehicular Networks. Vehicular Ad Hoc Network (VANET) is a type of Mobile Ad Hoc Networks (MANET). VANETs give us with the infrastructure for developing new systems to improve drivers' and passengers' safety and comfort. VANETs are distributed self-organizing network systems created between moving vehicles equipped with wireless communication devices. These type of networks are developed as part of the Intelligent Transportation Systems (ITS) to bring significant improvement to the transportation systems performance.

Each Vehicle Node is equipped with WAVE (IEEE 802.11p) protocol known as OBUs (On Board Unit) and the stationary infrastructure units are called RSUs (Road Side Unit). There are mainly three types of communication areas in vehicular networks: Vehicle-to-Vehicle (V2V), RSU-to-RSU (I2I) and Vehicle-to-RSU (V2R or V2I). (Hadi Arbabi*, et al*, 2010)The RSUs can also communicate with each other as well as with other networks. Vehicular Networks are expected to deploy variety of advanced wireless technologies such as Dedicated Short Range Communications (DSRC), which is an improved version of the WAVE (IEEE802.11p) technology apt for VANET environments. The DSRC is created to support the data transfer in rapidly changing communication environments. The most fundamental VANET communication scenario is shown in figure 1.

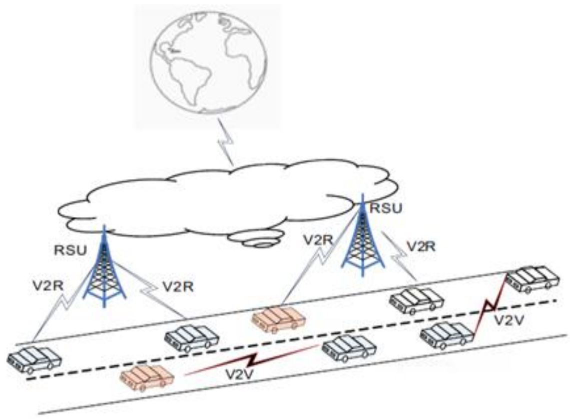

Figure 1 Basic VANET Scenario ((Vaishali D, *et al*, 2011))

VANET applications are Safety, Cooperative Collision Avoidance (CCA), Emergency Warning Messages (EWM), Cooperative Intersection Collision Avoidance (CICA), Traffic Managements, Advertisements, entertainment and comfort applications like Electronic toll collection.

[Claudia, *et al*, 2011]A new MAC protocol called the IEEE 802.11p is used by the WAVE stack. The IEEE 802.11p basic MAC protocol is the same as IEEE 802.11 Distributed Coordination Function (DCF), which uses the Carrier Sense Multiple Access/Collision Avoidance System (CSMA/CA) for accessing the shared medium. The IEEE 802.11p Medium Access Control extension layer is based on the IEEE 802.11e (IEEE, 2003) that uses the Enhanced Distributed Channel Access (EDCA) like Access Category (AC), virtual station, and Arbitration Inter-Frame Space (AIFS). Using EDCA, the

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Quality of Service (QoS) in the IEEE 802.11p can be obtained by categorizing the data traffic into different classes with different priorities. The basic communication modes in the IEEE 802.11p can be implemented by either using broadcast type communication , where the control channels (CCH) are used to broadcast safety critical and control messages to all the neighboring vehicles, or using the multi-channel operation mode where the service channel (SCH) and the CCH are used. The latter mode is called the WAVE Basic Service Set (WBSS).

In the WBSS mode, stations (STAs) become members of the WBSS in any one of two ways, a WBSS provider or a WBSS subscriber. Stations in the WAVE move very rapidly and it's necessary that these stations establish communications and start transmitting data at a very high rate. Therefore, the WBSSs don't require MAC sub-layer authentication and/or association. The provider forms a WBSS by broadcasting a WAVE Service advertisement (WSA) on the CCH. The Protocol architecture of IEEE802.11p DSRC is shown in Figure 2.

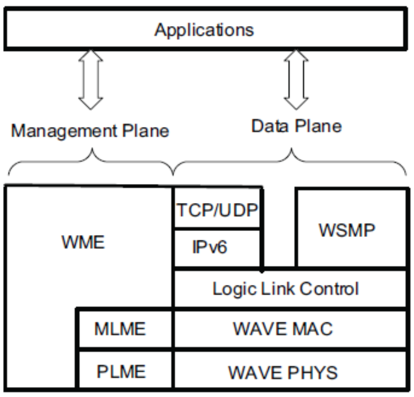

Figure 2 Architecture of IEEE802.11p (Claudia, *et al*, 2011)

V2V uses DSRC based WAVE protocol for collision avoidance messages and V2I uses WiMAX or UMTS/LTE networks for lane-changes /assigning vehicle priorities.

1.1 V2V, I2I AND V2I Model

Vehicular Ad-Hoc Network (VANET) communication has recently become an increasingly popular research topic in the area of wireless networking as well as the automobile industries. The goal of VANET research is to create a vehicular communication system to enable quick and cost-efficient distribution of data for passengers' safety and comfort. While it is very important to check and evaluate protocol implementations in a real world scenario, simulations are still commonly used as a first step in the protocol development for VANET research.(Vaishali D, *et al*, 2011) Several communication networking simulation tools already exist to provide a platform to test and evaluate network protocols, such ns-3, ns-2, OPNET and Qualnet.

One of the most crucial parameters in simulating ad-hoc networks is the mobility of the nodes. It is important to use a realistic mobility model so that the observations from the simulation correctly reflect the real-world performance of a VANET. For example, a vehicle node is typically restricted to the streets which are separated by buildings, trees or other objects. Such obstructions often increase the average distance between nodes as compared to an open-field environment with lesser number of obstructions. Many prior studies have shown that a realistic mobility model with sufficient level of details is very important for accurate network simulation results.

(Valery, *et al*, 2006)Vehicular node mobility is represented by mobility models. Mobility models represent the movement of mobile users, and how their location, velocity and acceleration change with respect to time. Such models are very frequently used for simulation purposes when new communication or navigation techniques are investigated. Mobility of vehicular nodes is a crucial issue in VANET. The most prominently used mobility model for vehicular adhoc network is Random waypoint mobility model.

2. Implemented Model

The model that we have created consists of all the three types of connections needed in VANETS model. The three connections are

1. V to V: The nodes placed on both sides of the centre will behave as vehicles (mobile).
2. I to I: The nodes that have been placed in middle row will facilitate as Infrastructure (non-mobile).
3. V2I: The interaction between the mobile nodes and non-mobile nodes will demonstrate V to I communication.

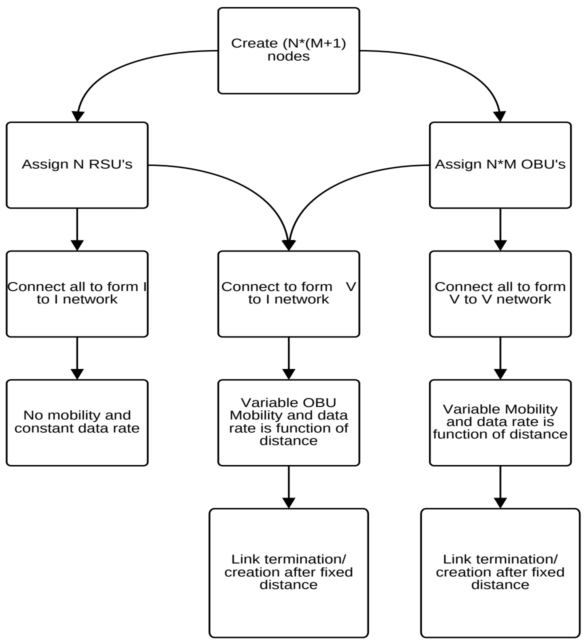

Figure 3 Flow chart

In the simulation environment we create 'N' RSUs and 'N*M' OBU's where M is the number of lanes taken into consideration. Then we connect each node to the other nodes that are present in its domain (area of reach) approximately of 100 units. The connectivity between mobile nodes denotes V-to-V communication, similarly the connection between stationary nodes denotes I-to-I connection and connection between stationary and mobile nodes denotes V-to-I connection.

I-to I communication has constant data rate, but V-to-V and V-to-I have variable data rate and it is a function of distance between nodes. The links between the nodes are terminated when nodes go out of range and links are created when the nodes get into range of particular nodes. The flow is shown in Figure 3.

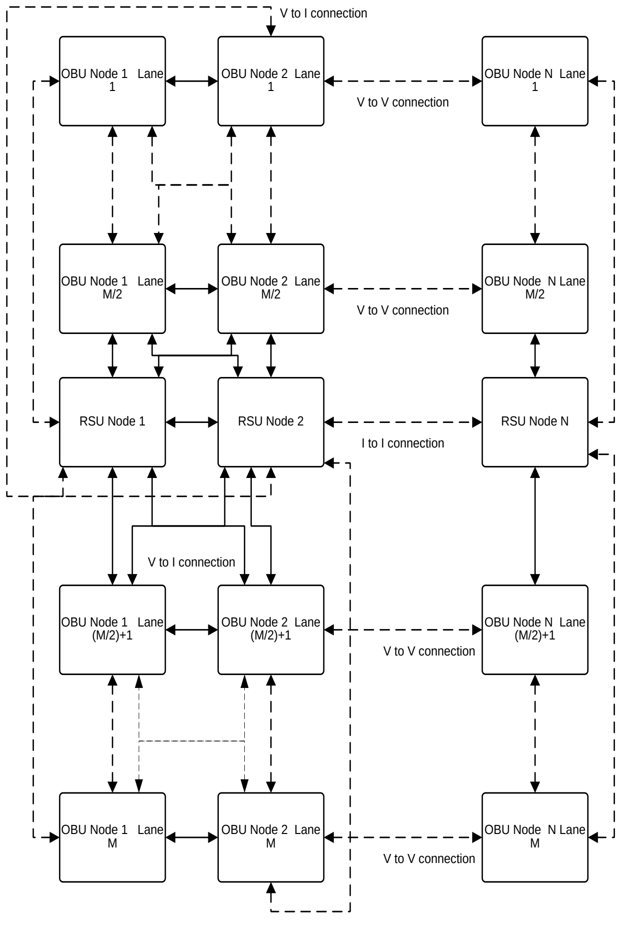

Figure 4 Block diagram

The actual realization of nodes is shown in Figure 4.Here the nodes in domain of each other have established a connection.

The above Figure 5 explains configuration of the RSUs (Infrastructure).We begin by creating N*(M+1) nodes on the whole, where N nodes are used as Infrastructure (RSUs). Then we install the stationary mobility model in them and specify their positions. We install Wave (IEEE801.11p) in the nodes to define the physical and data link layer (MAC). Further we install OSLR routing protocol. Then each network device is assigned an IPv4 address (for further advancement we can use IPv6 addressing). Finally an application layer protocol UDP is installed.

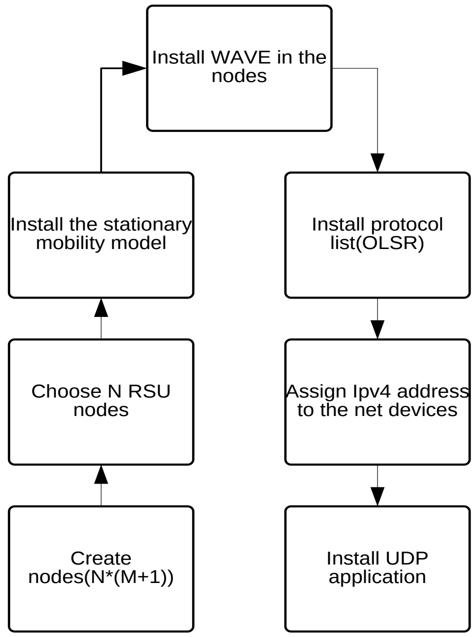

Figure 5 RSU Configuration

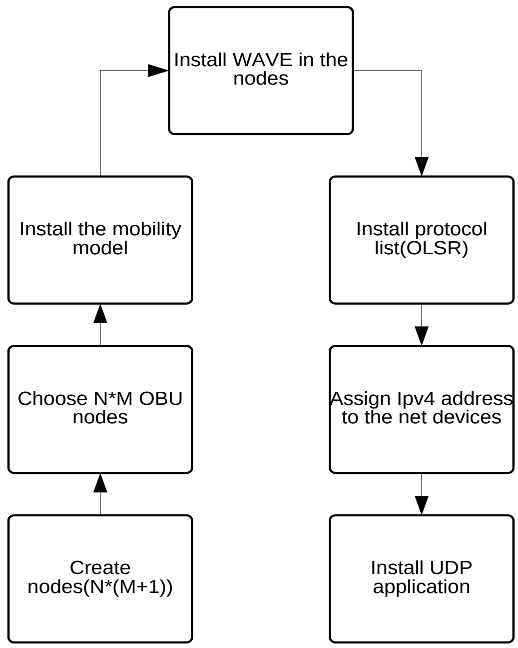

Figure 6 OBU Configuration

The above Figure 6 explains configuration of the RSUs (Infrastructure). N*m nodes from the above created nodes are used as mobile nodes (OBUs). Then we install the stationary mobility model in them and specify their positions. We install Wave (IEEE801.11p) in the nodes to define the physical and data link layer (MAC). Further we install OSLR routing protocol. Then each network device is assigned an IPv4 address (for further advancement we can use IPv6 addressing). Finally an application layer protocol UDP is installed.

3. Observation and Statistics

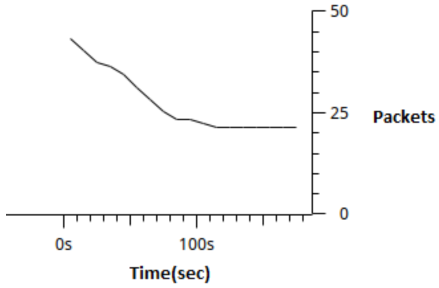

Figure 7 Packets vs. Time graph

At time t=0 the packet delivery and reception rate was high 44 packets/sec. As the nodes move with constant velocity of 1 unit/sec, the distance between certain nodes increases and between certain nodes decreases. This effects the packet rate and it decreases exponentially till it reaches 22 packets/sec at t=153s. This is the instance where the mobile units (OBUs) have been disconnected from the infrastructure (RSU's), i.e. only independent I-to-I and V-2-V communication takes place and V-to-I has been terminated. We have following packet lengths

Packet Lengths with filter:

Topic / Item	Count	Rate (ms)	Percent
Packet Lengths	492	0.002757	
0-19	0	0.000000	0.00%
20-39	0	0.000000	0.00%
40-79	0	0.000000	0.00%
80-159	410	0.002298	83.33%
160-319	82	0.000460	16.67%
320-639	0	0.000000	0.00%
640-1279	0	0.000000	0.00%
1280-2559	0	0.000000	0.00%
2560-5119	0	0.000000	0.00%
5120-4294967295	0	0.000000	0.00%

Figure 8 Packet Length Statistics

The nodes in the network communicate as follows

IP Destinations with filter:

Topic / Item	Count	Rate (ms)	Percent
IP Destinations	492	0.002757	
10.1.1.2	28	0.000157	5.69%
10.1.1.12	8	0.000045	1.63%
10.1.1.4	22	0.000123	4.47%
10.1.1.5	127	0.000712	25.81%
10.1.1.13	29	0.000163	5.89%
10.1.1.6	63	0.000353	12.80%
10.1.1.1	90	0.000504	18.29%
10.1.1.11	18	0.000101	3.66%
10.1.1.3	107	0.000600	21.75%

Figure 9 IP Destination Statistics

The used IP addresses have been shown below. As we have used UDP protocol which broadcasts the packets, the address 255 is 100%.

IP Addresses with filter:

Topic / Item	Count	Rate (ms)	Percent
IP Addresses	492	0.002757	
10.1.1.2	28	0.000157	5.69%
10.1.1.255	492	0.002757	100.00%
10.1.1.12	8	0.000045	1.63%
10.1.1.4	22	0.000123	4.47%
10.1.1.5	127	0.000712	25.81%
10.1.1.13	29	0.000163	5.89%
10.1.1.6	63	0.000353	12.80%
10.1.1.1	90	0.000504	18.29%
10.1.1.11	18	0.000101	3.66%
10.1.1.3	107	0.000600	21.75%

Figure 10 IP Addresses Statistics

4. Results and Discussion

VANETs model uses fixed nodes as RSU and moving nodes as vehicles with restricted vehicular mobility is shown in Figure 12.

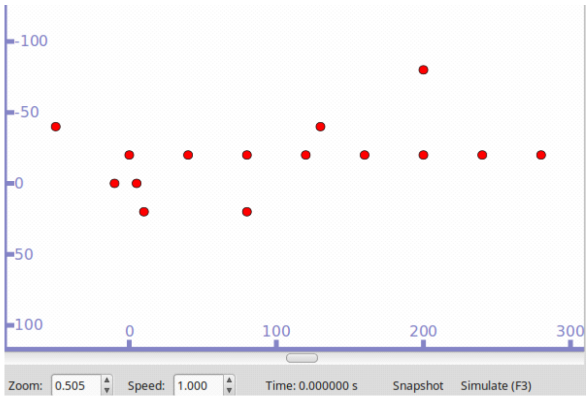

Figure 11 RSU and OBU

The simulation is implemented in network simulator – 3.20 (NS-3.20). The demonstration is shown in Figure 11.

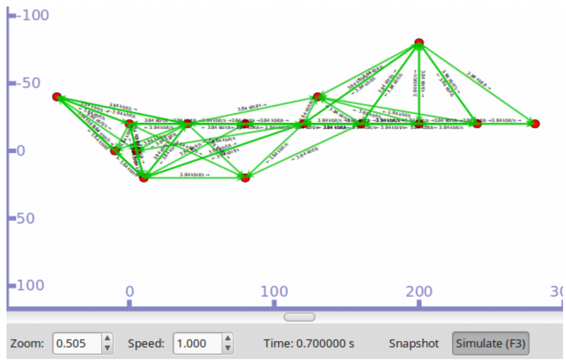

Figure 12 Simulation Scenario at t=0.7s

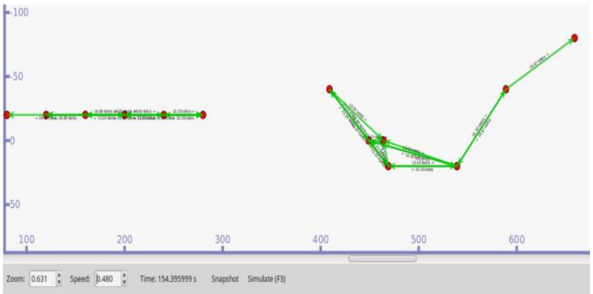

Figure 13 At t=154

At t=153s only V-to-V and I-to-I communication take place. There is no V-to-I communication as the link has been broken as the OBU's are further from the coverage area of the RSUs.

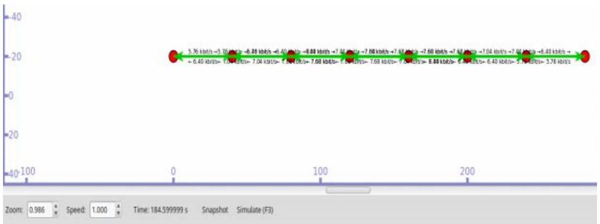

Figure 10 Simulation of RSUs at t>153s

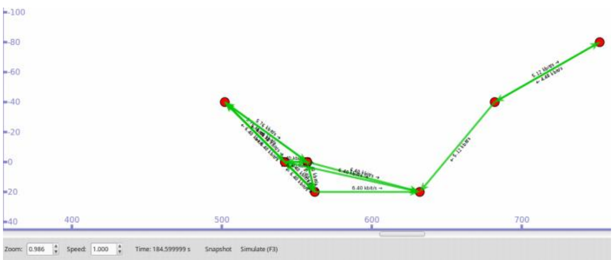

Figure 14 Simulation of OBUs at t>153s

Conclusion and Future Work

The vehicle-to-vehicle (V-2-V), (I-2-I) and vehicle-to-infrastructure (V-2-I) communications was done using WAVE on onboard unit and Wi-Fi on roadside unit. The horizontal and vertical handover decisions were made. The rate of data exchange directly varied with the distance between the nodes. This in turn varied the rate of packet exchange.

In future, enhanced systems will be considering more real-time constraints like congestion in the narrow roads or high density roads for implementing vehicular mobility models on a larger scale. Safety and emergency reporting messages must be delivered on time with higher priority.

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