Accurate Simulation of Vehicular Ad-Hoc Networks Using Veins Framework

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***Abstract*— Vehicular Ad-Hoc Networks (VANET) are a standardized category of Mobile Ad Hoc Networks (MANET) tailored for vehicle-to-vehicle communication. Quite a few simple VANET protocols have been designed to meet vehicle integration needs, but some appropriate mobility systems are essential to test the VANET protocol.In this research work, we propose a VANET model using TDMA as an access medium to transmit the data into various resource blocks and for our VANET simulations to be more accurate, we made an effort to reduce the total time required to deliver packets among vehicles and RSU's, while keeping in mind the data packet loss. For that we ran our network simulations using Veins, in which SUMO, a road traffic simulator, was paired with other event based network simulator OMNET++.**

***Keywords*— VANET , TDMA , SINR , SUMO, Veins**

I. Introduction

VANETs are a subclass of MANETs in which vehicles are basically node contacts. As such, a vast number of highly mobile nodes, gradually spread around various routes, can solve this sort of network. In VANETs (V2V,vehicle-to-vehicle communications),vehicles can communicate with one another. Moreover, to get some service, they should link to an infrastructure (V2I, Vehicle-to-Infrastructure).It is believed that this infrastructure is situated along the roads. The various types of VANET configurations are: dissemination of the V2V alert. Communication of the V2V community, beaconing of V2V,I2V / V2I alert.

The most significant purpose of VANETs is to help safety applications in which each vehicle regularly broadcasts safety signals. To establish cooperative community awareness, each safety message includes vehicle ID, velocity, and GPS location of the sending vehicle.However, the special features of VANETs, such as rapid change in topology and high mobility of nodes, raise the complexities of developing the MAC protocol for an effective broadcast operation. In recent years, a range of VANET research initiatives have been undertaken and tested. In-Vehicle Signage using Roadside Equipment (RSEs), Probe Data Collection, Electronic payment for applications for Tolling and Parking, and Navigation of Traveler Information are some of them.[10]

A. *Intelligent Transportation Systems*

In every country, accessibility is a core concern; whether it is commuting to university, workplace, or for any other reason people use the transit system to travel throughout the city. Leveraging people with an Intelligent Transport System (ITS) will save their time and make the city better. ITS is among the most significant applications of VANET aimed at achieving traffic efficiency by mitigating traffic problems. It enriches consumers with prior traffic statistics, regional real-time information on convenience, availability of seats, etc., which decreases travel time for travellers and increases their security and wellbeing. Additionally, they also ensure efficient infrastructure usage. The Traffic Management Centre (TMC) is a critical ITS unit. It is primarily a technological system governed by the transport authority which collects and analyses all data for further activity and regulation of congestion in live time. Some of the applications of ITS are Advanced Traffic Management System,Vehicle Control system and Commercial Vehicles Operations system.[20]

B. *Needs for 5G+ and 6G*

The primary objective of 5G+ and 6G wireless is to create a global business model where prices are cheaper and profits from networks are higher, with the availability of many more services than the existing 4G LTE [20].

1) Driverless automobiles: Something like an Autonomous Vehicle (AV) case reveals one of the essential needs of current wireless infrastructure: There is a need to link people in motion to systems on which they can rely to save lives, with near-zero latency.

2) Virtual and Augmented reality: In fact for a cloud-based platform to have a secure, real-time sensory experience for a wireless user, a connection in between system and its user can need up to 5 gigabytes of bandwidth.

3) Internet of Things: The functions performed by IoT hubs today could be played by 5G transmitters in the community in the future, serving as service hubs for all residences in their coverage areas.

4) Healthcare: The provision of low-latency coverage in rural areas will revolutionise critical care treatment for individuals around the globe, as connectivity at 5G level allows physicians in remote and rural areas to obtain real-time training and assistance from the finest doctors in the world, wherever they might be based.

C. VANET Architecture

There are three different types of communication in VANETs which are described as below:

- Vehicle to vehicle communication(V2V):
  It is a smart technology which allows the exchange of vehicle data from one vehicle to another. Contact is based on dedicated short-range communications (DSRC) with V2V technologies. V2V communication requires motor vehicles to use a protocol close to Wi-Fi to receive information more about speed and location of all V2V powered vehicles around it. This knowledge is then used to alert drivers to possible risks, helping to minimise collisions and delays in traffic. V2V could recognize dangerous road traffic environment, landscape and weather conditions Warnings within 300 metres. V2V has the potential to make driving more comfortable and safe for everybody on the street [9]. Some of its safety applications include Forward Collision Warning, Intersection Movement Assist, Do Not Pass and Control Loss Warning.
- Vehicle to infrastructure communication:
  V2I, or vehicle-to - infrastructure technology, gathers information such as traffic congestion, weather warnings, rate of bridge clearance, and then transmits it wirelessly to alert drivers of the situations they have to be informed of which safety aids are required. V2I-powered intelligent traffic signals help drivers to understand traffic patterns, helping to predict specific arrival times that will enhance coordination between motorists and customers.[9] Some of its safety applications include Cooperative Intersection Collision Avoidance Systems, Road departure warning system and Weather based hazards systems.
- Vehicle-to-Everything (V2X):
  V2X includes both V2V and V2I technology, also recognised as vehicle-to-everything. By granting them the ability to ”communicate” with the traffic grid, like other cars and utilities, the V2X technology makes any vehicle on the road smarter and safer. V2X will warn drivers about adverse weather situations, local injuries and traffic congestion, and other near-range adverse behaviors[9].

The figure below demonstrates the architecture of VANET.It certain Road Side Units (RSUs) and vehicles on the road.All these vehicles needs to communicate via V2V connections, and that is what the arrow indicates. Moreover,there is also some communication between the vehicles and the RSU. Hence, each vehicle communicates with nearby vehicles in a dynamic ad-hoc networking environment following V2V communications.

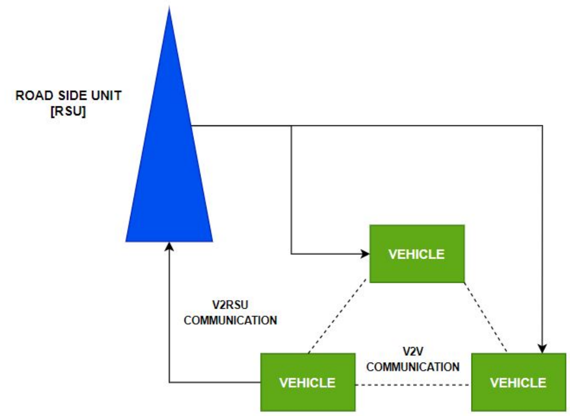

Fig. 1. An Illustration of VANET Architecture

D. VANET Simulators Classification

There are many simulators present which can be used for VANET simulation. Here we have grouped the current VANET simulators into 3 categories which are Network simulators,VANET simulators and Mobiity simulators.

Traffic flow simulator produces the necessary practical vehicular mobility traces to be used as input in the network simulator. Network simulators quantify and build the necessary elements in a wireless network, such as the precise framework of all nodes , packet sending and receiving assignments, data traffic exchange, channels, etc.

Time Division Multiple Access (TDMA) is a channel access system where time divisions are split into the available bandwidth and each section is only used by a single sender, eliminating packet collisions. Due to the lack of unified control and high slot allocation difficulty, TDMA, however, requires modifications to be used in ad-hoc networks.To maintain slot synchronisation and to decrease overhead messages[11], conflict-free scheduling systems need to be implemented. As vehicles show platoon activity and appear to drive in clusters, clustering is a natural occurrence that has been shown to occur on highways. Using different clustering algorithms, researchers have attempted to resolve the problems posed by TDMA.When it comes to vehicles clustered into groups we referred [12] where Vehicles traveling in the identical direction were put together in the same cluster Since clustering in various directions of moving cars causes overhead signalling because of repeated re-clustering. The clustering function of the CB-MAC protocol is also robust. RTCF (Request To Cluster Formation) will have to be submitted by an isolated vehicle in order to join a cluster. If a cluster existed, CH would submit ReTCl (Registration To Cluster) automatically and the isolated vehicle would join the cluster. If no cluster exists, however, a cluster created by the isolated vehicle would join in that cluster. However,If there was no cluster, a cluster would be formed by the isolated vehicle and it will be the CH.

E. About SUMO

SUMO is an open - source software, microscopic, multi modal simulation of traffic. This facilitates the simulation of how a given demand for traffic composed of single vehicles passes across a given road network. The simulation helps one to discuss a wide range of topics related to traffic control. It is strictly microscopic: each vehicle is clearly modelled, would have its own path, and travels across the network independently.SUMO is not only a traffic simulator, but a series of programs that help to plan and execute a traffic simulation. Since the sumo traffic simulation involves the simulation of its own context of the interpretation of road networks and increased traffic, both have to be generated using separate sources. We can create SUMO road networks by using a tool called "netgen" or by importing a digital road map.[7]The different files used in SUMO to make a Road Map are:- Node file(.nod.xml), Edge file(.edg.xml), Route file(.rou.xml), Network file (.net.xml) , Configuration file(.sumo.cfg.xml).

Similarly, netconvert, the road infrastructure importer, helps other traffic simulators such as VISUM, Vissim, or MATsim to read networks. Other popular formats, including Open Street Map, are read as well. The funding for TIGER networks was withdrawn because of the shortage of applications. Yet TIGER networks are also accessible and have been included in the OSM repository as shapefiles. In addition to these formats, "netconvert" can also read lesser-known formats, such as RoboCup system format.[6].The most popular applications for the SUMO suite are possibly the simulation of traffic in V2X-vehicle-to - vehicle and vehicle-to-infrastructure-communication analysis. SUMO is normally connected to an actual simulation of communication, such as ns2 or ns3, using TraCI.[6] SUMO's production began in the year 2000. Enabling the traffic science group with a method having potential to incorporate and test its own algorithms was the primary justification for creating an open source, microscopic road traffic simulation. To achieve a full traffic simulation, including the setting up methods for dealing with road networks, demand, and traffic controls, the software has no need to discuss all the required stuff.The DLR sought to make the algorithms deployed more comparable by using a similar design and model base by offering such a tool, and at the same time receive extra funding from other stakeholders. The traffic simulation provides external applications with a socket-based gui, enabling them to communicate online with a working simulation. Values and entity states that compose of the simulation can be both retrieved and modified. SUMO has already been used both by the DLR and external organisations in numerous initiatives.[5]

The primary motivation of this research is to minimize the total time required to send the data packets from both vehicles to RSU and vehicle to vehicle. Additionally, we aim to reduce the packet loss. Taking this two points in consideration we have conducted this research and have obtained valid simulation results.

The rest of the document is organized as follows: some recent previous work is demonstrated in Section 2. In Section 3, we present the proposed model and our solution methods are explained in section 4.The network simulation results are presented in Section 5, and finally, Section 6 presents the conclusion.

II. RELATED WORK

In the very first paper which we reviewed, M.S.Almalag et al [1] proposed an improved TDMA cluster-based MAC (ETCM) that provides (i)improved output with collision-free channel access and efficient time-critical safety message deliveries based on an improved logical frame structure that allocates two mini-slots for each vehicle at each sync interval of 100ms, ii) improved use of service channels with the dynamic reallocation of unused slots, and iii) improved use of service channels fairness among vehicles by balancing slot allocation. A series of simulations using the ns-3 network simulator has been studied using the proposed ETCM protocol. The results of the simulation show that with 99 percent transmission, the packet delivery ratio of security messages was significantly improved and the throughput (channel utilization) was significantly improved from 10 Mbps (in TC-MAC) to 25 30 Mbps (in ETCM) 7 channels (1 CCH and 6 SCHs) of 6 Mbps for a cluster of 100 vehicles. The researchers in [16] have used fixed infrastructure including road-side units to gather information from cluster heads and to fill the contact void that can arise when every data packet is lost. The task of selecting the CH according to the environment is provided to the RSU units. The above protocol attempts to facilitate coordination between the heads of the cluster and the adjacent clusters.

The other paper that we found interesting was [2] where they had proposed a framework to simulate VANET from OPNET Modeler and SUMO.Their proposal made it possible to use the OPNET Modeler to accurately simulate communications infrastructure and several existing models with a practical mobility model to measure the flow of vehicles on a real road.Their primary goal was to be versatile and simple to use with the use of Modeler's judicious features such as topology import. Their VANET simulation with many vehicle numbers or random seeds, however, demanded several OPNET scenarios and an equal number of topology imports, limiting a successful protocol.In order to explore more about routing protocols we explored [3] where, they evaluated the performance of HWMP, OLSR and DD routing protocols in a VANET crossroad scenario considering PDR, throughput and delay as evaluation metrics.In fact, to measure the efficiency of routing protocols, they used SUMO to produce the movement of vehicles and NS3.They found the standard IEEE 802.11p and TwoRayGround Propagation Loss Model for simulations, and sent multiple CBR flows over UDP. Moreover, various numbers of vehicles (20, 110 and 220 vehicles) have also been proposed for testing purposes.But one major drawback of their work was the negation of important parameters like routing overhead, traffic quantity and topology change.

Since we had not used SUMO before we surveyed a number of papers including [4] which could help us to understand,road infrastructure creation and traffic light simulation of real life road network of the specific locations,like in [4] using SUMO, they used the route map of the cities of Jamshedpur and Ranchi, India.They dwelt profoundly in the Vehicular Cloud, which has unique features such as autonomy, mobility, etc., and by an ad-hoc network the vehicles are linked to each other. Nodes had high mobility in this vehicular cloud network and network topology often shifted rapidly with time.It is possible to form vehicular clouds on the basis of the static and dynamic existence of the nodes.

If any car nodes are parked in a parking area or garage, they can create a static cloud, but they can exchange information and cloud installation as vehicles drive around the roadside, so it functions as dynamic clouds. Parked cars and moving vehicles have numerous types of services that are unused.In addition to that to evaluate the impact of road accidents and the overall traffic congestion time under certain conditions and to provide comprehensive analysis by reducing waiting time, this paper[8] proposed an extension of the mostly used open source traffic simulation SUMO (Simulation of Urban Mobility) to enable real time vehicles re-routing and to bypass the blocked road due to an incident, by updating their predefined static routes during simulation run-time. The primary goal of the paper is to extend the functionality of SUMO by designing a new re-routing mechanism that dynamically updates the route of the vehicles upon detection of any irrelevant conditions i.e. increase in traffic congestion or any occurrence of accident. The updated route will be completely based on the shortest path from the vehicle's location by excluding the area where the accident happened.In order to achieve this, they have created an incident on the simulator by stopping the vehicle for a certain fixed time period and thereby forming traffic jams. One of the key observations made in the project is that teleporting was a bug prevention measure to tackle random collisions, as in SUMO collisions arent technically defined but are observed. To overcome them, the two or more vehicles involved in a collision are teleported and showed all the missing features in current release of SUMO. To address the missing features in SUMO, they have combined SUMO with TraCI which is an API in python, to alter state of vehicle during simulation runtime and it involves using client-server communication.

The re-routing with TraCI has been initially tested by defining routes manually and the actions of specific vehicles could be monitored.But to perform it on a large scale scenario they use trigger mechanism to make the solution less complex as it consists in adding the road segments connected to the accidents lane to a list, and then comparing each vehicle's current lane ID to each trigger to identify the vehicles that need to be re-routed. They mentioned the alternative approach to the trigger mechanism is to reroute the vehicles that have accident lanes in their ongoing destination. When more vehicles deployed on the network the simulation steps are increased there by increasing in complexity.The main improvement brought up is re-routing mechanism performs well in case of one accident when compared to two to three accidents, which is mainly due to the small size of the map. They showed 35% improvement on Grid Network which is 10 minutes delay is reduced to 6.5 minutes and also performing some test cases on New York city road network lanes they have observed that road network topology plays a major role in effecting the re-routing solution. In conclusion they added, the more one way streets, single lane 2-way streets, traffic lights and junctions means the more complex a detour becomes.

Any VANET model can be looked at as two problems; routing and Medium Access Layer (MAC) protocols [14]. The routing problems usually deal with traffic congestion and accident avoidance or detection. Whereas the MAC protocols also take into consideration the inter-hop collisions (for a multi-hop network) and network traffic collision [15]. The TDMA aware scheme which is used in the paper helps in understanding a location based time division system. This scheme is called TDMA aware Routing Protocol for Multi-hop wireless vehicular ad hoc networks (TRPM) [15]. Here the road itself is divided into a zones and there is at least one device communicating in these zones. Each of these zones are sub-divided into time slots. Following a TDMA scheme, only one device can transmit at a given time slot. The next available time slot is selected at random for moving traffic [15].

In comparison to this, what makes our study distinct from the literature reviewed is the use of a hybrid technique, i.e. to make simulation more realistic, we want our nodes to respond to their environment as they receive warning signals to clear entry, reduce speed, keep a greater distance from the vehicle or need to adjust itinerary.We thus suggested the use of multi simulators, modelling the effect of mobility and network simulators on each other. Thus, though the mobility simulator would be intended to include macroscopic and microscopic details on roads and cars, the network simulator influences road traffic and enables adjustments to be made in relation to the exchanging of messages.

III. System Model and Problem Definition

A. Access Medium

The TDMA principle helps allocating the bandwidth to different vehicles by distributing time into different frames where each frame is divided into different time slots. Each vehicle can use the channel during its assigned time slot for communication.Many issues arise due to high mobility of the vehicles. Therefore, TDMA based MAC protocols should be taken into consideration for these high mobility of vehicles.

B. Constructing Realistic Road Network and Traffic

The below figure 2 shows our road structure having multiple lanes and intersections which we created by using java open street map editor as mentioned earlier.

The role of SUMO in enabling users to import road networks has streamlined the process of designing the mobility

Fig. 2. Constructive figure of our Road Structure in SUMO

model. The real world road network can be easily extracted and edited using the Java Open Street Map (JOSM) Editor, as seen in Figure 2.The structure consists of around 192 nodes.The architecture of our system model consists of roads and junctions. A suitable area was taken into consideration for our model.The map was then further processed through SUMOs command netconvert in order to generate simulation network containing heuristically computed values. Number of vehicles in the model will be dynamic as it is important to note the characteristic of the network depending on the traffic conditions.

C. Simulation Configuration-Hybrid Approach

The option of a network connectivity simulator is important when simulating a VANET system with a large number of vehicles theoretically exchanging several packets per second. Two essential criteria to acknowledge are easy maintenance, and the ability of road traffic and network connectivity simulators to interconnect.

We selected Veins, a hybrid simulation platform focused on long-established SUMO and OMNET++, in the quest for user satisfaction and inter-connectivity. SUMO embraces formats from various suppliers of maps. We have chosen the famous Open Street Map (OSM) and selected JOSM as our GUI and editor for OSM maps.Both SUMO and OMNET++ simulators are linked through a TCP socket. What this means is that the cars are first produced in SUMO and then transferred to the network simulator. OMNET++ finds all vehicles to be nodes and simulates the situation. If there is some alteration in the network, Veins will switch the SUMO car scenario.[18] [19]

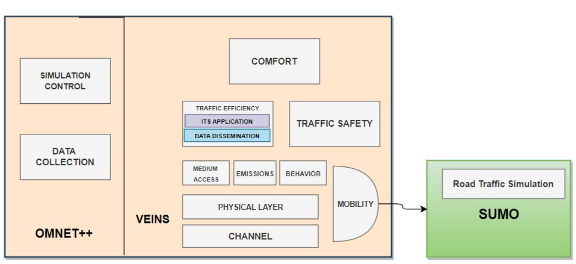

Fig. 3. Veins Architecture

In addition, veins include a vast range of simulation models that are commonly applicable to vehicle network simulation. Not all of them are required for each simulationand, in practice, it only makes more sense for a few of them to implement at most one in any given simulation. These models act as a toolbox: much of what is required to create a complex, highly accurate simulation of a vehicle network is already in place [19].

Figure 3 shows the veins architecture and its different components which are very much essential to setup and run the simulation.Figure 4 represents our network model in OMNET++.As it can be very well observed that we have included around 192 nodes and simulated it usinf TDMA as our access medium.That is, we divided the time horizon into slots of 0.1 seconds each. So based on the number of channels and slots the data will be transmitted.

Fig. 4. Our Network Model in OMNET++

The protocol for this correspondence was standardised as the Traffic Control Interface (TraCI). one may use the TraCI commands to adjust the direction of the traffic simulation. In Veins, we may configure the signals being received and the way the radios process them, but most notably, by calling the Veins TraCI units, one can change the activities taking place in the simulation, such as the velocity of the cars, the switching of the routes and also the actions of the traffic lights.[18] [19]

IV. Solution Methods

The problem which we are trying to solve is to minimise the time taken for communication of packets transmission between the nodes and also minimise packet loss. For that we have implemented a TDMA based approach to transfer the data. The communication exists between RSU to Vehicle and vehicle to vehicle. A timeslot is reserved for a certain period of time for a specific node to transmit and receive the required data. This approach not only helps to minimise the packet loss for receiving and transmission; which can be observed in Fig 9 but also reduce the time for transmission and receiving the which can be observed from Fig 8. It is also observed that by increasing the time horizon into slots from 0.1 seconds to 0.2 increases the total amount of time consumed for the overall simulation to run but the packets loss is increased to the interference and noise which was added to increase the span of time.

After conducting multiple experiments we observed that dividing the timeslots between 0.05 and 0.2 second and 0.1 second provided the best result of balance between total time taken and number of packets lost. The result of our experiment can be seen in the Simulation Results section.

V. Simulation Results

The simulation procedure was implemented using the setup, system model and specifications specified in the previous section. simulation output includes a variety of statistics for each vehicle and RSU, such as sent packets, total lost packets, SINR packets lost, RXTX lost packets, etc.

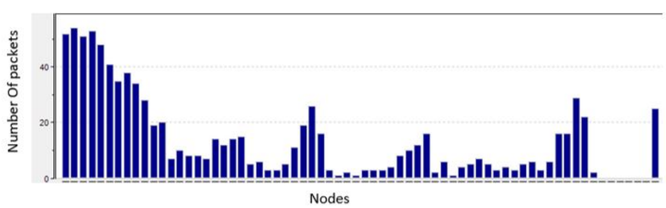

Fig. 5. SINR Packets Lost

Figure 5 shows the number of packets lost in each node because of interference and noise.

Figure 6 shows the number of packets lost in each node in total. Observing both graphs 5 and 6 we discovered that there were negligible number of packets lost because of some other reason except noise and interference. The end node; right most node in both the graphs represents the RSU, while the rest of the nodes represent the vehicles.

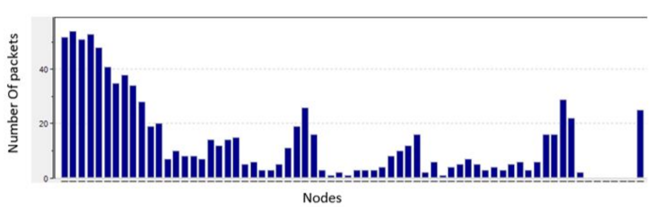

Fig. 6. Total Lost Packets

Figure 7 shows the number of packets sent through each of the nodes. The end node; right most node in the above graph represents RSU. The rest of the nodes represent the vehicles. Since, the RSU must communicate through all the remaining nodes, it transmits and receives the highest number of packets.

Figure 8 shows the total time taken by the packets for transmission in each node. The first node; the left most node represents the RSU. Since, the RSU has to communicate through all the rest of the nodes it transmits and receives

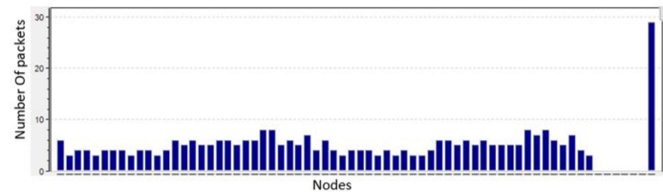

Fig. 7. Sent Packets

the highest number of packets.This eventually results in great amount of time consumed in comparison with other nodes.

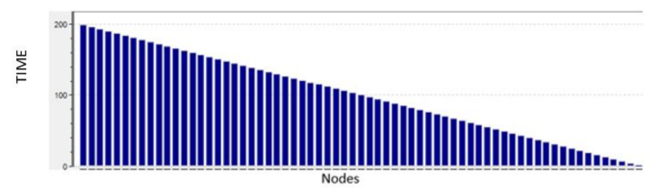

Fig. 8. Total Time In Each Node

Figure 9 displays, receiving and transmitting packet loss. Only some of the nodes observe the RXTX packet loss which can be clearly seen from Figure 9.

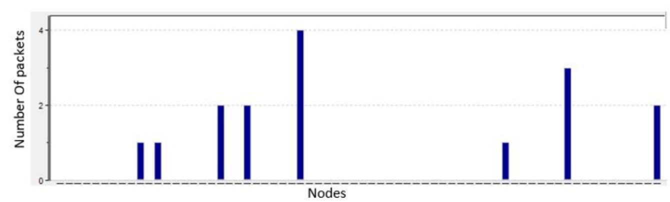

Fig. 9. RXTX Lost Packets

VI. Conclusion

After completing this course, we became highly familiar with different paradigms of wireless networks and felt confident to initiate this research. We tried to understand the topic in depth by reviewing in access to 12 different papers in our related work section.The outcome of that was, for our VANET simulation we decided to use the Veins simulation platform along with SUMO and OMNET++.Additionally we explored the working of JOSM editor and different commands related to the simulator.We achieved our primary objective which was to simulate a VANET model using TDMA as an access medium and then on the basis of that, data packets were transmitted in the vehicular network considering the transmission fairness among all pair of vehicles and minimizing the different packet loss.Furthermore, we obtained optimum result when the time slot was set to 0.1 seconds for the total time taken and number of packets lost, when we considered a interval between between 0.05-0.2 seconds.

REFERENCES

[1] Almalag MS, Olariu S, Weigle MC. Tdma cluster-based mac for vanets (tc-mac). In2012 IEEE international symposium on a world of wireless, mobile and multimedia networks (WoWMoM) 2012 Jun 25 (pp. 1-6). IEEE.

[2] FlorentKaisser CG, Kassab M, Berbineau M. A framework to simulate VANET scenarios with SUMO.

[3] Kolici V, Oda T, Sugihara Y, Spaho E, Ikeda M, Barolli L. Performance evaluation of a VANET simulation system using NS-3 and SUMO considering number of vehicles and crossroad scenario. In2015 9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing 2015 Jul 8 (pp. 22-27). IEEE.

[4] Amar AK, Kumar S. Traffic Simulation of Vehicular Cloud Network Using Sumo. International Journal. 2016 Jan;6(1).

[5] Krajzewicz D. Traffic simulation with SUMOsimulation of urban mobility. InFundamentals of traffic simulation 2010 (pp. 269-293). Springer, New York, NY.

[6] Behrisch M, Bieker L, Erdmann J, Krajzewicz D. SUMOsimulation of urban mobility: an overview. InProceedings of SIMUL 2011, The Third International Conference on Advances in System Simulation 2011. ThinkMind.

[7] "SUMO," 12 August 2020. [Online]. Available: https://sumo.dlr.de/docs/SUMO_at_a_Glance.html.

[8] D. Smith, S. Djahel and J. Murphy, "A SUMO based evaluation of road incidents' impact on traffic congestion level in smart cities," 39th Annual IEEE Conference on Local Computer Networks Workshops, Edmonton, AB, 2014, pp. 702-710, doi: 10.1109/LCNW.2014.6927724.

[9] K. Aries, "verizon connect," 2 february 2020. [Online]. Available: https://www.verizonconnect.com/resources/article/connected-vehicle-technology-v2v-v2i-v2x.

[10] Shladover S, Desoer C, Hedrick J, Tomizuka M, Walrand J, Zhang WB, McMahon D, Peng H, Sheikholeslam S and McKeown N Automated vehicle control developments in the PATH program., IEEE Transactions on Vehicular Technology 40(1), 114130. 1991

[11] Y. Gunter, B. Wiegel, and H. P. Grossmann, Medium access concept for VANETs based on clustering, in Proc. 2007 IEEE Vehicular Technology Conference, pp. 21892193.

[12] A. F. M. S. Shah, M. A. Karabulut, H. Ilhan and U. Tureli, "Performance Optimization of Cluster-Based MAC Protocol for VANETs," in IEEE Access, vol. 8, pp. 167731-167738, 2020, doi: 10.1109/ACCESS.2020.3023642.

[13] "not chaotic code," 20 may 2020. [Online]. Available: https://tech.chaotictoejam.com/index.php/2020/05/20/introduction-to-vanets.

[14] S. A. A. G. Ghahramani, A. M. A. Hemmatyar and K. Kavousi, "A Network Model for Vehicular Ad Hoc Networks: An Introduction to Obligatory Attachment Rule," in IEEE Transactions on Network Science and Engineering, vol. 3, no. 2, pp. 82-94, 1 April-June 2016, doi: 10.1109/TNSE.2016.2566616.

[15] M. Hadded, P. Muhlethaler, A. Laouiti and L. A. Saidane, "TDMA-Aware Routing Protocol for Multi-Hop Communications in Vehicular Ad Hoc Networks," 2017 IEEE Wireless Communications and Networking Conference (WCNC), San Francisco, CA, 2017, pp. 1-6, doi: 10.1109/WCNC.2017.7925601.

[16] Jayavel J, Venkatesan R, Ponmudi S. A TDMA-BASED SMART CLUSTERING TECHNIQUE FOR VANETS. Journal of Theoretical Applied Information Technology. 2014 Jul 20;65(2).

[17] H. Noori, "Realistic urban traffic simulation as vehicular Ad-hoc network (VANET) via Veins framework," 2012 12th Conference of Open Innovations Association (FRUCT), Oulu, 2012, pp. 1-7, doi: 10.23919/FRUCT.2012.8122092.

[18] C. Sommer, "veins," 31 march 2020. [Online]. Available: ttps://veins.car2x.org/documentation.

[19] M. Z. Chowdhury, M. Shahjalal, S. Ahmed and Y. M. Jang, "6G Wireless Communication Systems: Applications, Requirements, Technologies, Challenges, and Research Directions," in IEEE Open Journal of the Communications Society, vol. 1, pp. 957-975, 2020, doi: 10.1109/OJCOMS.2020.3010270.

[20] M. Choudhary, "Geospatial world," 15 january 2019. [Online]. Available: https://www.geospatialworld.net/blogs/what-is-intelligent-transport-system-and-how-it-works.