Investigation of Performance Metrics in OMNET++ for Vehicular Networks

K. S Nwizege, B.G Akoba, F.O Philip-Kpae, J. Danamina, P.G Irimiagha, L. U Akazua

Abstract: Road congestion, parking difficulty, and collision is very prominent in advanced and developing countries. Intelligent Transport Systems (ITS), with wireless technique has solution to these problems through the application of vehicular technology. The wireless deployment, safety and non-safety applications in vehicular communications can be achieved with proper implementation of network metrics. It is very clear and of no doubt that more research in wireless applications for vehicular networks is on the increase due its application in this modern era. Dedicated Short Range Communication (DSRC) has paved way for these applications in informatics, parking/congestion control, and safety application via the knowledge of the ITS. In this paper, we have made investigations on some performance metrics that have impact in the analysis of vehicular communications. We will use these metrics in our future work, to analysis the performance of vehicle networks with other rate algorithms using OMNET++ as implemented here.

Keywords: DSRC; ITS VANETs; vehicular networks; OMNET++

I. INTRODUCTION

In the late 1990s, this area experienced a rapid growth and interest with the existence of 2G, 3G, and 4G cellular networks. Due to the flexibility and portability of this technology, it steered up research interest in the field of Information and Communication Technology (ICT) with telecommunication engineers interested in how to employ the capabilities of this technology. In the last few decades, we have witnessed a dramatic growth in the wireless industry which has created a lot of employment as well as financial revolution in the wireless industry. Since the introduction of this technology, there has been a tremendous shift away from landlines telephones which were very effective since their introduction in 1979 to mobile cellular telephony in 1980. But no doubt as we can all see, that deployment of this technology has span through all countries of the world making life easier through conversion and messaging.

One of the advantages of wireless networks is MOBILITY. The users can connect to existing networks and can then move about freely without having to worry about getting disconnected.

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The central feature of all wireless networks is their ability to transmit data over the air in the form of electromagnetic signals. Ideally the wireless technology should free the user of any physical boundaries so that the user can roam freely without worrying about losing connectivity and performance degradation. For IEEE 802.11 networks, two sorts of media were conceived in the electromagnetic spectrum, the infra-red light and radio frequency. Devices such printers and mobile phones use infra-red technology to exchange data, while most IEEE 802.11devices use radio frequency as their transmission media.

Application of wireless technology has a significant impact worldwide in many sectors. It has made life easier and comfortable. The importance of wireless technology cannot be overemphasised with the flexibility it has provided for humanity. Another interesting aspect is in the application in vehicular communications, where vehicles could communication to each other directly or via an Access Point (AP) depending on the network topology.

However, the IEEE 802.11 standards have been at the core of wireless communication since the mid-1990's, and advances are now driven by the proliferation of wireless equipment into many electronic devices[9][10]. Wireless networks have emerged so well and become popular as they are deployed in almost every sector of life such as schools, hospitals, coffee shops, airports, restaurants. Modern mobile devices such as laptops, Personal Digital Assistance (PDAs) are capable of deploying these services. The standard regulates all operations of the different wireless standards. Vehicular communication adopts the principles of IEEE 802.11 standards in other to communicate with each other; hence the suitable wireless standard for vehicle is the IEEE 802.11p.

The IEEE 802.11p is the wireless standard adopted in vehicular networks. It is also known as Wireless Access in Vehicular Environment (WAVE) [7]. Vehicular networks now use the IEEE 802.11p as against the 802.11a standard which was earlier used before now. IEEE 802.11p is an extension of 802.11 Wireless LAN MAC and PHY layers [2] used in vehicular networks. It can be used by the Advanced Drivers Assistance (ADAS) and ITS. IEEE 802.11p is orthogonal OFDM-based to compensate for both time and frequency-selective fading. It is very similar to 802.11a in that it uses 5:2 GHz while 802.11p use 5:85 - 5:925 GHz. IEEE 802.11p emphases on reduced channel spacing (10 MHz instead of 20 MHz in 802.11a). The IEEE 802.11p wireless standard is implemented in this research as seen in Table I.

The rest of the paper is organized as follows: Section 2 is background of studies, while Section 3 deals with network topology; Section 4 is results/discussions, while Section 5 concludes the paper.

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II. BACKGROUND OF STUDIES

In this section, we will consider information very vital that will help in understanding of this subject and other common principles of operation.

A. Context –aware system

Context-aware refers to information such as speed, location, and distance or time. In [2], contextual-soundscape which is associated with environmental sound was implemented. This study was aimed at sound recognition in Smartphone. Also in [8], speed was the context information that was used in implementing the Context-Aware Rate Selection Algorithm (CARS). CARS algorithm used speed in dynamically changing the vehicles rate depending on channel condition.

In this study, we have considered location as a context-information. In this scenario, different environmental location which affects reception of signal was considered in this simulation.

B. Dedicated Short Range Communication (DSRC)

The DSRC specification, was originally developed in the Unites States (US), but it is now also in operation in the European Union (EU). DSRC is a wireless technology that is developed to support the communication between vehicles and between vehicles and infrastructure in a very dynamic network with a proposed transmission range of up to one kilometre [13]. DSRC enables a new class of communication applications that will increase the overall safety and efficiency of the transportation system [3]. It is a set of protocol and standard for operating one-way or two-way communications between vehicles in close range. Vehicles move at high-speed in unison using the inter-vehicle communications to allow very close quarters and coordinated velocity/direction changes. One of the applications of this is in electronic toll collection, where drivers entering or leaving certain road sections are automatically charged for their usage. Both the Federal Communications Commission (FCC) in the US and the European Telecommunications Standards Institute (ETSI) in the EU have allocated spectrum in the 5:9 GHZ range for DSRC. The European Committee for Standardisation (CES) specifies the DSRC physical layer, the data link layer, and the application layer. Some remarkable research has been done on DSRC ranging from computer simulations of a complex road-system to measure throughput, delay and packet success [9] to experimental measurements for outdoor set up and analysis of context-information for safety and non-safety applications on DSRC [8].

C. Vehicular networks

The frequent occurrence of accidents on our roads is a major concern for every nation, since accidents contribute a significant percentage to the daily death rate. This concern is one of the challenges facing research in vehicular communications and road safety. For several years now, vehicular networks have been a topic of unique research interest in the area of wireless and mobile communications. The number of road accidents can be reduced with greater communication and cooperation between vehicles and Road Side Unit (RSU) offered by the ITS [11]. Road safety applications will require reliable and timely wireless communications, while commercial applications will expect a high data rate. In order to provide a high rate of reliable data rate, an important technique for wireless communications is adaptive modulation and coding, which adapts to the communication channel conditions and attempts in order to provide the best possible communication performance. However, due to the high speed of vehicles, the time during which two vehicles or a vehicle and a roadside AP are in a communication range can be very short, which pose a big challenge for the rate adaptation of vehicle communication networks [12]. Vehicular networks now use the IEEE 802.11p as against the 802.11a standard which was earlier used before now.

IEEE 802.11p is an extension of 802.11 Wireless LAN MAC and PHY layers [2] used in vehicular networks. Before the deployment of this standard, the IEEE 802.11a was used for vehicular networks. It can be used by the Advanced Drivers Assistance (ADAS) and ITS. IEEE 802.11p is orthogonal OFDM-based to compensate for both time and frequency-selective fading. It is very similar to 802.11a in that it uses 5:2 GHz while 802.11p use 5:85 - 5:925 GHz. IEEE 802.11p emphases on reduced channel spacing (10 MHz instead of 20 MHz in 802.11a).

D. Vehicular Ad hoc Networks (VANETs)

VANET topology is very important in vehicular communication because of the high mobility and speed of vehicles approaching a speed of about 200km/h in a short distance [3]. VANET is a special case of network set up where vehicles communicate with each other via and Access Point (AP), this is same as known in a wireless network called vehicle to Infrastructure (V2I) network [5]. In this case where wireless node communicate directly with each other, the network is called Vehicle –to Vehicle (V2V) network, where as in vehicular network, it is called Mobile Ad hoc Network (M ANET)[6]. One of the roles or significance of VANET is to increase network performance [1].

VANET exhibits it roles in a complex distributed and large scale network. The capability of this set up is for data aggregation and network management [14]. This is observed when a large number of nodes occupied by the vehicles send lots of data and the vehicles keep building up as the communicate to each other via the AP as a base station. In VANET, both safety and non-safety applications can be implemented through the ITS.

III. NETWORK TOPOLOGY

In this section, we will consider the networks simulator used in this research, the network setup implemented, and performance metrics used in analysing the results obtained from our simulations.

A. OMNET++ simulator

There are many discrete event simulators such as Network Simulator 2/3 (NS2/3), OPNET, Global Mobile Information System Simulator (GloMoSIM), OMNeT++ is very efficient in simulating wired and wireless networks. OMNeT++ was used in this research because of its ability to simulate vehicular networks, and also a matter of choice in

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other to compare performance with other platforms. OMNeT++ uses two extension languages that the user must employ to write models and control the simulation. One is C++ and the other is called NEtwork Description (NED) [4]. In this simulator, the user describes the structure of a simulation model in the NED language.

One of the reasons for OMNeT++ is that, it has standard tool to study protocols for both wired and wireless networks. There are various tools in OMNeT++ that enable users to achieve reliable results, depending on the choice of tool in OMNeT++ simulator. Some of these tools are MIXIM, SUMO, and INETMANET [15].

In this research, we have chosen to use INETMANET because it contains the features required in implementing rate adaptation in vehicles. It also provides detailed models and protocols, as well as supporting infrastructures. Also, dealing with vehicular networks need proper choice of mobility model. This tool has already implemented mobility models, and it is also flexible in creating when it comes to creating your own model.

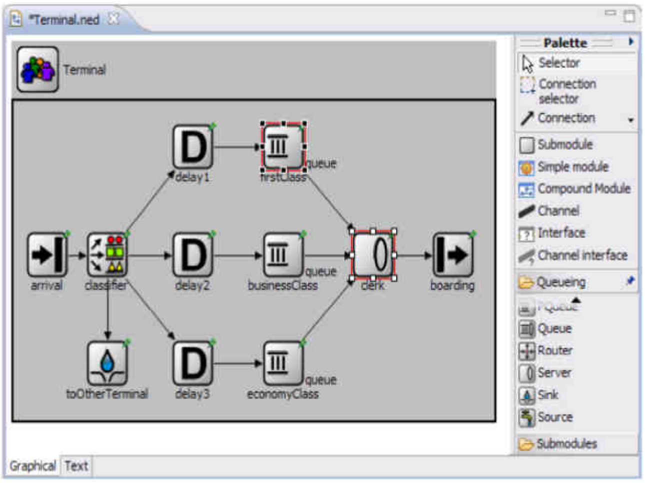

Figure 1. **OMNeT++ NED Editor.**

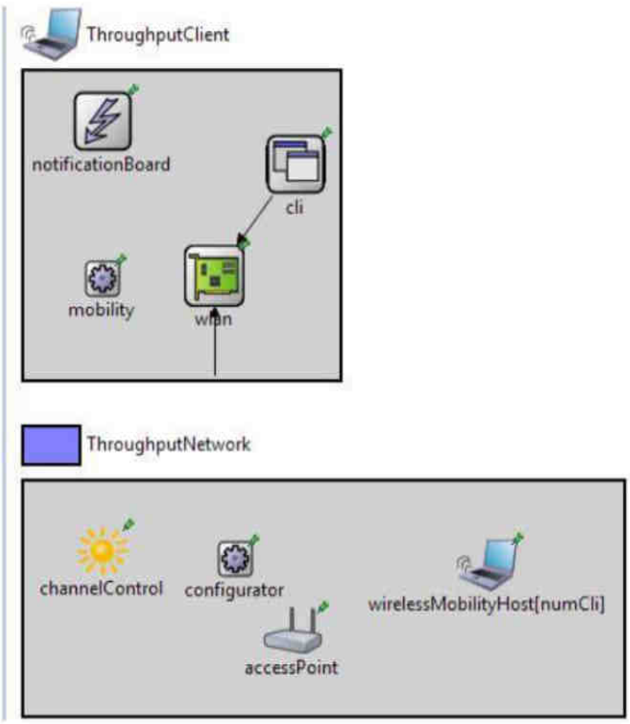

Figure 2 Simulation Model.

B. Network scenario

In this network configuration, a default linear mobility model in INETMANET was adopted. This mobility model determines how the nodes move around in the network. This mobility model deals with speed, angle , and acceleration parameters. Angle only changes when the mobile node hits a wall: then it reflects off the wall at the same angle. We adopted this mobility model because it has some of the parameters we need in implementing Context-Aware (CA) task in our research.

```
import inet.mobility.single.LinearMobility;
import inet.nodes.inet.WirelessHost;
import inet.nodes.wireless.AccessPoint;
import inet.world.radio.ChannelControl;
import inet.networklayer.autorouting.ipv4.IPv4NetworkConfigurator;

module ThroughputClient
{
    parameters:
        @display("i=device/wifilaptop;bgb=209,199");
        @node();
        string mobilityType = default("LinearMobility"); // how the node moves around. see: inet.mobility
    gates:
        input radioIn @directIn;

    submodules:
        notificationBoard: NotificationBoard {
            parameters:
                @display("p=52,32");
        }
        cli: EtherAppCli {
            parameters:
                registerSAP = false;
                @display("b=40,24;p=180,60,col");
        }
```

Figure 3. Linear mobility model in INETMANET.

C. Network configuration

In this article, nodes representing vehicles were configured to communicate with each other via an AP as seen in Figure 4. From this figure, vehicles communicate to each other via an AP. Positions of these vehicles keep changing as they move from one distance. In this scenario, propagation model is put into consideration as buildings and tall trees will affect signal reception. We also implemented a two-ray propagation model to combat with signal reception problems shown in Figure 5.

Figure 4. Wireless nodes with AP.

The two-ray ground model takes the path loss exponent from the path between transmitter and receiver. It considers both the direct path and a ground reflection path as shown in Figure 4. The advantage of this propagation model is that is gives more accurate prediction at a longer distance than the free space propagation model. Predicted received power at a distance is given as:

$$P_r(d)= \frac{P_{t}G_tG_rh_t^2h_r^2}{d^4L} \quad (1)$$

Where h_t and h_r are heights of the transmitted and received antennas, and G_t *and* G_r transmit and receive

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gain, **d** is distance and L which is also a measure of distance is added, assuming L=1, while P_t

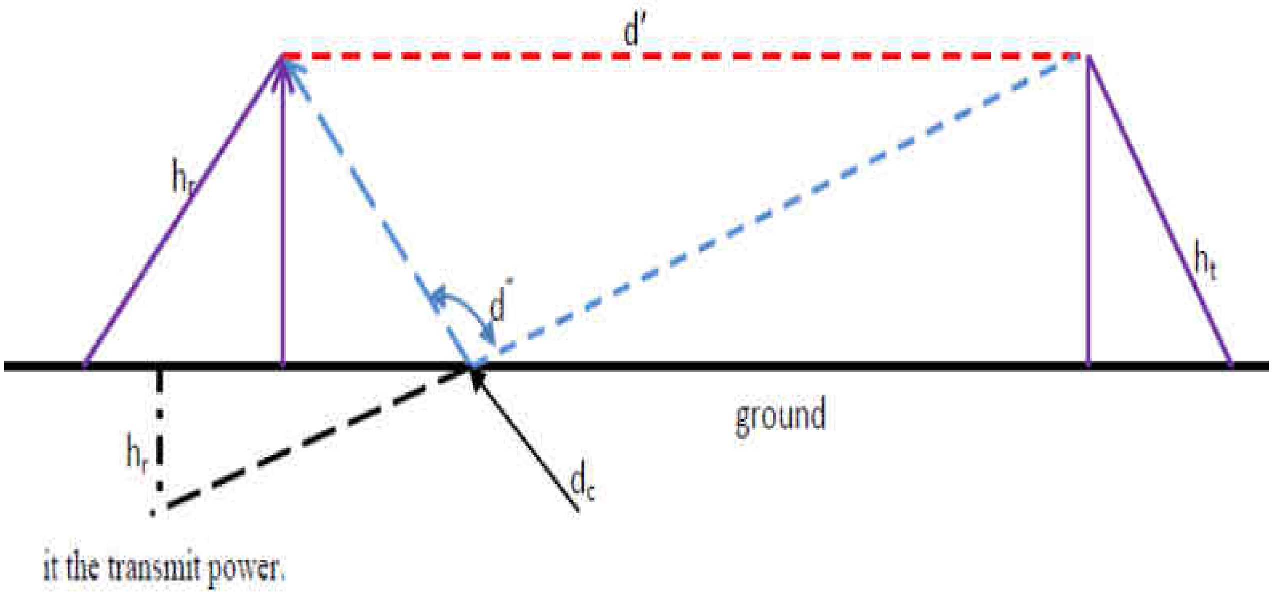

Figure 5. The two-ray ground model.

The setup is implemented using Adaptive Context Aware Rate Adaption Selection (ACARS). ACARS is designed with robust adaptation to transfer data for DSRC in vehicular networks; so as to mitigate the problem of Vehicle Collision (VC) for road safety. With this goal, ACARS algorithm can adapt to fast channel changes due to propagation phenomena, and yields better performance due to AP coordination and transmission of power control scheme. This algorithm is adaptive to wireless and mobile environments, since it is able to mitigate the challenges of short duration, fast change in link condition, and underutilization of link capacity which affect other schemes from selecting the optimum data range, since the time to communicate between two nodes is very short.

The channel operation in this set up is CH 178 which is the control channel having with a frequency of 5.89GHz as also indicated in the Table I. This implementation is focused on the safety application which falls in the control channel as shown in Figure 6.

D. Performance metrics

In this paper, we have investigated some metric parameters in OMNET++ which could be used in analysing the performance of the network. Some of them considered here are:

- **End-to- end Delay (d):** Is the average time it takes for a packet to arrive to a defined destination. In this paper, the end-to-end delay is referred to as the average time it takes for a packet to travel from a cluster member to the control center. The end-to-End delay is calculated as follow:

$$d= \left(\sum \frac{(arrive\ time - sent\ time)}{(number\ of\ sent\ messages)}\right) \ [14].$$

- **Throughput (t):** This is the numbered of successfully received packets or messages. It is achieved as:
  t = number of received packets – number of sent packets.
- Jitter (j): This is a metric parameter that deals with delay and similar to end-to-end delay, since both of them deal with latency in information delivery. Jitter is the variation of packet and data delivery between two systems, when some data take longer to travel from one source to the other. It results to network congestion, timing drift, and route changes.

$j = \Delta t_B - \Delta t_A$, where A and B are different points on the network.

Other metrics that can be analyzed from the INETMANET simulation are:

- Number of packets sent without retry
- Number of sent and received bits
- Number of dropped packets
- Minimum and maximum loss rate

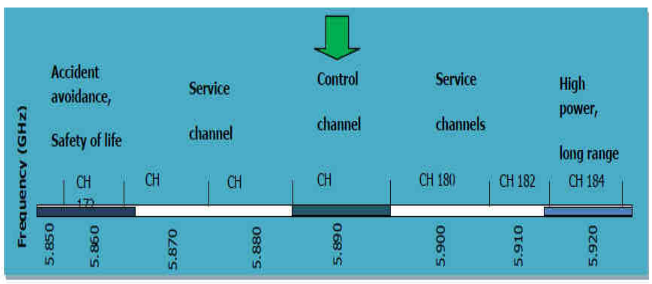

Figure 6. The seven proposed DSRC channels and their frequency bands.

IV. RESULTS AND DISCUSSIONS

In this section, we will identify and discuss some of the results obtained in INEMANET simulation.

A. Simulation/results

The results obtained from our simulations will be presented with just a single Rate Adaptation Algorithm (RAA) by using ACARS. Table I shows the parameters used in this simulation.

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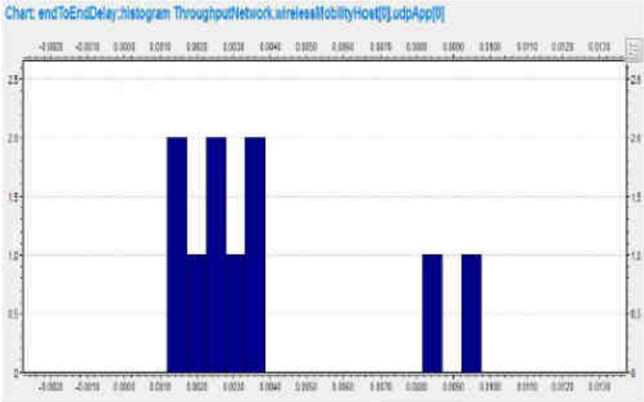

Figure 7.1. End-to-end delay for wireless host 0.

The positions of the vehicles are generated and determined by equations 2 and 3 respectively.

$$\Delta x = vt\cos(\theta) \quad (2)$$

$$\Delta y = vt\sin(\theta) \quad (3)$$

where **v** is velocity in m/s , **x** and **y** are coordinates , **d** is distance in meters and **t** is time in seconds.

Therefore, distance between Vehicle-to-Vehicle (V2V) or Vehicle-to-Infrastructure (V2I) can be determined by using equation (4). Furthermore, vehicles in communication range and those out of range can also be determined with the following equations. The positions generated by vehicles using equation, gives positions of the vehicles due mobility, and in turn gives rise to the distance of the vehicle from the AP.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + \cdots + (x_n - y_n)^2} \quad (4)$$

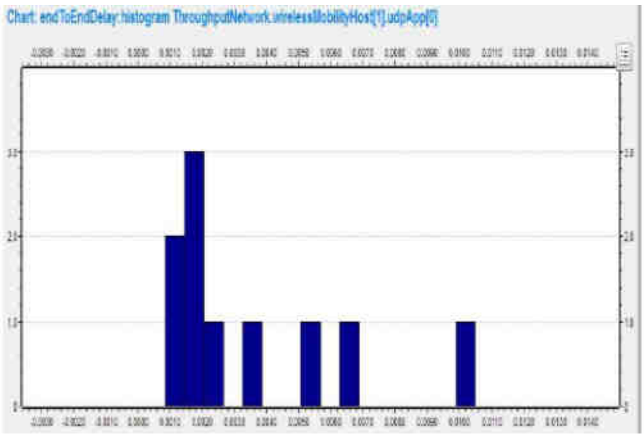

Figure 7.2. End-to-end delay for wireless host 1.

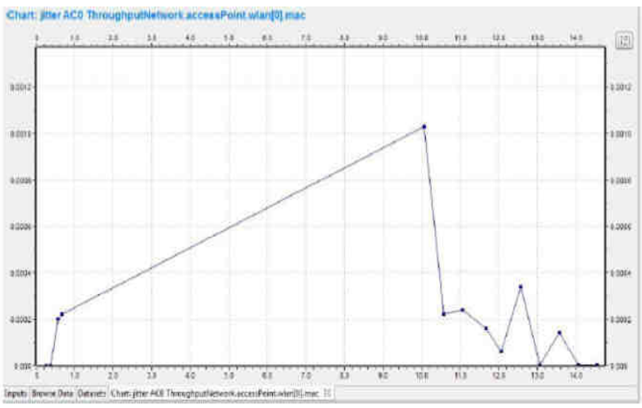

Figure 8. Jitter for AP.

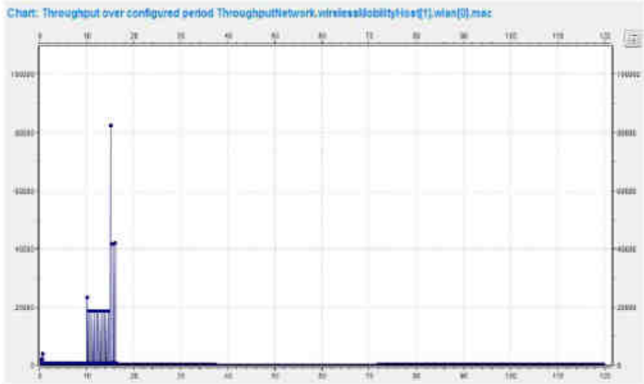

Figure 9.1. Throughput for host 1.

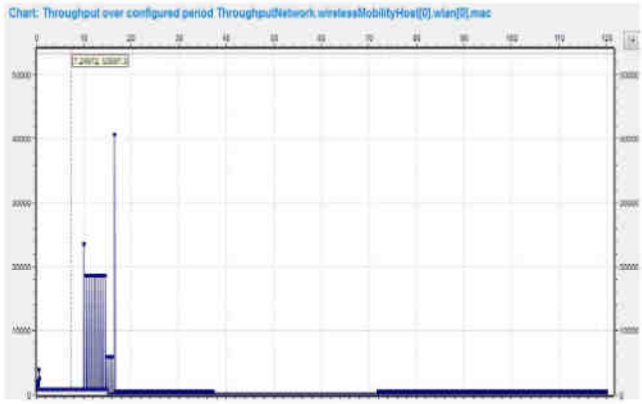

Figure 9.2. Throughput for host 0.

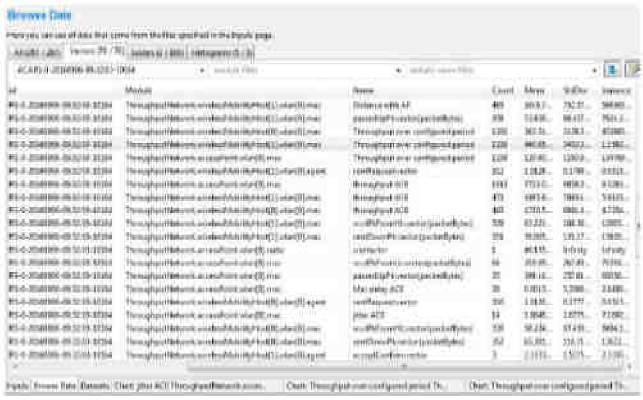

Figure 10. General metric parameters.

TABLE I. SIMULATION PARAMETERS.

Parameters (Units)	Values
Constraint Area (m)	2000
Number of Vehicles	150
Position of AP (m)	1000
PHY and MAC Protocol	IEEE 802.11p
Frequency (GHz)	5.89
Delay limit (s)	20
Normalized Transmit Power (mW)	20
Noise Power (dBm)	-110

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Update interval (ms)	100
ϒ (Path Loss exponent, Urban area cellular radio)	2.0
Mobility model	Linear
Max Queue Size	14
Simulation time (s)	120
Carrier frequency (GHz)	2.4
cwMin Data	31
Snir Threshold (dB)	4
Data rate (Mbps)	3, 4.5, 6,9,12,24,27
Maximum Retransmission	3

B. discussions

This research is only an elementary stage of studying the available metric parameters in OMNET++, so that we can identify which of them to use in analysing performance of vehicular networks in future works. We have not actually extracted the result from INETMANET, to illustrate the performance. This will be implemented in future work, since the metrics are still under investigations. But from graph obtained in Figures 7.1 and 7.2, we can observed the delay trend for two different wireless host, that there values changes as the mobility of the nodes changes. Also in figures 8, it shows the delay variation as the vehicle moves to and from the AP.

The network throughput is shown in figures 9.1 and 9.2 respectively, while figure 10 shows the detailed metric parameters that we can use in analysing the vehicle performance in the future works.

V. CONCLUSION AND FUTURE WORKS

This section considers the summary of the research, and the limitations presently that will be take care of in our future works.

A. Conclusion

Figures 7-9.2 show some metrics, and in figure 10 shows a more elaborate metrics which we will study and implement in our future works. This study and investigation, has made us to have an in-site of the metric parameters to deal with in analysing vehicular performance in OMNET++.

B. Future works

In the future, we will be exploring the metric parameters in OMNET++, and analysing other RAAs, so that comparisons can be made with our proposed ACARS. We will also consider other RAAs, and how they perform in this simulator compared to their implementation in other platforms such as MATLAB.

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REFERENCES

1. A. Muhtadi, D. Perdana and , R. Munadi , “Evaluation of AODV, DSDV, and ZRP Using Vehicular Traffic Load Balancing Scheme on VANETs”, Ijssst, vol. 16, issue 3, pp 1-7, March 2013.
2. H.Lim, J. lee, and K.Yongjin , “Mobile user context Awareness model using a novelty contextual-soundscape information” ,7th International Conference on Intelligent Systems, Modelling and Simulation, Cambridge ,pp.1-7, April 2016.
3. J. Guo, and N. Balon, “ Vehicular Ad Hoc Networks and Dedicated Short-Range Communication”, University of Michigan, Dearborn.pp.7-14,June 2006.
4. M. M Castro, “Metrics to Evaluate Network Robustness in Telecommunication Networks”, University of Strathclyde , pp. 13-20, May 25, 2011.
5. Xia. , R Gao, L. Wang, and R Hao, “Real-Time Performance Analysis of Infrastructure-based IEEE 802.11 Distributed Coordination Function”, School of Software, Dalian University, China. pp. 1-3, Dec 2011.
6. W.Alasmary, and W.Zhuang, “ Mobility impact in IEEE 802.11p infrastructureless vehicular networks”, University of Waterloo, Canada, pp.2-4, 2010.
7. Y.Wang ,A.Ahmaed ,B.Krsihnamachri , and K.Psounis , “IEEE 02.11p Performance Evaluation and Protocol Enhancement ”, Viterbi School of Engineering University of Southern California Los Angeles, CA 90089, USA. pp.1-6, , IEEE explore, Sept 2008.
8. P.Shankar, T.Nadeem, J.Rosca, l.Iftode, “CARS: Context Aware Rate Selection for Vehicular Networks” Department of Computer Science, Rutgers University, pp.1-6, Oct 2008.
9. T. Hewer, “High Performance Simulation and Modelling of Wireless Vehicular Ad-Hoc Networks", pp. 3-5 August 2011.
10. Bianchi, “Performance Analysis of the IEEE 802.11 Distributed Coordination Function", IEEE Journal on selected areas in communications, vol. 18,pp. 535-547, March 2000.
11. W. R. M. M. Artimy and W. J. Phillips, “Assignment of Dynamic Transmission Range Based on Estimation of Vehicle Density", ACM, pp. 40-48, 2005.
12. P. Sommer. “Design and Analysis of Realistic Mobility Models for Wireless Mesh Networks", pp. 1-4, September 2007.
13. A. Almohammedi et al, “Evaluating the Impact of Transmission Range on the Performance of VANET”, in International Journal of Electrical and Computer Engineering (IJECE), Vol 6, No 2, pp. 800-809, 2016.
14. S. Khakpour, R. W. Pazzi, and K. El-Khatib. “Using Clustering for Target Tracking in Vehicular Ad Hoc Networks", University of Ontario Institute of Technology 2000 Simcoe St North, Oshawa, L1G 7Y2, Canada, pp. 1-5, 2015
15. OMNet++. http://www.omnetpp.org/, accessed Oct, 2016

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