Journal of Science and Technology ISSN: 2362-1443
2023, Vol. 3, No. 1, 1-5

Performance Analysis of V2X Services in 5G Millimeter Wave Communication

Min Prasad Gharti
Nepal College of Information Technology,
minprasadgharti@gmail.com

Shashidhar Ram Joshi
Institute of Engineering
srjoshi@ioe.edu.np

Article History:
Received: 19 July 2023
Revised: 18 October 2023
Accepted: 13 December 2023

Keywords—V2X, ITS, DSRC, 5G, QoS, SINR, NS3, gNB, UE, LoS, NLoS

***Abstract*—Vehicle to everything (V2X) is the connection of vehicle and any other thing like vehicle, infrastructure, network, pedestrian etc. The emerging fifth generation (5G) cellular technology is the key enabler of digitalization of the transportation system which is still not commercialized. Millimeter band radio waves are proposed for 5G technology to get the large bandwidth. The millimeter band radio waves are highly attenuated by rain, vegetation, street lamps, buildings, etc. The emerging application in the field of vehicular industry like high density vehicle platooning, pre-crash sensing and automated overtake requires better quality of service (QoS). The results show the minimum SINR value of LoS channel is -13 dB and minimum SINR value of NLoS is -25.68 dB over the variation of distance from 10m to 400m, where the threshold SINR value is -10dB. The minimum transport block loss in the physical layer is 20% in 5 nodes whereas 60% in 40 nodes with constant distance 150m between gNB and UE in the NLoS channel. The maximum delay found is less than 1.5 millisecond. The Friis propagation loss model is used in the LoS channel whereas the millimeter wave propagation loss as well as the shadowing model is used in the NLoS channel. This research work is validated in NS3 simulator.**

I. INTRODUCTION

In the era of information technology, the millimeter wave communications open the door to implement the vehicle to everything communications (V2X), internet of things (IOT) and machine-to-machine communications (M2M). Basically, the vehicular network is classified as urban, sub-urban, highway and rural. The critical information is exchanged between connected vehicles to save from the accidents.

In the world scenarios, the traffic management and control are done through the use of various technologies but still vehicular management is not fully automated. But the scenario is changing from people driving vehicles to self-driving cars, automatic collision avoidance and critical information are exchanged using cellular networks. In the beginning of vehicle use, vehicles were managed through the people.

Different symbolic materials were used to guide the vehicle and notify other nearby vehicles with the use of glasses, horn, driver assistant etc. With the passing of time, various advancements have been made and developed in the vehicular management system.

The development of the cellular V2X [8] communication technology will dramatically change the guidance of route and exchange of information. In the developed countries, the traffic management and control, vehicle fare collection and communication have been done using the latest technology.

But in developing countries, people still used the traffic light, glass, vehicle horn and secondary communication medium to manage the vehicle and sharing of the safety and non-safety related messages. The latency requirements in automated driving and safety related service is shown below [10].

II. RELATED WORK

In 5G cellular technology, it is anticipated to use the millimeter band radio frequencies that play a vital role to get the gigabit data rate and ultra low latency [1]. The low latency and very high throughput capabilities of millimeter wave radio links in the cellular systems will need exploration in all layers of the communication protocol stack but it does not rely only at the physical layer.

The modeling of the millimeter wave channel is fundamental work to get the desired results in millimeter wave cellular networks [2]. The author uses Nakagami fading-based channel model in the performance evaluation of the 5G cellular networks as well as 3GPP channel model is used as a reference model. The author found that Nakagami gives more severe fading than the 3GPP model and it always gives a lower throughput.

The NR PHY abstraction model was based on exponential effective signal to interference-plus-noise ratio (SINR) mapping (EESM) and used current radio specification regarding channel coding, code block segmentation, MCS etc. [3].The PHY loss is 0% in fixed MCS in 10m distance between gNB and UE whereas 35% PHY loss is found in 30m distance.

The combination of carrier aggregation and network slicing to carry in the same interface simultaneous transmission of enhanced Mobile Broadband (eMBB) and Ultra-Reliable-Low-Latency (URLLC) traffic flows. When the two flows are completely isolated, the minimum delay can be achieved because the usage of dedicated carriers permit URLLC transmissions to be independently scheduled, without adding additional delay due to the presence of other eMBB packets in the queue. The 45% of the available resources are wasted because the carrier dedicated to URLLC is poorly utilized [4].

The attenuation of the signal depends upon the depth of the foliage. In the 15 GHz frequency, the attenuation predicted by the NZG model is closer to the standard. At frequencies such as 28GHz and 38GHz FITU-R gives the best fit at both In-leaf and out-of-leaf scenarios. The attenuation experienced due to foliage was higher in In-leaf scenarios than that of out-of-leaf at all the 5G frequencies [5].

III. RELATED THEORY

A. *Propagation Model*

The phenomenon of reflection, refraction and diffraction of waves when incident on the rain drops reduce the power of the signal by some value inducing the path loss. The path loss due to rainfall affects the radio coverage. At the higher value of frequency and rainfall rate the specific path attenuation increases which significantly changes the coverage area as well as the handoff parameters of the cellular broadband services. Though the significant change in signal level is seen above the 6 GHz frequency. The 5G services are allocated with different frequencies ranging from 600 MHz to 60GHz where rainfall effect will be severe for higher frequencies. The ITU-R P.838-2 recommendation defined the relationship between specific path attenuation and the rainfall rate and also defined the value of coefficient α of R for different frequencies. The signal loss due to rainfall shall be considered during the coverage planning and assigning handoff parameters of higher 5G frequency bands. The signal degradation due to the atmosphere is a complex process that depends on a variety of parameters such as obstacle, humidity, multipath propagation, rain, temperature, noise and interference. The electromagnetic waves are attenuated by rain through the process of and absorption. The rainfall rate and frequency determine the attenuation which results in small area coverage, path loss increases and consequently reduce the system performance. There are different types of path loss models that calculate the path attenuation of the radio frequency signals. All of them are not generalized for all environments and localities; instead they are suitable for some specific areas, terrain and climate. ITU recommendation proposed higher frequency band for 5G implementations the effect of rainfall will be significant in each corner of the rural, urban and suburban areas. The millimeter wave propagation model, the friis propagation model and shadowing model are used to evaluate the V2X services in 5G.

B. *Performance Metrics*

The SINR, delay, transport block loss in physical layer as well as packet delivery ratio are used to measure the quality of service (QoS).

Delay is the time taken by the packet to travel from source to destination. If it is lower, then the quality of service is better. Average delay is defined as the delay for a packet to be received to its destination. This is calculated by summing up the delay for all delivered packets and the dividing it by the total number of delivered packets. It is calculated in milliseconds. Mathematically, the average delay is given as

$$\text{Average delay} = \frac{\text{Delay}}{\text{Total number of received packets}} \quad (1)$$

PDR is defined as the ratio of the number of successfully delivered packets to the total number of packets that have been sent. The packet delivery ratio is the measure of how many packets are successfully received out of total transmitted packets.

$$Packet\ Delivery\ Ratio = \frac{No.\ of\ Recv.\ Packet\ at\ Dest.}{No.of\ \ Sent\ Packet\ by\ Source}. \quad (2)$$

Medium Access Control layer payload is called a transport block (TB). The transport block loss defines how many packets are successfully decoded in the receiver side.

IV. METHODOLOGY

The classification of the vehicle is type1, type 2 and type3. The classification is based on the size of the vehicle. The modeling of the vehicle obstruction by one vehicle to another vehicle is required to enhance QoS of the 5G millimeter wave communications. The categorization of nodes is based upon the type of vehicle. The nodes like truck, buses, car, high speed ambulance, very important person vehicle, motorcycle, bicycle and fire brigade are classified on the basis of their importance and specific usage. The sharing of critical information among the nodes with guaranteed QoS and defined latency is the challenging task to the latest technology. The fifth generation millimeter wave broadband cellular technology meets the above requirements. The parameters related with V2X communication are speed, direction, position, receive signal level etc. In vehicular communication systems, various types of messages are exchanged between nodes. Traffic is divided into safety and non-safety traffic. The safety traffic is related to the driving but non-safety traffic is related to the management and infotainment. Researchers focus on safety traffic which cannot tolerate the delay. The message transmission latency includes downlink and uplink transmission delay. The proposed system consists of UE, gNB and building obstacles.

Concentrating on the objective of this research, the quality of service is determined using the parameters like data rate, bandwidth used, the latency improvement and degradation of interference involved during the transmission. The V2X communication will be simulated in a realistic based environment setup so as to facilitate the overwhelming link life time. Therefore, data rate, SINR and the delay will be measured continuously using experimental setup.

A. Network Simulator

A NS-3 network simulator consists of a variety of networking technologies and protocols and helps users to build complex networks. NS-3 is a discrete-event network simulator and freely available software. NS-3 supports Linux, Mac operating system (OS) and Windows OS.

B. Simulation Scenario

Let, the gNB represents the radio base station and UE represents the end user as shown in fig. 1. The carrier frequency of 28GHz and 100 MHz bandwidth is used. The LoS and NLoS channels are considered in between gNB and UE. The various distances start from 10m to 400m and user numbers starting from 5 to 40 are set for the simulation to study the various parameters of the channel. The fading based millimeter wave channel model is used. The 30dB transmit power is set to both gNB and UE having 4 antennas in the radio base station and 1 antenna in user equipment.

Simply, a building is a house that is made from different materials having different sizes and models. Basically, there are three types of buildings: residential, office and commercial. The building has different external wall types that are wood, stone and concrete.

A building is represented as a rectangular parallelepiped. The walls are parallel to the x, y and z axis. A building is divided into a grid of rooms which is described by number of rooms along the x-axis, number of rooms along the y-axis and number of floors. The x and y room values start from 1 and increase along the x and y axis. The vertical axis is represented by z-axis and used to increase the floor number. All the rooms of the building are the same size.

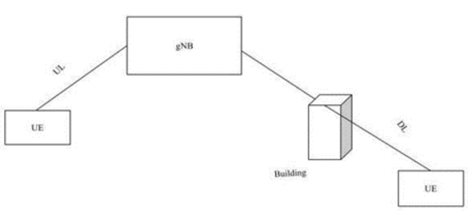

Fig. 1. Block diagram of system with building obstacle

V. RESULT AND DISCUSSION

The uplink and downlink SINR, delay, packet delivery ratio, transport block loss in physical layer and comparison between LoS and NLoS channel is studied based on the tuning of the parameter distance between UE and gNB ,number nodes and different propagation model.

A. SINR

Fig. 2 illustrates the variations of SINR ranges from -3.9 dB to -13 dB when number of node equal to 20 and distance varying from 10m to 400m.

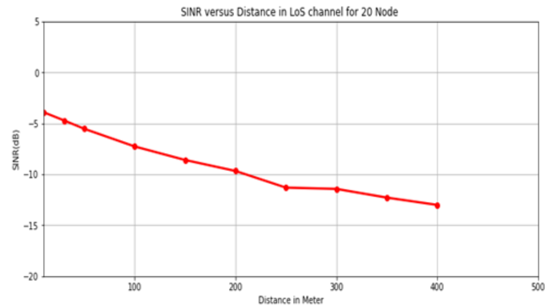

Fig. 2. Variations of SINR (dB) over changing the distance in LoS channel

In NLoS channel, the minimum value of SINR is -8.3 dB and maximum value of SINR is -25.68 dB as shown in fig 3. When the distance increases from 10m to 140m, the TB loss found is as expected. When the distance increases above the 150m, all the TB are corrupted and the service outage is found. So, in NLoS with slow fading, the range of communication is up to 150m as shown by this research.

Fig. 3. Variations of SINR (dB) over changing the distance in NLoS channel

B. Physical layer transport block loss

In fig. 4, the TB loss is zero when setting the number of nodes from 5 to 40, LoS channel and distance between UE-gNB is 150m. In a LoS channel having 150m distance, the performance of 5G millimeter wave communication is better.

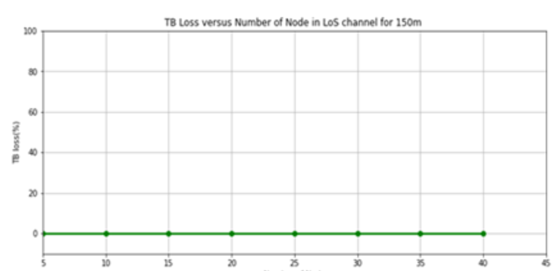

Fig. 4. Transport block loss (%) vs number of node in LoS channel

In NLoS channel having various numbers of nodes from 5 to 40 and communications ranges up to 150m, the maximum TB loss found is 60% and minimum TB loss found is 20%. The fig. 5 shows that TB loss and increment of the distance is proportional. When the distance is increased, the TB loss also increased.

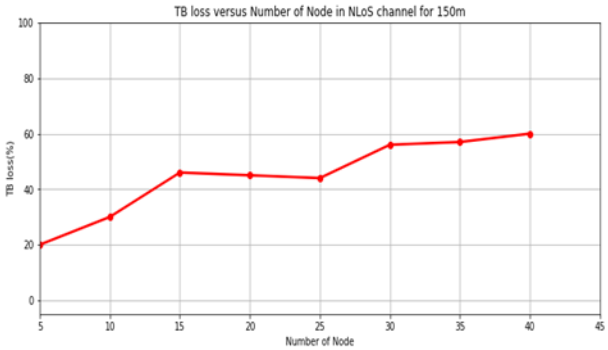

Fig. 5. Transport block loss (%) vs number of node in NLoS channel

C. *Delay*

The delay time is measured by taking number node from 5 to 40, minimum distance between UE and gNB is 10 m and maximum distance between UE and gNB is 150 m as shown in fig. 6. Here, we found that the maximum delay time is 0.838 millisecond and minimum delay time is 0.767 millisecond. This delay time meets the standard delay time of 5G cellular technology i.e. less than 1 millisecond.

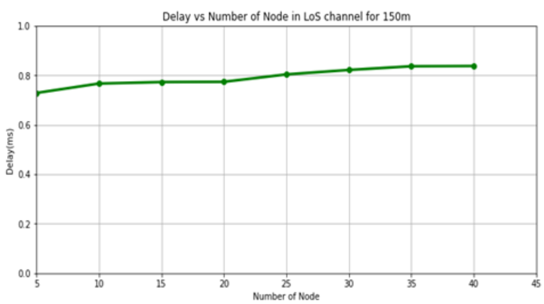

Fig. 6. Delay vs number node in LoS channel

In NLoS channel having a number node from 5 to 40 and minimum distance between UE-gNB is 10 m and maximum distance between UE-gNB is 150m, the maximum delay found is 1.12 millisecond and minimum delay found is 0.79 millisecond as shown in fig. 7.

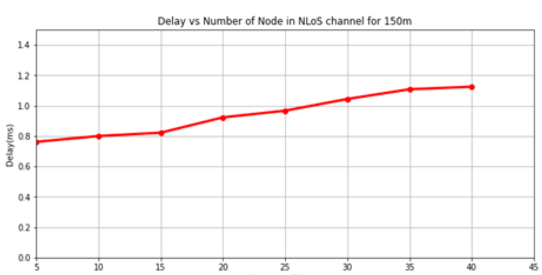

Fig. 7. Delay vs number node in NLoS channel

D. *PDR*

In LoS channel mode, the maximum packet delivery ratio observed is 99% and minimum PDR is 85%. When the number of nodes is less, the PDR is high. But, when the number of nodes increases, the PDR is reduced because there is limitation in the resources to provide the data service. The optimal PDR is obtained at node 20 ar shown in fig 9.

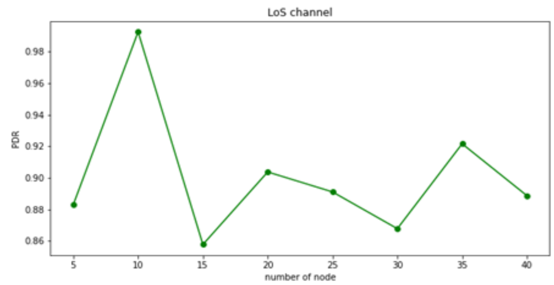

Fig. 8. PDR vs number of node over LoS channel

In NLoS channel, obstacle is present in between transmitter and receiver. From the experiment, the maximum PDR is 90% and the minimum PDR is 70%. The fig. 8 shows that, at number of node is equal to 20, there is maximum packet delivery ratio and at number of node is equal to 10, there is minimum number of that value.

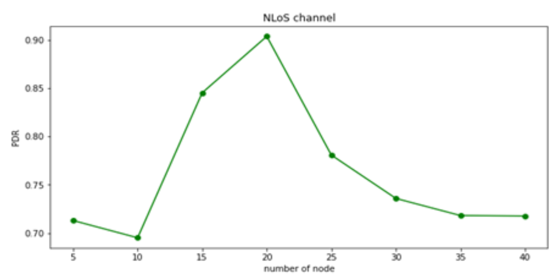

Fig. 9. PDR vs number of node over NLoS channel

VI. CONCLUSION AND FUTURE ENHANCEMENT

With the increase of the distance of the node from the gNB, the receive signal is decreased as well as increases the packet delivery time. The system without the presence of obstacles, the results are found as expected and meet the requirements of 5G cellular technology. In addition, the system with obstacles in between transmitter and receiver, the performance metrics like signal quality, transport block loss, packet delivery ratio and delay are measured. The experiment showed that the LoS channels outperform the NLoS channel based on the parameter SINR, PDR, TB loss and delay.

The threshold SINR value found is -10 dB when setting transmit power 30 dB both in gNB and UE. The TB loss (%) in the receiver at 5 nodes is 20% and 60% loss at 40 node when using millimeter wave propagation loss model.

This research work can be extended using machine learning algorithms, various propagation model and frequency. The researcher can use reinforcement machine learning algorithm, 3GPP propagation loss model and various frequencies in the range of 30GHz to 300GHz to examine the performance of the 5G cellular technology. The Doppler effect can be added to determine the performance of motion objects.

REFERENCES

[1] M.Mezzavilla, M.Zhang, M.Polese, R.Ford, S.Dutta, S.Ragan and M.Zorzie, " End-to-End Simulation of 5G mmWave Networks," IEEE Communications Surveys and Tutorials, 2018.

[2] M.Polese and M.Zorzi," Impact of Channel Models on the End-to-End Performance of mmWave Cellular Networks," arXiv:1806.06125v1, 2018.

[3] S.Lagen, K.Wanuga, H.Elkotby, S.Goyal, N.Patriciello, H.Giupponi, " New Radio Physical Layer Abstraction for System-Level Simulations of 5G Networks" , arXiv:2001.10309v2, 2018.

[4] M.Pagin, F.Agostini, T,Zugno, M.Polese and M.Zorzi, "Enabling RAN Slicing Through Carrier Aggregation in mmWave Cellular Network" , arXiv:2005.10142v1, 2020.

[5] M.Shaik , A.Kabanni and N.Nazeema, " Millimeter wave Propagation Measurements in Forest for 5G Wireless Sensor Communications", IEEE, MediterraneanMicrowave Syposium, 2016.

[6] Ibrahim A. Hemadah, K.Satyanarayana, M.El Hajjar and L.Hanzo, " Millimeter-Wave Communications: Physical Channel Models, Design Considerations, Antenna Constructions and Link-Budget" , IEEE Communications Surveys and Tutorial(Volume:20), 2018.

[7] J.Huang, C.Xiang Wang, H. Chang, J.Sun and X.Gao, " Multi-Frequency Multi-Scenario Millimeter Wave MIMO Channel Measurements and Modeling for B5G Wireless Communication Systems", IEEE Journal on Selected areas in Communications(Volume: 38) , 2020.

[8] H. Khan and M.Bennis , "On the Application of Network Slicing for 5G-V2X", European Wireless 2018; 24th European Wireless Conference, 2018.

[9] A.Din Trabelsi, H. Marouano, F.Zarai and A. Meddeb-Makhlouf, " Dynamic Scheduling Algorithm based on Priority Assignment for LTE-V2X vehicular Networks",International Wireless Communications and Mobile Computing Conference , 2018.

[10] K. Lee, J. Kim, Y.Park, H. Wang and D. Hong , " Latency of Cellular-based V2X: TTI-independePerspectives on TTI-proportional latency and TTI-independent-latency" , IEEE Access(Volume:5), 2018.