

Digital-twin-enabled geometry-based network architecture for autonomous unmanned vehicles

by

Jannatul Ferdous (191014003)

*Thesis report (CSE499) submitted in partial fulfillment of the
requirements for the degree of*

Bachelor of Science in Computer Science and Engineering

Under the supervision of

Dr. Nafees Mansoor



**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
UNIVERSITY OF LIBERAL ARTS BANGLADESH**

FALL 2022

© *Jannatul Ferdous*
All rights reserved

DECLARATION

Project Title Digital-twin-enabled geometry-based network architecture for autonomous unmanned vehicles
Authors *Jannatul Ferdous*
Student IDs 191014003
Supervisor Dr. Nafees Mansoor

We declare that this thesis report entitled *Digital-twin-enabled geometry-based network architecture for autonomous unmanned vehicles* is the result of our own work except as cited in the references. The thesis report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Jannatul Ferdous
191014003

Department of Computer Science and Engineering
University of Liberal Arts Bangladesh

Date: February 02, 2023



Department of Computer Science and Engineering
University of Liberal Arts Bangladesh
Mohammadpur, Dhaka - 1207

CERTIFICATE

This is to certify that the thesis report entitled **Digital-twin-enabled geometry-based network architecture for autonomous unmanned vehicles**, submitted by **Jannatul Ferdous** (Student ID: 191014003) is a undergraduate student of the **Department of Computer Science and Engineering** has been examined. Upon recommendation by the examination committee, we hereby accord our approval of it as the presented work and submitted report fulfill the requirements for its acceptance in partial fulfillment for the degree of *Bachelor of Science in Computer Science and Engineering*.

Dr. Nafees Mansoor, Associate Professor

Dept. of CSE, University of Liberal Arts Bangladesh

Bijan Paul, Senior Lecturer

Dept. of CSE, University of Liberal Arts Bangladesh

Sabrina Jesmin, Lecturer

Dept. of CSE, University of Liberal Arts Bangladesh

Niaz Ashraf Khan, Lecturer

Dept. of CSE, University of Liberal Arts Bangladesh

Place: Dhaka

Date: February 02, 2023

ACKNOWLEDGEMENTS

I would like to convey my sincere appreciation to my research supervisor, *Dr. Nafees Mansoor*, for allowing me the right set of instructions and opportunity to conduct research and motivating me each and every day, and showing me that it was possible to walk in the path of this research field. The irreplaceable guidance he provided throughout my thesis work and his vision and sincerity have deeply inspired me to work further. In order to complete the task and convey the work as clearly as possible, he has taught the methodology. It was true honor and joy for me to work and gain knowledge under his supervision.

I am greatly obligated to my respectable teachers of the Department of Computer Science and Engineering at the University of Liberal Arts Bangladesh who continuously supported me throughout my undergrad journey and taught me how to think outside the box. I got the opportunity to learn and experience something new every day without any doubt. Not every time it was a moment of joy for me but their motivation, continuous guidance, and teaching methods have encouraged me to push myself harder and driven me to be the person that I became today.

I am blessed to have my parents in all sorts of hardships that came along with my journey. The enormous amount of support, love, and never-ending prayers they showered upon me and I have received from them are indescribable. I will always be beyond grateful to my parents for the immense sacrifice they have made for educating me for my future. Nonetheless, I would like to acknowledge my friends and relatives for their continuous support and motivation.

Lastly, I would like to appreciate each and every person who has showered me with their continuous support to complete the thesis work explicitly or implicitly.

Jannatul Ferdous

University of Liberal Arts Bangladesh

Date: February 02, 2023

Dedicated to
my loving Mother
– *Jannatul Ferdous*

ABSTRACT

In modern times, Intelligent Transportation Systems are necessary for effective communication between vehicles, and the shift to information-driven transportation is connected to the concept of a digital twin Almeaibed et al. (2021). Wireless technologies such as VANET (Vehicular Ad hoc Network) have received increasing consideration lately in vehicular communication. Recent studies have shown that Vehicle-to-Vehicle (V2V) communication effectively impacts vehicular traffic and the road environment. However, efficient management of VANETs' operations and coordination leads to several optimization problems that require to be resolved. It is seen that it highly takes into consideration nearby objects including moving objects (adjacent vehicles) as well as static objects (such as Buildings and vegetation), and the sharing of uncommon channels which act as an obstruction in the network. Hence, an optimal geometry-based network in Intelligent Transportation Systems can provide efficient communication between vehicles by taking into consideration the surrounding environment. This research aims to acknowledge how the information sharing between autonomous vehicles gets obstructed due to the surrounding environment and how the factors interrupt reliability in V2V communications. This will try to improve the current road scenarios by strengthening information sharing among connected vehicles' where the surrounding measurements are taken explicitly .

Keywords:ITS (Intelligent Transportation System), VANET (Vehicular Ad hoc Network), V2V, V2I, LOS condition, BLOS(non - LOS condition buildings/ vegetation), VLOS (non - LOS condition vehicles).

Contents

1	Introduction	1
1.1	Brief Background	1
1.1.1	Problem statement	2
1.2	Aims, objectives and Motivation	3
1.2.1	Aims	3
1.2.2	Objectives	3
1.2.3	Motivation	4
1.3	Project Specification	5
2	Literature Review and Analysis	6
2.1	Studies on V2V Communication	6
2.2	Related Work	7
2.3	Analysis	7
3	Methodology	9
3.1	Proposed Method	9
3.1.1	Overview of the proposed System	9
3.1.2	System Model	11
4	Design and Development	14
4.1	Flowchart Design	14
4.2	Pseudo code of the architecture	15
5	Result analysis	17
5.1	Performance Parameters	17
5.1.1	Geography Data	17
5.1.2	Vehicular Mobility Data	17
5.2	Simulation Results and Outcome	18

6	Conclusions	20
6.1	Social, Legal, Ethical, and Environmental Issues	20
6.2	Future works	20
	References	22

List of Figures

1.1	Broadcasting information between vehicles	4
1.2	Information Sharing among vehicles in same direction	4
3.1	The type of links in the vehicular environment and how they are obstructing efficient communication with them.	10
3.2	Equation for large scale signal variation. Here, G_{ground} variable is used to measure the coefficient of the reflection and distance Z_{ground} is used for measuring the reflected ray from the ground.	11
3.3	A path loss exponent γ has been used in this equation. Here at a reference distance of d_0 the loss of path is DL_{d0} variable.	11
3.4	Equation 03 denotes the log-distance model of path where at distance 'd' the received power is ' P_r ' which is measured in decibels unit, considering the unit gained by the antenna. And the ' P_t ' is the transmitted power which is also measured in decibel units.	12
3.5	This equation 04 refers to the use of attenuation through the transmission model in order to execute transmission through vegetation. Here, the per meter mean excess loss of transmission due to vegetation is measured with the variable SEL and the frequency with f in gigahertz.	12
3.6	Equation 5 here measures the power in an E field of the concerned rays such as LOS, reflected and diffracted ones.	12
3.7	Here, E_0 = at a reference distance d_0 the envelope E field ω = angular frequency t = time, E field is evaluated in respect to this duration M_j = reflected ray j reflection coefficient S_k = coefficient of the diffraction from the diffracted ray k	12

3.8	Here,	
	θ_i = incident angle. r is the proportional permittivity of the material.	13
3.9	This equation 08 has been used for calculating the ensuing power	13
3.10	This equation 09 has been used for measuring small-scale variables, where,	
	$\sigma_{\min}$ = smallest small scale deviation for given los kind of i	
	$\sigma_{\max}$ = the highest value of deviation for los type of i	
	SBi= Number of moving objects for every unit of area	
	SBmax= Max Number of moving objects for every unit of area	
	DFi = Area of steady objects for every unit of area	
	DFmax = Max surface of steady objects for every unit of area	13
3.11	After combining both the signals and finding out σ , the resultant power is measured through this equation	13
4.1	Flowchart of the architecture.	14
5.1	Openstreetmap and SUMO configuration	18
5.2	Google earth visualization shows the obstructed and non-obstructed links for a specific location	19

List of Tables

3.1	Link types and method for propagation.	11
-----	--	----

Chapter 1

Introduction

For a very long time, technology has been encouraged to advance quickly in the field of transportation. Wireless Technologies such as VANET has been introduced in transportation for effective V2V communication where two nodes can appropriately communicate as share information among each other. These emerging technologies have been paving the way for unmanned autonomous vehicles. Researchers from academia and industry are collaborating to create and enhance autonomous vehicle designs that will rely on inter-car computers, communications, and decision-making Ghafoor et al. (2018). Among all aspects of modern transportation, dynamic vehicular movement, and uneven data distribution are the primary causes of intermittent connectivity Zhao et al. (2022).

1.1 Brief Background

The advancement of active transportation technology systems has been supporting drivers of moving vehicles to avoid traffic jams and accidents. There are many technologies have been proposed to acknowledge the scenarios and improve vehicular communication. The growth of connected cars and the Internet of Things (IoT) presents some intriguing prospects for people to commute conveniently and safely Mir & Filali (2017). DTN offers a virtual overview of the transportation network, which can be used to better control traffic and organize public transportation servicesY. Wu et al. (2021). The recent advancements have led to an ever-growing diversity of definitions that could result in the technology's deployment being carried out ineffectivelyVanDerHorn & Mahadevan (2021). Vehicles participating in data exchange are given more power through wireless connectivity, which also encourages

the development of vehicular networks (VNs) in vehicular contextsZhao et al. (2022). In Intelligent Transportation Systems (ITS), widespread use of Vehicular Ad hoc Networks (VANET) has been used for an adequate period to continuously improve traffic management efficiency and reduce vehicle collisions/accidents on roads. V2V communication can observe the surroundings beyond the visible range, and exchange a wide range of information on vehicle mobility which increases traffic efficiency and improves driving safety by enabling resources. Functionalities of connected vehicles involve lane-changing support and constructive collision avoidance for intelligent transportation systemsGhafoor et al. (2018). However, the scenarios of information sharing change as the communication range is interrupted due to physical obstruction that can put a great impact in blocking the communication signals.

1.1.1 Problem statement

For everyday moving around the city people highly depends on public or private transportation where most of our time is wasted on the roads due to heavy traffic flow or roadblocks which occur for various reasons and result in car collisions/accidents. This has raised the requirements for advanced technologies and shown that information sharing among autonomous vehicles can reduce the impacts of such scenarios and provide efficient communication between vehicles. Such wireless technology as VANET has been proposed for effective data transmission among vehicles. In vehicle ad hoc networks (VANETs), multi-hop data distribution is crucial for the implementation of collision avoidance and much more fascinating applicationsC. Wu et al. (2015). Efficient information broadcasting among cars or other transportation not only improves communication among vehicles but also saves a lot of time and hassle for drivers and pedestrians. There are many broadcasting applications have been proposed and the majority of these applications employ a one-to-many propagation in which a single vehicle transmits a message that is sent to all other vehicles in a remarkably brief period of time, even when there are many hops Palazzi et al. (2007). Various protocols have been proposed formats, based either on IEEE 802.11 or on channelization such as time division, space division, and code division multiple access Omar et al. (2011). However, the surrounding objects such as buildings, trees, and vehicles are key factors and act in disturbing vehicle communication in the road scenario. On the other hand, the uncommon channel also results as obstructing factor in vehicular communication. This reduces the efficient communication among

vehicles as the communication signals get interrupted which increases delay and loss of information.

1.2 Aims, objectives and Motivation

The aim, objective, and motivation of the work came from real-world scenarios and the hassle faced daily on the roads where there is no efficient communication procedure followed. Even if information sharing as broadcasting among unmanned vehicles is considered the surrounding objects, environments and the uncommon channel sharing between the vehicles will result in decreasing the efficiency of information sharing.

1.2.1 Aims

Any objects or obstruction between vehicles while broadcasting can reduce the efficiency of information sharing among them. of A massive truck blocking the communication between two nodes or vehicles(transmitter and receiver) might result in extra attenuation that is more than twenty decibels which are higher than the attenuation brought on by any personal automobiles Zhao et al. (2020). Hence, it is important to acknowledge the channel sharing and obstructions among two or multiple nodes which has a great impact on vehicular communication.

The aim of the research is to resolve the issue of communication between vehicles taking into consideration the types of communication links (LOS, VLOS, BLOS) and common channels that exist and cause obstruction and inefficient communication between vehicles

1.2.2 Objectives

With the knowledge of link obstructions in road scenarios connected autonomous vehicles (CAV) can efficiently broadcast messages or information to each other. The primary objective of our research came from the scenarios where effective message transmission from a source to other nodes was considered. However, which gave born to important objectives of the research which are given below:

- Acknowledge how the links are shared among vehicles.
- Identify how links are interrupted due to moving and steady objects.

- Consider the channel sharing among vehicles and how it works as an obstruction as well.
- Lastly, have better broadcasting among vehicles as shown in the figure below.

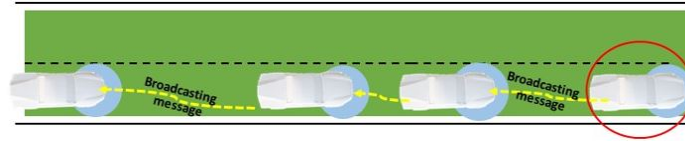


Figure 1.1: Broadcasting information between vehicles

1.2.3 Motivation

On a daily basis, drivers, passengers, and pedestrians have to face safety, security, and health issues for inefficient information sharing among vehicles. Several broadcasting strategies have been put out, where statistical-based schemes need nodes to keep any neighbor information and rebroadcast choice solely depends on local data Bakhouya et al. (2011). However, the geographic factor can flip the information sharing among nodes where broadcasting and rebroadcasting get highly affected by it. Hence, the motivation for the research came from situations such as roadblocks or vehicle collisions/accidents occurring on the road because of inefficient vehicular communication due to geographical factors which results as an obstruction between the nodes. The

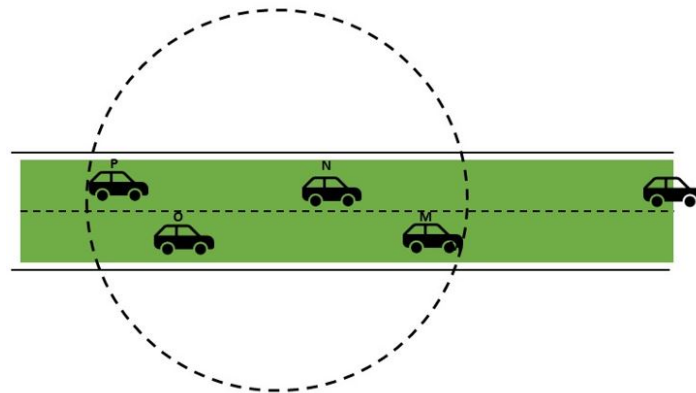


Figure 1.2: Information Sharing among vehicles in same direction

figure above shows how efficiently information sharing or broadcasting takes place

for the vehicles moving in the same direction without taking other key factors into consideration.

1.3 Project Specification

In VANETs, the broadcast is one of the core services that can distribute different traffic data Zhang et al. (2019). The primary objective is to effectively propagate messages from a source node to other destination nodes situated in the same neighborhood Bakhouya et al. (2011). By minimizing the number of retransmissions, an effective wireless multi-hop broadcast protocol should enable rapid dissemination Bononi & Di Felice (2007). In urban environments vehicles continuously move in different directions where the communicating vehicles are seen to be on different roads and mobile objects and steady objects are critical for modeling vehicular channels as both of the objects provide shadow, reflection, and diffraction Viriyasitavat et al. (2015). Due to the fact that vehicle distribution is dependent on road topology, buildings, and other obstructions may cause the signal's strength to drop, especially in urban areas with plenty of roadside structures Zhao et al. (2020). The study aims to specify the problem that arises with vehicle mobility in urban areas and tries to focus on improving the issues by considering those situations. Specific measures will be taken as links obstruction and uncommon channels to meet the need and constraints associated with the problem.

- The design specification for the study includes considering the issues as communication links obstruction due to vehicles or buildings or vegetation , non obstruction and uncommon channel sharing.
- The impact of the proposed model will be evaluated which will try to ensure that how the links and channel sharing have been putting a greater impact on V2V communication.

Chapter 2

Literature Review and Analysis

VANET has a more dynamic nature compared to any other network topology. Where designing efficient information dissemination can be an issue due to the dynamic nature of objects. Many studies have tried to address those constraints and the overview of the previous studies will be focused on and analyzed in the latter study.

2.1 Studies on V2V Communication

Many studies have lately focused on V2V communication where vehicular distance, speed, nodes reliability, and efficient broadcasting ways have been taken into measurement. Effective V2V application development calls for improved comprehension and familiarity with the area in which the vehicles are mostly used Mir & Filali (2017). The maximum number of V2V communication system applied research focuses on simulation-based performance evaluations and testbed implementations Mir & Filali (2017). There have been proposed protocols for efficient broadcasting considering minimizing the broadcast delay and efficiency Zhang et al. (2019), producing backbone vehicles Bononi & Di Felice (2007), fast-delivery multi-hop broadcast Boban et al. (2010), quality of service assured in packet forwarding in the reliable path to the destination Ghafoor et al. (2018). Whereas, the main constraint in broadcasting or multicasting vehicular environment can be the surrounding objects such as cars, buildings, foliage, or uncommon channel, reducing the link stability.

2.2 Related Work

Research on VANET has mostly ignored how vehicles affect vehicle-to-vehicle (V2V) communication Boban et al. (2010). Several studies have been on VANET to improve V2V communication, such as software-based architecture for better-centralized control Gao et al. (2018). There are many studies that have considered the link generation among vehicles where the measurements were performed in different scenarios where some have considered only highway scenarios Nilsson et al. (2017), and some considered open space, urban, and suburban Boban et al. (2013). On the other hand, Karedal et al. (2010) has given thought to all the scenarios(suburban, rural, and highway). However, the lack of proper data dissemination and inefficiency in route-finding techniques it becomes troublesome to analyze the link dynamicity. Studies have shown that signal fading in inter-vehicular communication is mainly influenced by two dominant types: the Line of sight and ray reflected from the ground Zhang et al. (2019). Researchers have taken into consideration these dominant rays and it has been shown that some of them fit well in different scenarios(urban or suburban). Popular models have been proposed and used to calculate the behavior of the dominant rays by considering the link type and taking the measurement data into account.

2.3 Analysis

The dynamic nature of VANET faces numerous challenges in terms of data transmission as the links are quite vulnerable due to vehicle mobility; thus with the weaker link stability the lifetimes of links reduces and the data transmission or broadcast faces a struggle to reach their expected nodes Sudheera et al. (2019). Hence, to improve the link quality and how they are being affected by different literature reviews, an analysis has been done which shows how the researchers have considered different scenarios in V2V communication. Some research has identified how different links can cause obstruction because of surrounding environments.

- In Karedal et al. (2010) and has performed measurements into Freeway, urban, suburban, and remote scenarios and considered the measurement data in LOS condition. The results showed it fits well in urban scenarios.
- In Boban et al. (2010) the measurements were taken into free space, suburban and city scenarios and used two-ray models which are superior to the model of

the open space path loss model and results showed that vehicles significantly obstruct LOS condition and it only fits well in LOS condition.

- In Nilsson et al. (2017) it is seen how vehicle shadowing can reduce the performance of V2V connectivity in multilink operations. The paper showed how the shadowing effect of a car can block V2V communication. Autocorrelation and cross-correlation of signal fading are analyzed in highway scenarios and it shows that it is crucial to differentiate the issue.

From various research and studies, it is seen that few researchers have acknowledged obstructed and unobstructed link types for some given scenarios. However, the uncommon channel can act as an obstruction in link generation which hasn't been acknowledged properly. Including all the factors, this field can have a vast scope to modify link stability and reduce channel loss in the routing and broadcasting information among unmanned vehicles in the future.

Chapter 3

Methodology

3.1 Proposed Method

3.1.1 Overview of the proposed System

The vehicular network employs different models for broadcasting messages. The communication between vehicles can be efficiently done with the consideration of static objects, moving objects, and channel sharing among them. However, communicating with moving objects (Vehicles) and surrounding objects (Buildings/Foliage) can have a profound impact on V2V communication as they can act as an obstruction that may cause the signal's strength to drop, especially in urban areas. In our study, we will try to bridge the gap between signal attenuation and variation in vehicular mobility by taking into consideration link stability which gets affected by the surrounding environments and distinguish the characteristics of the different types of links. Also, another type of link obstruction will be considered if the common channel sharing is not found.

Hence we are proposing a geometry-based architecture where four types of scenarios will be taken into consideration. The scenarios include:

- 1: LOS (Line of Sight): Where there is no obstruction between the transmitter and receiver vehicles.
2. VLOS (Line of Sight of Vehicles): Where the Links are obstructed because of any in-between trucks/ cars or vehicles.
3. BLOS (Line of Sight Buildings or foliage): Where the communication between the transmitter and receiver is obstructed because of in between buildings or foliage. Here, the reflection and diffraction of the links are seen which increases attenuation.

4. Uncommon Channel: If in the V2V communication, there is no obstructing factor such as steady objects (building or vegetation) or moving objects (vehicles) is not found then there can be different sorts of obstruction that an uncommon channel. In this scenario the vehicles don't share a similar channel then it will act as an obstruction in vehicular communication as well.

Here we took into account channel fading and shadowing for each type of link in which small and large-scale signals are measured based on the surrounding objects. To implement the architecture we will use r tree to store the building or vehicle objects in the geographic database. The outline of the building will be gathered from OpenStreetMap and SUMO will provide vehicular mobility information. The proposed architecture will provide a visualization with the help of Google earth visualization.

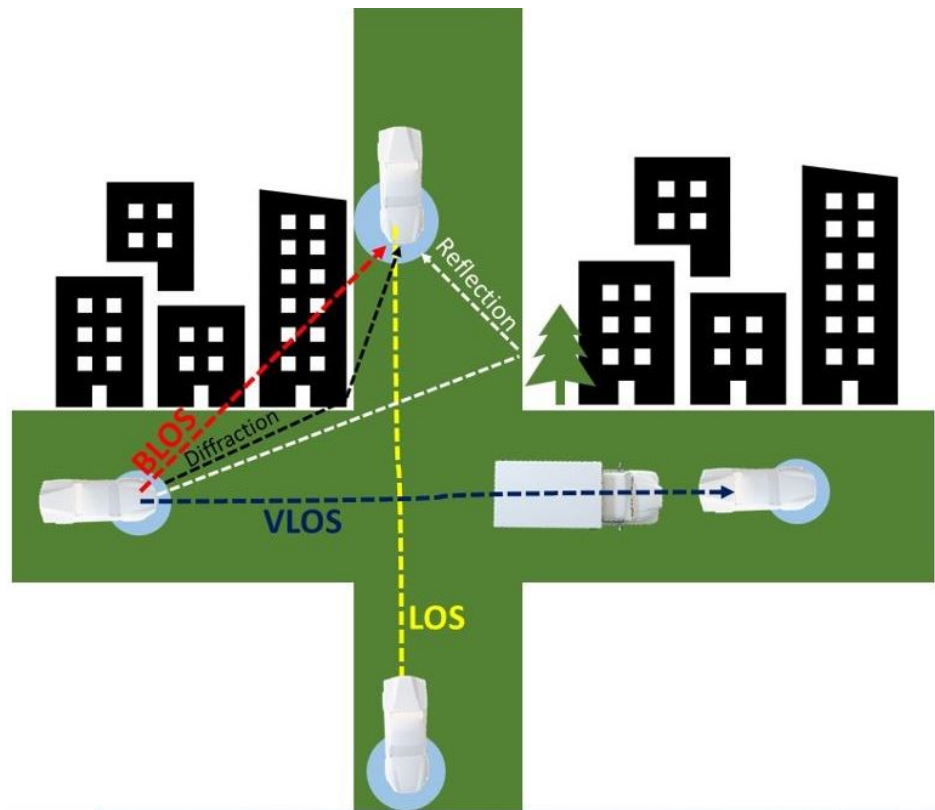


Figure 3.1: The type of links in the vehicular environment and how they are obstructing efficient communication with them.

3.1.2 System Model

In the static world and moving vehicular scenario steady objects such as infrastructure or vegetation and moving objects are the main reason for reflection and diffraction Boban et al. (2014).

For Line of sight communication, we utilize the model of two-ray ground reflection. For VLOS communication we consider their location and utilize the concept of the multiple knife edge in diffraction He et al. (2014).

Link Type	Propagation Model
LOS	two ray ground reflection Boban et al. (2013)
VLOS	vehicle side diffraction knife edge model Boban et al. (2010) He et al. (2014)
BLOS	Log distance path model

Table 3.1: Link types and method for propagation.

$$|NTOT| = \frac{x_0 y_0}{f_{LOS}} \cos(\omega_c (t - \frac{d_{LOS}}{c})) + G_{ground} \frac{E_0 D_0}{G_{ground}} \cos(\omega_c (t - \frac{G_{ground}}{c})) \text{ ----- (1)}$$

Figure 3.2: Equation for large scale signal variation. Here, Gground variable is used to measure the coefficient of the reflection and distance Zground is used for measuring the reflected ray from the ground.

Log-Distance Path Loss in Deep-Fade Areas:

$$DL(d) = DL(d_0) + 10\gamma \log_{10} \frac{d}{d_0} \text{ ----- (2)}$$

Figure 3.3: A path loss exponent γ has been used in this equation. Here at a reference distance of d_0 the loss of path is DL_{d_0} variable.

$$DrDL(d) = Dt - d L(d) \text{ ----- (3)}$$

Figure 3.4: Equation 03 denotes the log-distance model of path where at distance 'd' the received power is 'DrDL' which is measured in decibels unit , considering the unit gained by the antenna. And the 'Dt' is the transmitted power which is also measured in decibel units.

$$SEL = 0.79f^{0.61} \text{ ----- (4)}$$

Figure 3.5: This equation 04 refers to the use of attenuation through the transmission model in order to execute transmission through vegetation. Here, the per meter mean excess loss of transmission due to vegetation is measured with the variable SEL and the frequency with f in gigahertz.

Combining Multiple Rays: E-Field and Received Power Calculations

$$|DTOT| = \left| D_{LOS} + \sum_j D_{Ref13} + \sum_k D_{diffrk} \right| \text{-----(5)}$$

Figure 3.6: Equation 5 here measures the power in an E field of the concerned rays such as LOS, reflected and diffracted ones.

$$|ETOT| = \frac{E_0 D_0}{d_{LOS}} \cos(\omega_c(t - \frac{d_{LOS}}{c})) + \sum_j M_j \frac{E_0 D_0}{d_j} \cos(\omega_c(t - \frac{d_j}{c})) + \sum_k S_k \frac{E_0 D_0}{d_k} \cos(\omega_c(t - \frac{d_k}{c})) \text{-----(6)}$$

Figure 3.7: Here,

E0D0 = at a reference distance d0 the envelope E field

ω_c = angular frequency

t = time, E field is evaluated in respect to this duration

Mj = reflected ray j reflection coefficient

Sk = coefficient of the diffraction from the diffracted ray k.

Equation for measuring M according to vertical and horizontal orientation,

$$M_{||} = \frac{-\epsilon_r \sin \theta_i + \sqrt{\epsilon_r - \cos^2 \theta_i}}{\epsilon_r \sin \theta_i + \sqrt{\epsilon_r - \cos^2 \theta_i}}$$

$$M_{\perp} = \frac{\sin \theta_i - \sqrt{\epsilon_r - \cos^2 \theta_i}}{\sin \theta_i + \sqrt{\epsilon_r - \cos^2 \theta_i}}$$

Figure 3.8: Here,
 θ_i = incident angle. r is the proportional permittivity of the material.

$$S r = \frac{|N_{TOT}|^2 \lambda^2}{480 \pi^2} \text{-----(08)}$$

Figure 3.9: This equation 08 has been used for calculating the ensuing power

Modeling Small-Scale Signal Variations :
Accounting for Small-Scale Signal Variations:

The small scale signal deviation σ is calculated following the below equation,

$$\sigma_i = \sigma_{min} + \frac{\sigma_{max} - \sigma_{min}}{2} \cdot \left(\sqrt{\frac{SB_i}{SB_{max}}} + \sqrt{\frac{DF_i}{DF_{max}}} \right)$$

Figure 3.10: This equation 09 has been used for measuring small-scale variables, where,

σ_{min} = smallest small scale deviation for given los kind of i
 σ_{max} = the highest value of deviation for los type of i
 SB_i = Number of moving objects for every unit of area
 SB_{max} = Max Number of moving objects for every unit of area
 DF_i = Area of steady objects for every unit of area
 DF_{max} = Max surface of steady objects for every unit of area

$$S r T O T i = 10 \log_{10}(S r i) + A(0, \sigma i)$$

Figure 3.11: After combining both the signals and finding out σ , the resultant power is measured through this equation

Chapter 4

Design and Development

4.1 Flowchart Design

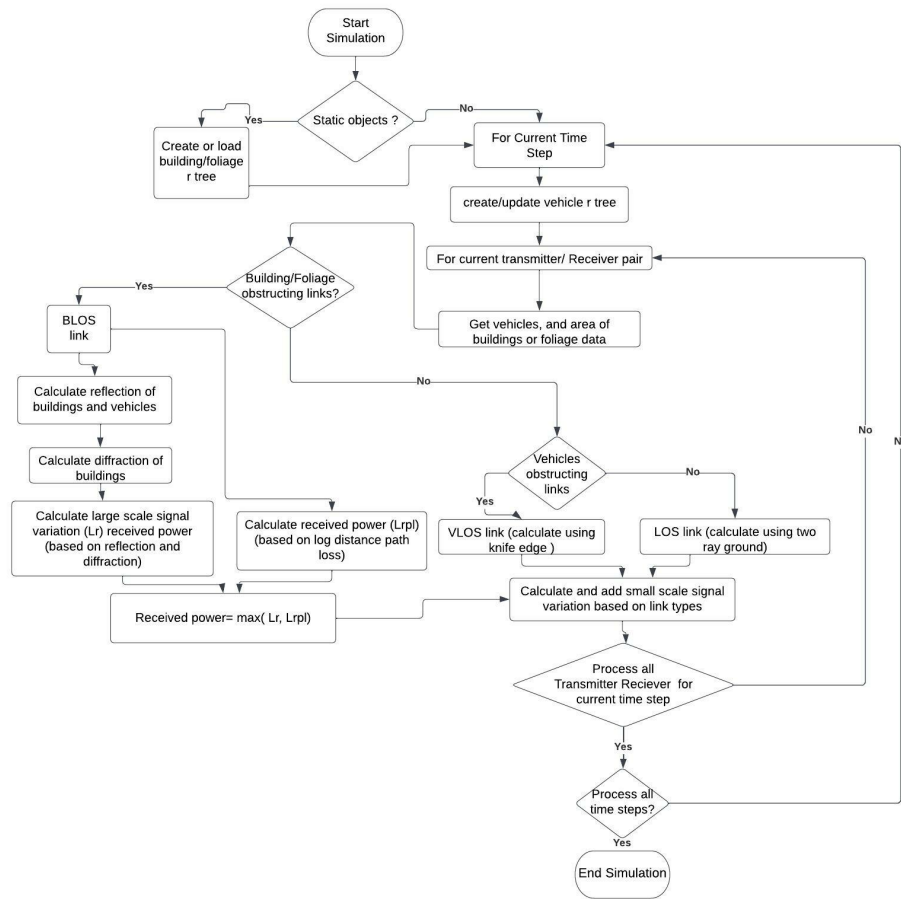


Figure 4.1: Flowchart of the architecture.

The flowchart above shows how the proposed model will perform for different link types and calculate outputs accordingly.

4.2 Pseudo code of the architecture

```

START
if Steady objects ? then
    | Produce or load building/vegetation r tree;
else
    | For ongoing TimeStep;
    | produce/load vehicle r tree;
    | For ongoing transmitter/ Receiver connection;
    | Obtain vehicles inf, and area of infrastructure or vegetation info;
end
if Building/Foliage obstructing links== True then
    | BLOS link;
    | calculate reflection of buildings and vehicles;
    | calculate diffraction of buildings;
    | calculate large scale signal variation (Lr) ; /* (depending on reflection
    | and diffraction) */
    | measure the power recieved (Lrpl)); /* (depending on log distance
    | channel loss) */
    | evaluate and add small-scale transmission fluctuation ; /* depending
    | upon objects and link types */
else
    | else if Vehicles obstructing links==True then
    | | calculate VLOS using knife edge;
    | end
    | LOS or uncommon channel;
    | if LOS==True then
    | | LOS link calculate using two ray ground;
    | else
    | | uncommon channel;
    | end
    | end
while BLOS or VLOS or LOS do
    | evaluate and add small-scale transmission fluctuation ; /* based on link
    | types */
    | if Transmitter Reciever for current time step== true then
    | | check Process all time steps;
    | | if Process all time steps== False then
    | | | END Simulation;
    | | else
    | | | GOTO 5;
    | | end
    | else
    | | GOTO Step 7;
    | end
end
END

```

Chapter 5

Result analysis

The proposed system will be measured in terms of some parameters to analyze how it performs. To analyze the results, the performance metrics parameters have been taken into consideration.

5.1 Performance Parameters

To Show the results of the obstruction through obstructed unobstructed and channel sharing of the links we will need geometry data and vehicular mobility data which will ensure the model's performance analysis effectively. Later, Matlab is used to derive the desired output in KML format to show in google earth visualization.

5.1.1 Geography Data

The geographical data of the road infrastructure and layout of the area is needed to understand how the links might get obstructed due to them. Hence, the data of the infrastructure is derived from OpenStreetMap. OpenStreetMap is the free source database of outlines of buildings and foliage which provides worldwide layouts through a huge userbase and it has a vast network of contributors. To accomplish this, the OSM file or format must undergo several conversion steps before being merged with completely random trips and path information.

5.1.2 Vehicular Mobility Data

In the urban areas, vehicles are continuously moving on different streets. Hence, for vehicular mobility data, SUMO is utilized to generate urban mobility traces for an

actual-world road architecture map. After plotting the map from OpenStreetMap we config it in SUMO to get the floating car data.



Figure 5.1: Openstreetmap and SUMO configuration

5.2 Simulation Results and Outcome

This results shows a visual representation of obstructed and unobstructed links in the road scenario. After plotting the kml file plotting in Google earth visualization. The results show the transmitter-receiver signal has been generated in the Vehicular road scenario.



Figure 5.2: Google earth visualization shows the obstructed and non-obstructed links for a specific location

Chapter 6

Conclusions

The links that act as an obstruction have been considered in this research. The model is designed in MATLAB which can be utilized for vehicular and infrastructure communication. The model has tried to consider each of the link types described earlier (LOS, VLOS, BLOS, uncommon channel) and it is seen from the analyzed results that in terms of links generation, each case can be presented accurately by the model.

6.1 Social, Legal, Ethical, and Environmental Issues

The proposed study aims to consider the types of links their behavior and obstruction factors and channel sharing through unmanned autonomous vehicles. This futuristic link stability and channel sharing among unmanned vehicles are considered to uphold a higher level of safety measurements for all groups of people daily using the roads. The proposed study was done in a virtual environment and it doesn't address any illegal method to collect and maintain data on geometry data or vehicular mobility data as it was collected from the free source database and configured in a stimulating environment to trace the mobility. Furthermore, it focuses on how the information is shared or the links are obstructed by not raising any environmental issues.

6.2 Future works

The next follow-up or future work aims to focus on performance efficiency through the network. The main base of that is the obstructing communication of the network

structure and uncommon channel performance analyzing through a network performance and measuring the outcomes. A model initially holds the system's prior requirement, with those we will try to derive an efficient outcome with the measured performance.

References

- Almeaibed, S., Al-Rubaye, S., Tsourdos, A., & Avdelidis, N. P. (2021). Digital twin analysis to promote safety and security in autonomous vehicles. *IEEE Communications Standards Magazine*, 5(1), 40–46.
- Bakhouya, M., Gaber, J., & Lorenz, P. (2011). An adaptive approach for information dissemination in vehicular ad hoc networks. *Journal of Network and Computer Applications*, 34(6), 1971–1978.
- Boban, M., Barros, J., & Tonguz, O. K. (2014). Geometry-based vehicle-to-vehicle channel modeling for large-scale simulation. *IEEE Transactions on Vehicular Technology*, 63(9), 4146–4164.
- Boban, M., Vinhoza, T. T., Ferreira, M., Barros, J., & Tonguz, O. K. (2010). Impact of vehicles as obstacles in vehicular ad hoc networks. *IEEE journal on selected areas in communications*, 29(1), 15–28.
- Boban, M., Viriyasitavat, W., & Tonguz, O. K. (2013). Modeling vehicle-to-vehicle line of sight channels and its impact on application-layer performance. In *Proceeding of the tenth acm international workshop on vehicular inter-networking, systems, and applications* (pp. 91–94).
- Bononi, L., & Di Felice, M. (2007). A cross layered mac and clustering scheme for efficient broadcast in vanets. In *2007 ieee international conference on mobile adhoc and sensor systems* (pp. 1–8).
- Gao, Y., Zhang, Z., Zhao, D., Zhang, Y., & Luo, T. (2018). A hierarchical routing scheme with load balancing in software defined vehicular ad hoc networks. *IEEE Access*, 6, 73774–73785.
- Ghafoor, K. Z., Kong, L., Rawat, D. B., Hosseini, E., & Sadiq, A. S. (2018). Quality of service aware routing protocol in software-defined internet of vehicles. *IEEE Internet of Things Journal*, 6(2), 2817–2828.
- He, R., Molisch, A. F., Tufvesson, F., Zhong, Z., Ai, B., & Zhang, T. (2014). Vehicle-to-vehicle propagation models with large vehicle obstructions. *IEEE Transactions on Intelligent Transportation Systems*, 15(5), 2237–2248.

- Karedal, J., Czink, N., Paier, A., Tufvesson, F., & Molisch, A. F. (2010). Path loss modeling for vehicle-to-vehicle communications. *IEEE transactions on vehicular technology*, 60(1), 323–328.
- Mir, Z. H., & Filali, F. (2017). Large-scale simulations and performance evaluation of connected cars-a v2v communication perspective. *Simulation Modelling Practice and Theory*, 73, 55–71.
- Nilsson, M. G., Gustafson, C., Abbas, T., & Tufvesson, F. (2017). A measurement-based multilink shadowing model for v2v network simulations of highway scenarios. *IEEE Transactions on Vehicular Technology*, 66(10), 8632–8643.
- Omar, H. A., Zhuang, W., & Li, L. (2011). Vemac: A novel multichannel mac protocol for vehicular ad hoc networks. In *2011 ieee conference on computer communications workshops (infocom wkshps)* (pp. 413–418).
- Palazzi, C. E., Ferretti, S., Roccetti, M., Pau, G., Gerla, M., et al. (2007). How do you quickly choreograph inter-vehicular communications? a fast vehicle-to-vehicle multi-hop broadcast algorithm, explained. In *Ccnc* (pp. 960–964).
- Sudheera, K. L. K., Ma, M., & Chong, P. H. J. (2019). Link stability based optimized routing framework for software defined vehicular networks. *IEEE Transactions on Vehicular Technology*, 68(3), 2934–2945.
- VanDerHorn, E., & Mahadevan, S. (2021). Digital twin: Generalization, characterization and implementation. *Decision support systems*, 145, 113524.
- Viriyasitavat, W., Boban, M., Tsai, H.-M., & Vasilakos, A. (2015). Vehicular communications: Survey and challenges of channel and propagation models. *IEEE Vehicular Technology Magazine*, 10(2), 55–66.
- Wu, C., Chen, X., Ji, Y., Ohzahata, S., & Kato, T. (2015). Efficient broadcasting in vanets using dynamic backbone and network coding. *IEEE Transactions on Wireless Communications*, 14(11), 6057–6071.
- Wu, Y., Zhang, K., & Zhang, Y. (2021). Digital twin networks: A survey. *IEEE Internet of Things Journal*, 8(18), 13789–13804.
- Zhang, X. M., Yan, L., Chen, K. H., & Sung, D. K. (2019). Fast, efficient broadcast schemes based on the prediction of dynamics in vehicular ad hoc networks. *IEEE Transactions on Intelligent Transportation Systems*, 21(2), 531–542.
- Zhao, L., Bi, Z., Hawbani, A., Yu, K., Zhang, Y., & Guizani, M. (2022). Elite: An intelligent digital twin-based hierarchical routing scheme for softwarized vehicular networks. *IEEE Transactions on Mobile Computing*.
- Zhao, L., Han, G., Li, Z., & Shu, L. (2020). Intelligent digital twin-based software-defined vehicular networks. *IEEE Network*, 34(5), 178–184.