LOCATION-AWARE VEHICLE-TO-VEHICLE GAMING OVER VEHICULAR AD-HOC NETWORK (VANET)

BY

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DEDICATION

I dedicate this thesis to my parents whose love, support, and encouragement to continue my higher education and be successful and productive in real life laid the foundation to complete this work.

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LIST OF ABBREVIATIONS

ITS	**:**	**Intelligent Transportation System**
MANET	**:**	**Mobile Ad Hoc Network**
VANET	**:**	**Vehicular Ad Hoc Network**
OBU	**:**	**On-Board Unit**
RSU	**:**	**Road Side Unit**
V2V	**:**	**Vehicle to Vehicle**
V2I	**:**	**Vehicle to Infrastructure**
I2V	**:**	**Infrastructure to Vehicle**
I2I	**:**	**Infrastructure to Infrastructure**
AODV	**:**	**Ad hoc On Demand Distance Vector Routing**
DSDV	**:**	**Destination Sequence Distance Vector**
DSR	**:**	**Dynamic Source Routing**
RREQ	**:**	**Route Request**
RREP	**:**	**Route Reply**
RERR	**:**	**Route Error**
DSRC	**:**	**Dedicated Short-Range Communication**

WAVE	:	**Wireless Access in Vehicular Environment**
WSMP	**:**	**Wave Short Message Protocol**
WSM	**:**	**Wave Short Message**
FCC	**:**	**Federal Communications Commission**
GPS	**:**	**Global Positioning System**
IEEE	**:**	**Institute of Electrical and Electronics Engineers**

ABSTRACT

Full Name : Barakat Pravin Maratha

Thesis Title : Location-Aware Vehicle-to-Vehicle Gaming over Vehicular Ad-Hoc Network (VANET).

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The continuous increase in the number of vehicles in the transportation system calls for an improvement of traffic safety and efficiency of the overall transportation infrastructure. With the recent advancement in wireless communication technologies, a new emerging technology known as VANET (Vehicular Ad-Hoc Network) has become an active research area due to its tremendous potential to improve vehicle and road safety, traffic efficiency, and convenience to both drivers and passengers. It brings the power of wireless networks to vehicles, allowing them to communicate among themselves or with roadside units to enable a promising future of Intelligent Transportation System (ITS). VANET is considered as a subclass of mobile Ad-hoc network (MANET) with some distinct challenging features of dynamic topology and fast vehicle speed. VANET provides multi-hop transmission to reach out of transmission range receivers through packet routing. IEEE 802.11p is the recommended MAC and PHY layer wireless standard for VANET to support safety, traffic management and infotainment applications. Most of the research contributions in this area have focused on safety-related applications and information dissemination. However, the increasing demand in the computer software industry more specifically the gaming and the idle time we spend in vehicles while traveling as well as

the 802.11p being provided free of charge calls for seeking the feasibility of another type of applications such as online gaming over VANET. In this thesis, we mainly focus on the feasibility of a new type of applications namely online gaming over VANET. Since the performance of communication in VANET mainly depends on how well the underlying routing protocols being used, first we present an analytical study of implementing different MANET routing protocols (AODV, DSDV, and DSR) for VANET in a highway scenario using NCTUNS 6.0 network simulator. The rationale for selecting MANET routing protocols was because they are approved by the Internet Engineering Task Force (IETF) and their source code availability in many VANET simulators. Different simulation parameters have being evaluated to recommend the best routing protocol for online gaming. Secondly, we proposed our mobility model and an enhanced routing protocol to match the requirements of online gaming applications and its delay bounds. Finally, we evaluated our proposed scenario of online gaming with the proposed mobility model and enhanced routing protocol and compare it with the traditional MANET routing protocols in terms of throughput, end to end delay and Quality of Service (fewer packet drops). Our results indicate that the proposed mobility model and the enhanced routing protocol is very promising by keeping the delay and packet drops within the delay bounds of online gaming applications.

ملخص الرسالة

الاسم الكامل: بركات برافين بالكريشنا مراتا

عنوان الرسالة: الالعاب بين المركبات عبرادراك مواقعهاعلى شبكة السيارات (VANET)

التخصص: علوم وهندسة الكمبيوتر

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استمرار ازدياد عدد المركبات فى نظام النقل يدعو الى تحسين سلامة المرور وكفاءة البنيه الاساسية لوسائل النقل بشكل عام. مع التقدم فى تكنولوجيا شبكة الاتصالات اللاسلكية، اصبحت التقنية الجديدة الناشئة ما تعرف باسم الشبكات المخصصة للمركبات (VANET) مجالا نشطا للبحث بسبب قدرتها العالية على تحسين سلامة امن الطرق، كفاءة حركة المرور وتوفير وسائل الراحة للسائقين والركاب على حدا سواء. هذه التقنية الجديده جلبت قوة الشبكات اللاسلكية الى السيارات بالسماح لهم بالاتصال لاسلكيا فيما بينهم او مع الوحدات المتوفره على جانب الطريق لتمكين مستقبلا واعدا الا وهو نظام النقل الذكي (ITS). يعتبرVANET فئة فرعية لشبكة اقران الهاتف المحمول (MANET) مع وجود بعض السمات المميزة مثل التغير المستمر لهيكل الشبكات والسرعة العالية للسيارات. VANET توفر امكانية التواصل بين المركبات، حتى اذا كانت خارج نطاقها اللاسلكي، عن طريق مركبات وسطية (Multi-hop) وبروتوكول توجية الحزم (Routing Protocol). يعتبر IEEE 802.11p المعيار اللاسلكى على طبقة MAC و PHY الموصى بها للاستخدام في ال VANET من اجل دعم تطبيقات الامن، ادارة مرور المركبات و ايضا تطبيقات التسلية. معظم البحوث فى هذا المجال تركز على التطبيقات المتعلقة بسلامة المرور، ونشر المعلومات. ولكن مع زيادة الطلب فى صناعة برمجيات الحاسوب خصيصا الالعاب عبر الانترنت (Online Gaming)، واوقات الفراغ التي نقضيها فى المركبات اثناء التنقل والسفر، وكذلك توفر خدمة IEEE 802.11p مجانا، يدعو لدراسة جدوى نوع اخر من التطبيقات مثل ممارسة الالعاب عبر الانترنت في بيئة ال VANET. فى هذه الاطروحة، نركز اساسا على امكانية استخدام نوع جديد من التطبيقات الا وهى الالعاب عبر الانترنت على بيئة ال VANET. بما ان اداء الاتصال في بيئة ال VANET يعتمد بالدرجة الاساسية على كفاءة بروتوكولات التوجيه (Routing Protocols) ، لذلك قمنا اولا بدراسة تحليلية في امكانية استخدام بروتوكولات التوجية MANET (AODV, DSDV and DSR) في بيئة ال VANETعلى طريق سريع باستخدام مضاهى الشبكة NCTUns 6.0 واستخدام افضل بروتوكول يناسب تطبيقات الالعاب عبر الانترنت من حيث التاخير. السبب الرئيسي في اختيار بروتوكولات التوجيه MANET لانها معتمدة من قبل Internet Engineering Task Force (IETF) وايضا توفر برامج المصدرفى الكثير من مضاهى الشبكات. ثانيا، قمنا بعرض مقترح لنمودج حركة المركبات التي تناسب الالعاب عبر الانترنت في بيئة ال VANET لظمان التواصل بين المركبات لاكبر فترة زمنية ممكنة. ايضا قمنا بتحسين اداء افضل بروتوكل تم اختيارة من المرحلة الاولى من حيث تقليل نسبة الحزم الضائعة (Dropped Packets). اخيرا، تم تقييم سيناريوالالعاب عبرالانترنت في بيئة ال VANET باستخدام نمودج حركة المركبات المقترح وبروتوكول التوجية المحسن ومقارنتها بالبروتوكول ونمودج التنقل التقليدي. النتائج اوضحت ان نمودج التنقل المقترح و بروتوكول التوجية المحسن يمثل افضل اداء لتطبيقات الالعاب عبر الانترنت من حيث التاخير ونسبة الحزم الضائعة.

CHAPTER 1

INTRODUCTION

Intelligent transportation system (ITS) is intended to enhance the deficiencies of the traditional road transportation system through the usage of the modern wireless communication technologies. It can reduce car accidents, lower traffic congestions and makes travel more comfortable [1]. Nowadays, vehicles can communicate among themselves and with the infrastructure as human or smartphones and this is all made possible with the technology of VANET [2].

A Vehicular Ad-hoc Network or VANET is a technology that uses moving vehicles as nodes or routers to form an Ad-hoc network. Each vehicle is equipped with wireless facilities which allows vehicles approximately 300 meters apart to connect and create an ad-hoc wireless network [3].

VANET is attracting researchers in the area of road safety, traffic efficiency, congestion control etc. Apart from safety and traffic management applications, passengers are also attracted by their interesting usage of infotainment applications between vehicles such as chat, video conferencing or online gaming. One of the most challenges faced by VANETs is the link duration which is very unreliable due to the highly dynamic topology and the high speed of vehicles [4].

Based on the communication that takes place among vehicles and vehicles to infrastructure, VANETs are broadly categorized into (i) Vehicle-to-Infrastructure (V2I), (ii) Vehicle-to-Vehicle (V2V) and (iii) Hybrid (V2I and V2V). V2I communication deals with the data transfer between the On Board Units (OBU) equipped in the vehicles and Road Side Units (RSU) which are deployed on the sides of the roads with some predetermined distances between them. In V2V, data is transferred between OBUs of the vehicle peers [5]. As shown in Figure 1, Infrastructure to Infrastructure (I2I) uses different wireless technology standard other than IEEE 802.11p and thus not categorized under VANETs. The VANET technology is greatly enhanced with the Global Positioning System (GPS) which provides the road layouts, position, direction and speed of the vehicles which are significant parameters for applications and routing protocols [6].

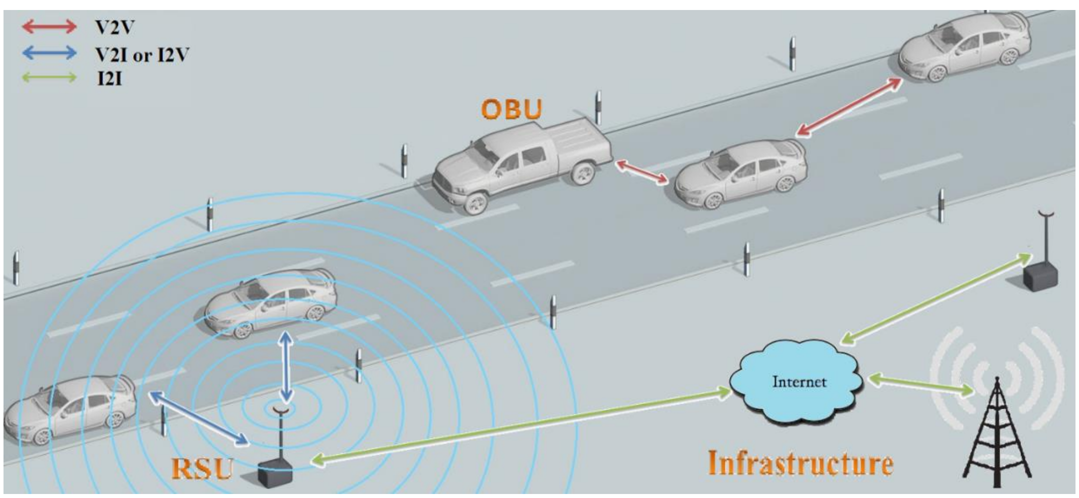


Figure 1 Wireless technology for future vehicular communication

The Federal Communications Commission (FCC) realized the requirement of inter-vehicle communication and dedicated 75MHz of the frequency spectrum around the 5.9GHz (5.850 to 5.925 GHz) band range known as Dedicated Short-Range Communication

(DSRC). Wireless Access in Vehicular Environment (WAVE) or sometimes are known as IEEE 802.11p, is a core part of DSRC. As shown in Figure 2, IEEE 802.11p standards are oriented towards physical and MAC layers. IEEE P1609.x standards deal with the functionality and complexity of higher layers [7].

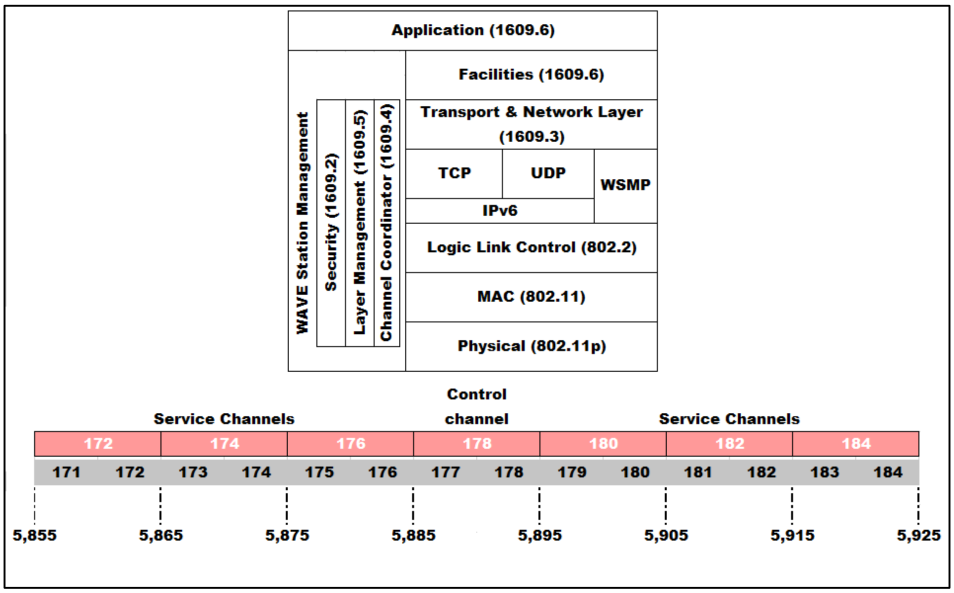


Figure 2 An Overview of WAVE protocol stack with DSRC channel allocation

Some car manufacturers already incorporated this technology in their products and we expect that passengers will soon ask for utilizing all their favorite wireless networking applications, including online games over moving vehicles. The currently available in-vehicle gaming experience is passive which means that there is no real-time interactivity between passengers in different vehicles.

Online gaming is computer games played over networks, commonly the Internet. This type of games gained their popularity due to the real-time interaction between players spread worldwide. As a result, a large number of players gets involved in one single gaming session simultaneously by subscribing to an internet game server (client-server architecture) and paying a reasonable amount of fees. As games become more complex, exchange of data increases among players and this demands powerful servers to support real-time gaming experience. The existence of relatively high latency on the internet is the obvious factor that affects the performance of online games [8].

However, online gaming over VANET has some distinct features compared to online internet games or wired network games. Unlike current internet online games, VANET games are more difficult to build because of the unstable vehicular communications. It operates in a fully distributed environment with no infrastructure support (Peer to Peer) and the number of players is restricted by the number of nodes inside the vehicular ad-hoc wireless networks [9]. As vehicles start incorporating this technology in their new line production, we envision that passengers sooner or later will demand fully utilizing this technology including online gaming over VANET which is an interesting range of real-time applications to engage passengers in different vehicles during long travel with family or friends.

1.1 Motivation

The main incentive for our study is the idle time we spend in vehicles per person. For example, in US people spend more than 250 hours per year per person in vehicles [9]. In addition, recently it has been noticed that many people especially kids and teenagers are engaged in computer games in their free times. Although many car manufacturers incorporated entertainment systems inside the vehicles such as AM/FM radio receiver, CD/DVD player, TV, and GPS, all these applications are considered passive and there is no real-time interactivity between passengers in different vehicles. Interactive applications such as live chat, video conferencing and online gaming present an interesting range of infotainment applications to engage passengers in different vehicles especially during long travel with family or friends. Finally, the launching of the latest wireless technology for VANET namely 802.11p and its ability to function without infrastructure as well as the fact of being practically free of charge for the end user is what motivates us to investigate its applicability not only for active safety applications but also for comfort and entertainment applications such as online gaming.

1.2 Research Objectives

The aim of our study is to seek the feasibility of a new type of application namely online gaming over the VANET environment. To achieve this goal, we have to first investigate the requirements of online gaming in terms of delay and percentage of packet loss bounds. Then we need to select the best routing protocol through analytical study that suits the requirement of online gaming over VANET. In addition, we need to use a mobility model with added driver behavior interaction to reflect the mobility of a group of vehicles moving towards a common destination.

The main objectives of our thesis is outlined below:

- Investigate the requirements and challenges of online gaming over VANET environment.
- Survey of MANET routing protocol for use in VANET.

- Select the best MANET routing protocol for online gaming.
- Propose a mobility model to suit the requirement of online gaming.
- Enhance the selected routing protocol in terms of:
    - Average end to end delay.
    - Percentage of packet loss.
- Establish a simple mathematical Model for online gaming.

1.3 Research Methodology and Validity

We have chosen to conduct our study using both qualitative and quantitative approaches. In a qualitative approach, we have conducted a detailed literature review using reliable sources such as IEEE, ACM, and books on wireless ad-hoc networks in order to acquire relevant data, which will assist us in fulfilling our main objective namely online gaming over VANET. Using this method, we gained insights on the requirements and challenges of online gaming over VANET, issues of routing protocols over VANET, mobility models, and simulators.

In quantitative approach, we have selected NCTUns simulation tool which was investigated through the qualitative approach to validate our findings. Using this tool, we have designed our online gaming scenario and tested our proposed mobility model and the enhanced routing protocol. The results generated from this tool are then analyzed in order to reach the conclusion of our study.

The potential challenges that affect the outcome of any research are known as validity threats. As per the literature review [10], there are four different types of validity threats namely: internal, external, statistical conclusion and construct. We addressed these validity threats as follow: To overcome the internal validity threat, we conducted simulation for our study and tried to simulate real scenarios. The simulator we used is capable enough in showing results in the form of graphs. For this reason, same type of network parameters (nodes, traffic signals, and obstacles) are selected for each simulation scenario. To overcome the issues of external validity threat, we performed a detailed literature review of simulators and mobility models. After comparison of various simulators, we chose realistic traffic simulator i.e. NCTUns, it provided network design that is more coherent to the real environment. To avoid misleading statistical validity threat, we have used pivot power tables and AWK scripting language to generate graphs from the gathered data. This made it easy to compare performance results from simulation and excel charts. Finally, to fulfill the construct validity, we have used standard resources i.e. IEEE, ACM etc. for definitions and all parameters in our simulation study were measured according to the SI (System International) units.

1.4 Main Contribution

The main contributions of our thesis work are listed below:

- Developed a driver behavior mobility model and integrated it with NCTUns 6.0 VANET simulator to prolong the game duration.

- Enhanced the DSDV routing protocol to suit the delay bounds and percent packet loss of online gaming applications.
- Developed a probabilistic mathematical model for path duration in online gaming.
- Proved that online gaming is feasible for VANET.

1.5 Research Roadmap

The rest of the thesis is organized as follows. In chapter 2, we provide a detailed background knowledge about the requirements and challenges of online gaming, the state of the art in VANET, issues, and challenges of routing protocols, VANET simulators, and mobility models. Chapter 3 literature reviews the state of the art of MANET and VANET routing protocols, their issued and challenges. Chapter 4 presents a performance evaluation for selecting the best MANET routing protocol for online gaming. Chapter 5 details our proposed online gaming scenario and evaluate its performance in terms of throughput, the percentage of packet drops and average end to end delay using our proposed mobility model and enhanced routing protocol. Finally, Chapter 6 concludes our study and point out some future work directions of this thesis.

1.6 Summary

Vehicular Ad-Hoc Networks (VANETs) gained its popularity due to the fast enhancements in the wireless network technologies, especially the IEEE 802.11p standard. Despite the challenges of fast speed of vehicles and frequent network topology changes, VANET has become an active research area for different types of applications such as safety, traffic management, and congestion control as well as comfort and entertainment applications. It is also playing a vital role in a big project for enhancing road transportation known as Intelligent Transportation System (ITS). Recently, it has been noticed that many mobile users especially kids and teenagers get involved in playing interactive games in their free time. Although many research work has been addressed to develop new algorithms and routing protocols, but most of them mainly focus on safety and traffic management applications and very few has addressed gaming over VANET. Playing games over VANET is a challenging task due to the stringent delay requirement, fast speed of vehicles and frequent network topology changes. Nowadays, new car manufacturers have incorporated the IEEE 802.11p wireless technology in their products for free and we expect that passengers will soon ask for utilizing this technology for different applications, including gaming over VANET.

CHAPTER 2

BACKGROUND

In this chapter, we present the necessary background knowledge and challenges to support a new type of application over VANET namely online gaming. We start with VANET's, its architecture, applications, and challenges. Then we review the challenges and requirements of online gaming over VANET. In addition, we review and compare the different wireless standards available for VANET. Finally, we review and compare the different mobility models and simulators available for conducting VANET's simulation study.

2.1 VANET's Review

The turn of the 21st century has seen a rapid advancement in the way people communicate. Several novel schemes have been developed to enhance and augment communication among people from all walks of life, from the farmer surfing the web with his phone in a remote forest to an astronaut conducting a teleconference video call from space. Advancements in wireless communication technologies coupled with the increasing demand for state of the art vehicles and the use of mobile devices like smartphones, PDA, laptops etc. by vehicle users have led to the development of the Vehicular Ad-hoc Networks (VANET) [11]. Further, the need to improve vehicular road safety and enhance transportation efficiency has made VANET an attractive field of research for academics and industrialists alike. VANET systems present a unique architecture for addressing most of these human needs and communication dynamics. Also, the design of VANET systems like any other network system faces critical challenges like routing, security, privacy, channel spectrum allocation and so on.

2.1.1 VANET's Architecture

Since VANET is a subclass or a variant of Ad-hoc networks, the system design architecture of VANET follows the normal network protocol stack comprising of the physical layer, the Media Access Control (MAC) layer, the network layer, the transport layer and finally, the application layer. A layered architecture of VANET along with a brief description of the function of each layer is given below.

The physical layer of the network is responsible for the transmission of a raw bit over an available or chosen communication channel. The main concern in the physical layer is to ensure that a 1 bit transmitted arrives at the receiver as 1 bit. This layer is generally concerned with issues of modulation, spectrum allocation, channel estimation and equalization, communication error optimization, channel coding multiplexing, and so on. The choice of the physical layer specifications for any network is a crucial aspect of the network design.

The MAC layer is generally concerned with the allocation of channel space for different transmissions on the same multi-access channel in a VANET. The key issue in this sublayer is to minimize as much as possible, the number of transmission collisions by adopting a reliable and efficient MAC protocol.

The network layer controls the geographical addressing operation and is designed to control the routing of packets from the source node to the destination node in a VANET. Functions core to the network layer is routing schemes, congestion control, vehicular movement, data dissemination, etc.

The primary function of the transport layer is to isolate the upper application layer from the unreliable issues of the lower layer and guarantee an end-to-end communication between two communicating hosts (vehicles) in a VANET. Issues of delay, congestion, among others are design requirements satisfied by the transport layer.

Finally, the application layer consists of processes being it a video conferencing tool or an online game that are needed by users of the network. Issues of encryption, data security, and application development are core to this layer.

However, in terms of communication that takes place between vehicles, VANET architecture can be divided into three folds [12], namely, Vehicle-to-Infrastructure (V2I), Vehicle-to-Vehicle (V2V) and Hybrid (V2I and V2V).

In Vehicle-to-Infrastructure (V2I), applications inside the vehicles can access the internet by communicating with cellular gateways or wireless local area networks (WLANs). Figure 3, expounds this concept where data transfer occurs between the On Board Units (OBU) equipped in the vehicles and Road Side Units (RSU), which are deployed on the sides of the roads with some predetermined distances between them.

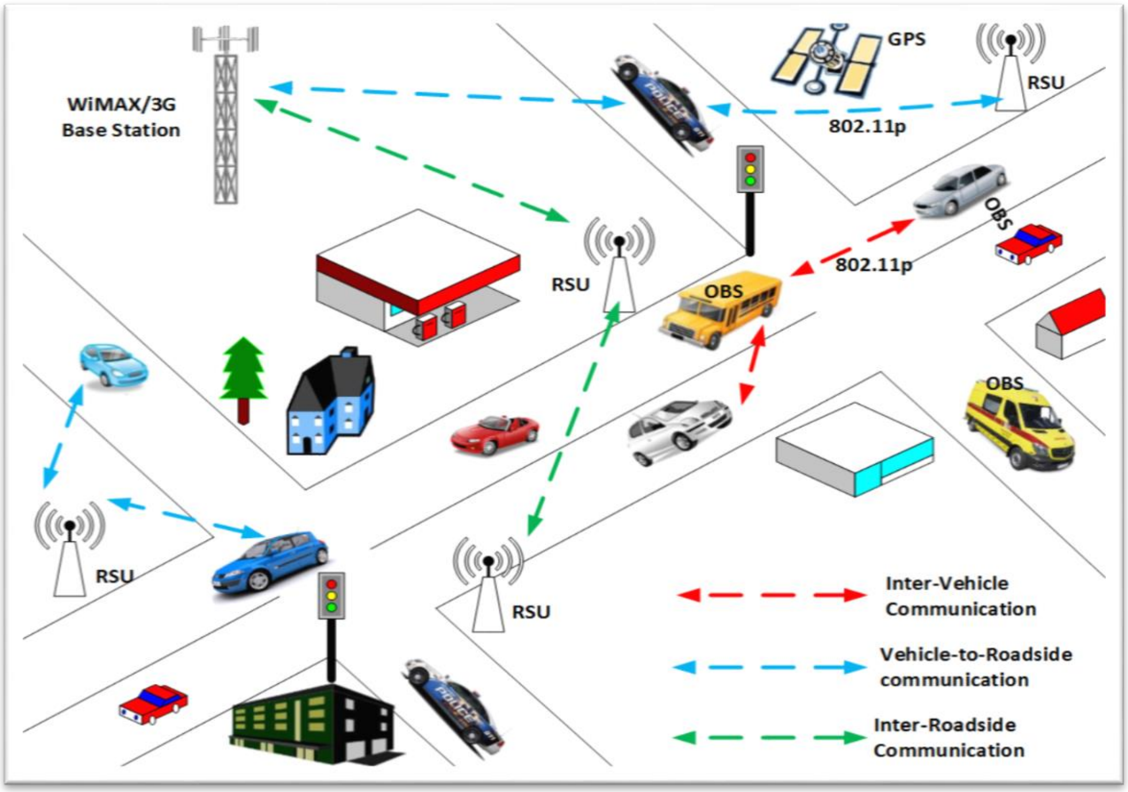


Figure 3 VANET Communication Architecture

In Vehicle-to-Vehicle (V2V), inter-vehicular communication is allowed without the need for infrastructure support. Data sent to a vehicle or picked up by a vehicular sensor, can be relayed to another vehicle directly by a one-to-one communication or indirectly through several vehicular hops. Inter-vehicular data transfer can occur between On Board Units (OBUs) without employing the services of the Road Side Units (RSUs).

In Hybrid (V2I and V2V), also known as inter-road side communication, this architecture allows for an ad-hoc communication between peer infrastructure units or information exchange between the infrastructure(s) and vehicles through multiple or single hops depending on their trajectory, speed or position with respect to each other and the infrastructure. The inclusion of the V2V scheme adds reliability to the network and extensibility to cover out of transmission range vehicles through multi-hop.

2.1.2 Challenges in VANET

VANET systems face a myriad of challenges during deployment both in the fields of research and industry. Despite inheriting many features from MANETs, VANETs possess unique features which differentiate them from other Ad-hoc networks. These unique characteristics are listed below[13]:

- VANETs generally are prone to rapid changes in topology and frequent fragmentation due to the moving vehicular nodes (vehicles). Hence the effective network diameter is relatively small.
- VANETs are generally not constrained by scarce power supply since vehicles normally have a constant DC power supply.
- The network scale and density of VANETs are prone to dynamic changes.
- The network topology is dependent on users’ reaction to data reaching them and hence VANETs are prone to dynamic topology changes.

These unique qualities of VANETs present network designer with several challenges in the design, building and the deployment or implementation of these networks. Key among these challenges are:

2.1.2.1 Wireless Access Technology

Lots of wireless access standards have been developed over the years and the particular standards chosen by designers for the connectivity of VANETs is a challenge. Due to the unique features of VANETs, the chosen wireless standards must provide protocols and parameters for high-speed vehicular communication using one or more of several media. The main technological standards for wireless access are:

- Cellular Standards (2G/3G/4G): With their pseudo-ubiquitous nature, these infrastructure networks present some core merits, namely, wide coverage area, high available bandwidth, and transmission capacity, and a highly secure system for communication. Despite these strengths, high cost and latency issues make it nearly impossible to employ these networks for VANETs.
- IEEE 802.11p Variant: Several IEEE 802.11 wires standards have been developed as different variants emerge to cope with changing communication requirements. The newly defined 802.11p variant of these standards was specially designed to support inter-vehicular or vehicle-to-infrastructure communication, for mobile vehicles operating at speeds up to 200 km/h, and supporting communication ranges of several hundreds of meters and operating at a band of 5.9 GHz. This wireless protocol is further explained in detail in the subsections later.
- Combined Wireless Access: Researchers have delved into developing more robust schemes by combining some wireless access standards. The Continuous Air Interface for Long and Medium range (CALM M5) developed by ISO TC 204 WG16 is an example of these hybrid schemes. This particular technology is adopted from the 802.11p with the incorporation of some additional interface protocols. The

supported cellular standards are the 2G, 2.5G, and 3G. Infra-red communication systems and systems operating at a band of 60 GHz are also supported. These combined access technologies provide an increased flexibility and redundancy, thus giving an enhanced application performance.

- Dedicated Short Range Communications (DSRC): A novel wireless communication service that was developed for inter-vehicular and vehicle-to-roadside short and medium communication is the Dedicated Short Range Communications (DSRC) [14]. This system was designed to provide high data transmission with minimal communication latency in small areas or zones of communication. With these advantages, this scheme is suitable for applications such as vehicle-to-vehicle safety messages, traffic information, toll collection, drive-through payment, and several others. Table 1 compares the DSRC standards developed in Japan, Europe and the United States.

Table 1 DSRC Standards in Japan, Europe and USA

Features	**JAPAN**	**EUROPE**	**USA**
Communication	Half-duplex (OBU) /Full duplex(RSU)	Half-duplex	Half-duplex
Radio	5.8 GHz band	5.8 GHz band	5.9 GHz band
Bandwidth	80 MHz	20 MHz	75 MHz
Channels	Downlink:7/Uplink:7	4	7
Channel Gaps	5 MHz	5 MHz	10 MHz
Data rate	Down/Up-link	Down-link/500 Kbits/s	Down/Up-link
	1 or 4 Mbits/s	Up-link/ 250 Kbits/s	3-27 Mbits/s
Coverage	30 meters	15-20 meters	1000 meters
Modulation	2-ASK,4-PSK	RSU: 2-ASK	OFDM

2.1.2.2 Power Management Issues

Due to the readily available source of power in vehicles, communication modules or network nodes are not constrained by limited power supply availability like some non-infrastructure based networks like wireless sensor networks. Rather, the limitation lies in the amount of power allowed to transmit since transmitting at a very high power disrupts and interfere with other transmissions. This creates a relationship of inverse proportionality between the density of the network and the allowable transmission power. In the routing of packets, a network may adjust the transmission power to maximize the overall throughput and simultaneously minimize the interference. In [15], the number of neighboring nodes is kept within some threshold range by adjusting the transmission power whereas in [16], the adjustments of transmission power is used to improve the 1-hop broadcast coverage.

2.1.2.3 Routing Issues

The issue of routing in VANETs has attracted a lot of research attention. The unique nature of VANETs makes it highly challenging to adopt the traditionally developed MANETs routing protocols for VANETs. The main difficulty in using these protocols, however, lies in the fact that, most MANET routing protocols assume that intermediate nodes can always be found between source and destination and end-to-end connection can always be established, but frequent network partitioning in VANETs makes this assumption void in the routing of packets in VANETs [17]. This work presents a novel routing protocol for effective data transmission in VANETs.

2.1.2.4 Broadcasting and Message dissemination

Current and perceived future application will require effective means of transferring a vast amount of information on the VANETs operation area. Broadcasting, due to its low cost and ability to transmit a large amount of data, is therefore the default solution that comes to mind. Several broadcasting techniques have been developed throughout the years. Wideband digital techniques like the DAB, DVB, DVB-H, S-DMB, T-BMD and DDB and low bandwidth techniques like FM radio (adopted for RDS/TMC) have been used as broadcasting solutions for message or information dissemination in VANETs. Another solution that comes to mind is satellite broadcasting techniques where real-time traffic information services are already available [18].

2.1.2.5 Channel Spectrum Issues

Inter-vehicular communication systems are predicted to last for a long time and hence there is a need to obtain a somewhat permanent operating bandwidth spectrum for these communications. In the US, a spectrum of 75 MHz at 5.9 GHz (from 5.850 to 5.925 GHz) has been allocated by the FCC for V2V and V2I communications. As agreed by VSC and VII Consortiums, the best technology available for the communications systems using this spectrum would be a derivative of IEEE 802.11. Thus the already mentioned development of the IEEE 802.11p and ISO TC204 are well suited for VANETs applications. Unfortunately, a continuous spectrum of 75 MHz in DSRC band is not available in Europe. Hence, the Car2Car (C2C) has proposed a derivative of the US approach. The proposal allocates 2 x 10 MHz for the primary use of safety critical applications at 5.9 GHz range (5.875 - 5.925 GHz). This band is used as a control channel in the US, and its allocation in Europe would allow for worldwide harmonization [19].

2.1.2.6 Security and Privacy

Security is an issue that should be painstakingly surveyed and addressed in the outline of the vehicular correspondence framework. A few dangers conceivably exist, including fake messages bringing about the disturbance of activity or much imperil vehicle administrators, bargaining drivers' private data, trading off car controls, and so on. The issues to be addressed are the honesty of information obtained (if received information could be trusted), strength (flexibility towards impedance and simple upkeep) and proficiency, e.g. continuous message confirmation. Security is likewise a noteworthy issue that should be addressed. Anonymity must be protected, i.e., the interchanges ought not to make the vehicle following or recognizable proof feasible for non-trusted parties. The avoidance of security worries at the early outline stage could bring about various lawful issues after the arrangement of the system. On the off chance that, as it is in the systems administration world, every node (vehicle) is given an exceptional, perpetual MAC address, then it could be conceivable to track a vehicle and its client. Hence IEEE 802.11p presents progressively doled out MAC addresses, alongside an instrument for copy MAC address discovery [20].

2.1.2.7 Modeling and Simulation Issues

By utilizing traditional MANET approaches, road activity has certain properties that can't be effectively displayed mundane. Vehicles don't move arbitrarily but instead follow the road foundation; road signs, traffic lights, and different autos impact nodes' conduct. Nodes move at generally rapid, system thickness changes powerfully, contingent upon the area, late occasions (e.g. mishaps) or time. Consequently, one could either manufacture an advanced road activity mobility model on top of some prevalent system test system (NS-2/3, OPNET, GloMoSim) or use mobility flows from another source. This could be either estimation based road activity flows or flows got from an outsider vehicular movement test system (e.g. CORSIM, VISSIM). An intriguing endeavor has been made in [21], where creators figured out how to interlink NS-2 test system with VISSIM, a vehicular activity test system, together with application test system in light of Matlab/Simulink environment. This methodology allows one to watch how the VANET usefulness influences the drivers' conduct, henceforth impacting the system parameters. Yet this arrangement is not optimal from the proficiency perspective. Instead of utilizing three distinct situations (running on various working frameworks), having a solitary, uniform reenactment environment with the system, vehicular activity, and driver conduct models would enhance computational effectiveness and lessening multifaceted nature by a tremendous fold.

2.1.3 Applications

Based on the type of communication rendered, either V2V or V2I, the applications of VANETs are classified as into the following classes: Safety oriented, Commercial oriented, Convenience oriented and Productive Applications [20].

2.1.3.1 Safety Applications

This category of applications includes but not limited to; monitoring of the surrounding road, approaching vehicles, the surface of the road, road curves, etc. Road safety applications can be further classified as:

- Real-time traffic: The constant movement information can be put away at the RSU and can be accessible to the vehicles at whatever point and wherever required. This can assume an imperative part in tackling the issues, for example, automobile overloads, maintain a strategic distance from congestions and in crisis cautions, for example, mishaps and so on.

- Co-operative message transfer: Moderate/Stopped Vehicle will trade messages and co-work to help different vehicles. Despite the fact that unwavering quality and idleness would be of real concern, it might mechanize things like crisis braking to keep away from potential mishaps. Correspondingly, crisis electronic brake light might be another application.
- Post-crash notification: A vehicle included in an accident would broadcast cautioning messages about its position to trailing vehicles so it can require choice with investment close by and in addition to the roadway watch for tow away backing.
- Road hazard control notification: Inter-vehicular notification about road information like landslides or road feature notification with regards to curved roads, sudden downhills etc.
- Cooperative collision warning: Advance notifications are given to vehicular operators approaching each to avoid possible collision with vehicles.
- Traffic vigilance: Installed cameras on vehicles RSUs can work as input and act as a tool in low or zero tolerance campaign against driving offenses.

2.1.3.2 Commercial Applications

In this class of applications, vehicle drivers and passengers could render several services such as web access, streaming audio, streaming live news and shows, getting current weather information, VoIP services and so on. These applications are classified as:

- Internet access: Users can surf the net if vehicles can access the internet through RSU if the RSU is operating as an IP router.
- Remote vehicle personalization or diagnostics: Information relating to personalized settings and diagnostics can be uploaded or downloaded respectively.
- Digital map downloading: Guide of regions can be downloaded by the drivers according to the necessity before heading out to another range for travel direction. Additionally, Content Map Database Download goes about as an entryway for getting important data from versatile hotspots or home stations.
- Real time video relay: On-demand videos like TV series, news streams and movies will not be confined to the home or office hence vehicle users can ask for real-time video relay of his favorite programs.
- Value-added advertisement: Service providers, who want to attract customers to their services like petrol or gasoline pumps, highways restaurants, and diners, motels, vehicle repair shops etc. could announce their services to the travelers within communication range. This application may even be made available without necessarily connecting to the internet.

2.1.3.3 Convenience Applications

Convenience applications are mainly designed for traffic management with a goal to improve traffic efficiency by increasing the degree of convenience for vehicular operators and travelers, especially in crowded, traffic prone cities. The Convenience applications can be classified as:

- Route diversions: Route and excursion arranging can be made if there should be an occurrence of road congestions.

- Electronic toll collection: Installment of the toll should be possible electronically through a Toll Collection Point. A Toll gathering Point might have the capacity to read the OBU of the vehicle. OBUs work by means of GPS and the on-board odometer or tachograph as a move down to decide how far the Lorries have flown out by reference to a digital guide and GSM to approve the installment of the toll by means of a wireless connection. TOLL application is valuable to drivers as well as to Toll administrators.
- Parking availability: Notifications regarding the availability of parking in the metropolitan cities helps to find the availability of slots in parking lots in a certain geographical area.
- Active prediction: It foresees the up and coming geology of the road, which is relied upon to upgrade fuel utilization by adjusting the cruising speed before starting a drop or arising. Besides, the driver is likewise helped.

2.1.3.4 Productive Applications

We are intentionally calling it productive as this application is additional to the above applications. The Productive applications can be classified as:

- Natural advantages: AERIS research project [20], is to produce and get ecologically important continuous transportation information, and utilize this information to make noteworthy data that backing and encourage "green" transportation decisions by transportation framework clients and administrators. Utilizing a multi-modular methodology, the AERIS project will work in association with the vehicle-to-vehicle (V2V) correspondences research push to better characterize how associated vehicle information and applications may add to moderating a portion of the negative ecological effects of surface transportation.

- Time utilization: In the event that a voyager downloads his email, he can change jam activity into a gainful assignment and read on board framework and read it himself if movement stuck. One can scan the internet when somebody is sitting in a car for a relative or companion.
- Fuel saving: At the point when the toll framework application for vehicle gathers toll at the toll corners without ceasing the vehicles, the fuel around 3% is spared, which is devoured when a vehicle as a normal sit tight regularly for 2-5 minutes.

2.2 VANET Requirements for Online Gaming

Online gaming is computer games played over a well-established infrastructure network such as the internet. Due to the large scale and centralized management, online games demand that they operate in a Client-Server (C/S) architecture. Common examples of these types of games are First Person Shooter (FPS), Real-time Strategy Games (RTS) and Role-Playing Games. Each of these games has different delay requirements that vary from 100 to 200ms for an enjoyable gaming experience. The common QoS metrics for internet games are an end-to-end delay, jitter, and percent of packet loss and are listed in Table 2.

.

Table 2 QoS Metrics for infrastructure online gaming

Traffic Class	Technology Attributes	Response time Expected by Users	Delay (ms)	Jitter (ms)	Loss Rate	Error Rate
Video Conferencing	Real-time and Symmetric	Lip-synch: <100 ms	<150	<400	<.1%	< 1%

However, playing games over VANET is challenging due to dynamic network topology and high speed of vehicles. VANETs have very limited players compared to online games due to the formation of clusters of vehicles. Thus for small scale and decentralized management of players, the Peer-to-peer (P2P) architecture is more appropriate for online gaming over VANETs [21]. The required data rates for most online games are quite modest when compared to the DSRC data rates (from 6 Mb/s to 27 Mb/s), with the majority of games generating below 100 Kb/s per player.

In this section, we point out the most important characteristics the underlying VANET protocols need to have in order to support online games. Since DSRC is the standardized VANET technology on physical and data link layers, the focus on the desirable characteristics for gaming applications has been presented for only higher layer protocols.

2.2.1 Network Layer Challenges

In order to support the long connection duration requirement for highly interactive applications like online gaming, a multi-hop routing protocol is required [22] to efficiently route packets from the source node to the destination node. Further, a QoS-aware, position-based routing protocol that forms routes based on predicted connection duration and link characteristics would be very beneficial to such interactive applications. For instance, the GPS information and the received signal strength could be used to provision for better link stability, lower delay, and longer connection duration. The use of WSMP (Wave Short Message Protocol) for games, instead of IP, could be an interesting option, especially because single Wave Short Message (WSM) can be delivered to multiple destinations, and WSMP leaves it to the application to differentiate between messages. Also, WSMP is designed to provide a rapid and a reliable datagram delivery with minimum overhead with a header size of only 11 Bytes.

2.2.2 Transport Layer Challenges

Depending on the type of transmission needed, games over internet use TCP and/or UDP but in general, TCP is preferred when a reliable transmission is necessary. When the key requirement is the fast transmission of data packets like player coordinates in a fast-paced game, UDP is most often employed. However, numerous studies [9, 21, 23] have shown that connection-oriented transport protocols, such as TCP, perform poorly in wireless ad-hoc networks, especially when the nodes are mobile. High mobility in VANETs presents a dynamic QoS and hence creates a significantly different environment that requires transport protocols to be aware of the underlying network conditions. Besides physical characteristics of the network, VANET transport protocols have to account for the fact that WAVE networking service shall support the connectionless unacknowledged operation of the Logical Link Control (LLC) layer. Hence, segment acknowledgments are an essential and required component of VANET transport protocols. Also, successive segments in VANETs can arrive over different intermediate nodes, thus making it possible for segments to arrive out of order. The protocol could incorporate segment reordering via the use of sequence numbers so as to avoid this problem.

2.2.3 Application Layer Challenges

Besides the mechanisms used by games on the internet to compensate for high delay, jitter, and packet loss, games in VANETs will have to acknowledge specific properties of VANET environment such as:

2.2.3.1 Connection Duration Awareness

Given the possibility of an intermittent connection between players, games should have the ability of “seizing the moment”, considering the scarcity of the connection and enabling the interaction between players, even in the case where connection duration is of the order of seconds. In [9] , three types of interaction between players are presented for VANET based online games:

- Shorter communication with the player in the vehicle traveling in the opposite direction.
- Longer communication with the player in the vehicle traveling in the same direction.
- Determinably prolonged, but potentially intermittent communication. This case could happen when passengers operating in different vehicles share the same short-term (e.g., both of the vehicles exit the highway on the next exit) or long-term destination (e.g., both vehicles are going to Jeddah). A gaming application may have access to the destination information via GPS. A similar scenario can be

perceived in the case of platooning, where several cars are in coordination along with a highway.

2.2.3.2 Fast Switching Between Players and Sessions

Given the fluctuating way of VANETs, an application, for example, a game ought to have the capacity to suit incessant player movement between various gaming sessions that may happen either because of the gamer's inclination or on account of physical detachment between players. The researchers in [9] present diverse situations where the game engine and the hidden conventions protocols should provide for:

- Fast and efficient game session change.
- Flawlessly supporting both unicast and multicast/broadcast, for instance, if player A joins the amusement session in the middle of B and C, unicast correspondence ought to be changed to numerous multicast or broadcast.
- Employing a distributed model where each vehicle or network node replicates its game session ensures that consistency will not be impacted by other vehicles exiting and entering the gaming session.

2.2.3.3 Disconnection Tolerance

In internet web recreations, players for the most part not tolerant to organize based intrusions of gameplay and ordinarily tend to change diversion servers in the event of successive interference and blackout of gaming sessions. Subsequently, organize interferences must be represented in VANETs because of high mobility that empowers gamers to interface just for a specific measure of time. Hence, any VANET diversion whose fundamental design is not adjusted to represent the system based intrusions would hazard a low prominence and utilization by gamers. Be that as it may, utilizing the instruments portrayed above i.e. association term mindfulness and quick exchanging in the middle of gamer and gaming sessions, the gaming application can be composed in a way that guarantees the joining of system based interferences. In a multiplayer session, a gamer is permitted three sorts of activities [9]: position change, player–object connection, and player–player association. At the point when players are in the correspondence scope of each other, they associate in the diversion. Be that as it may, when there are no different players accessible, a player ought to have the capacity to play by satisfying different objectives in the diversion (e.g., connecting with items in the amusement and traveling through the amusement world). Moreover, the diversion must have the capacity to flawlessly consolidate recently reachable players in the amusement, without exasperating player's action in the diversion.

2.3 IEEE 802.11p Standard Overview

Wireless Access in Vehicular Environment (WAVE) is considered as a core component of DSRC. IEEE 802.11p standards are oriented towards PHY and MAC layers. IEEE P1609.x standards deal with the functionality and complexity of higher layers [24].

2.3.1 IEEE 1609-Standards for Wireless Access in Vehicular Environments

Wireless connectivity among moving vehicles can be provided by the infamous 802.11a variant compliant devices with data transmission rates up to 54 Mbps. Despite this, vehicular traffic applications present greater challenges than fixed infrastructure based wireless networks. Some of these challenges in vehicular traffic scenarios are due to several features not found in static wireless networks but inherent to VANET based applications. Key among these features are varying driving velocities, dynamic traffic patterns, and changing driving environments [25].

Traditional IEEE 802.11 Media Access Control (MAC) operations require significant frame overheads when used in vehicular scenarios. For example, rapidly fast data exchanges are required to ensure timely communications for vehicular safety.

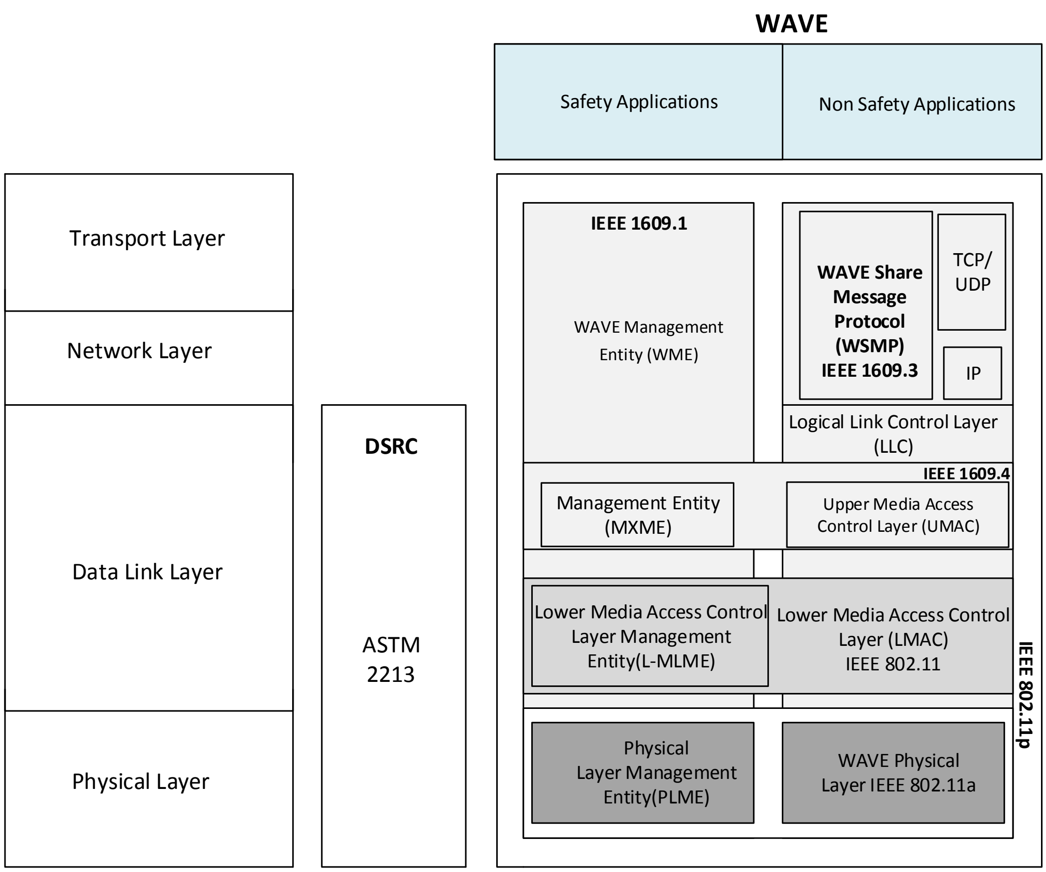


Figure 4 WAVE, IEEE 802.11p, IEEE 1609x and OSI Reference Model

In these scenarios, the scanning of wireless channels for beacons from an Access Point coupled with the multiple handshakes required to establish connection would present a highly complex design challenge and large data overheads (for instance, two moving vehicles approaching each other in the opposite direction at high speed, have a very short duration for possible connection and hence making a communication between them extremely difficult to establish).

To address these challenges of the IEEE MAC operations, the Dedicated Short Range Communications (DSRC) effort of the ASTM 2313 working group migrated to the IEEE 802.11 standard group which renamed the DSRC to IEEE 802.11p Wireless Access in Vehicular Environments (WAVE). In contrast to the regional standards of DSRC, by incorporating DSRC into IEEE 802.11, WAVE has become a standard that has received a high popularity among Vehicular Ad-hoc Network engineers. From Figure 4, it is evident that IEEE 802.11p is bounded in its scope of operation by the scope of IEEE 802.11 which is designed to operate in the physical layer and the MAC layer.

The different roles of operation and the sophistication found in DSRC are tackled by the higher layers of the standards in IEEE 1609. These standards define the way processes that make use of WAVE operate in the WAVE environment, based on the management activities defined in IEEE P1609.1, the security protocols defined in IEEE P1609.2, and the network layer protocol defined in IEEE P1609.3. The 802.11p is found below the IEEE 1609.4. This standard also handles the functioning of upper layers. This support can be done without necessarily dealing with the variables of physical channel access. Wireless Access for Vehicular Environments (WAVE) presents two variants of devices: the first is the Road Side Unit (RSU), which is a stationary device and On-board Unit (OBU) which is a mobile device. Road Side Units and On-board Units may provide or use services and can alternate between these two functions. Mostly, static WAVE equipment host an application which is a service provider, and a non-stationary device that hosts a peer application. Sometimes there are applications on devices not stationed at the RSU which functions as a service provider to the On-Board Unit. This WAVE standard describes applications that are hosted on the Road Side Units although it is built to multiplex requests from remote applications and therefore having access to the On-board Unit. In WAVE, multiplexing is done using Orthogonal Frequency Division Multiplexing (OFDM). This technique is used to combine the signal into several narrowband subcarriers or subchannels to give data payload communication rates of 3, 4.5, 6, 9, 12, 18, 24 and 27 Mbps in 10 MHz channels. Table 3 shows an overview of these standards.

Table 3 IEEE 1609/802.16e Standards

IEEE Standard	Description
IEEE Standard 1609	Presents the total architecture, model of communication, management structure, security operations and physical access for wireless communications in the vehicular environment, the basic architectural components are OBU, RSU, and the WAVE interface.
IEEE Standard 1609.1-2006	Enables interoperability of WAVE applications and describes major components of the WAVE architecture and defines command and storage message formats.
IEEE Standard 1609.2-2006	Describes security services for WAVE management and application messages to prevent attacks such as eavesdropping, spoofing, alteration, and replay.
IEEE Standard 1609.3-2007	Specifies addressing and routing services within a WAVE system to enable secure data exchange, enables multiple stacks of upper/lower layers above/below WAVE networking services, and defines WAVE Short Message Protocol (WSMP) as an alternative to IP for WAVE applications.
IEEE Standard 1609.4-2006	Describes enhancements made to the 802.11 Media Access Control Layer to support WAVE.
IEEE Standard 802.16e	Enables interoperable multi-vendor broadband wireless access products.

2.4 Simulation Tools, Models, and Platforms for VANET

The dynamics in topology and the operational environment of VANETs present difficulties in the characterization, implementation, and evaluation of VANET systems in real-time.

Outdoor experimentation could be employed in the evaluation of VANET protocols and applications, but due to the unpredictability in node dynamics in real-time implementation settings, these evaluation techniques tend to be expensive, complex and difficult. To conduct the evaluation of VANET protocols and overcome these limitations, researchers make use of simulation tools for the evaluation of VANET protocols before real-time deployment.

2.4.1 Mobility Models for VANET

In comparison to known simulation models for VANET systems, which treat all network nodes in an identical manner, a mobility model that has the ability to distinguish between nodes by their functions was developed by [26]. This role-based technique allows vehicles to have distinguishing roles and to have operations in the scope of both microscopic and macroscopic mobility. Results indicate that the issue of non-real life patterns in the traffic of a network and problems that do not mimic real-time applications can be dealt with by the use of the role-based mobility model. This role-based mobility model, however, encounters some inherent limitations. This simulation model is incapable of dealing with complex traffic elements such as overpasses, bridges, and tunnels. In [27] a wireless network tool for simulating VANET named VGSim was proposed. This simulation model is an integrated networking and microscopic vehicular mobility simulation platform that can be used to model vehicular mobility in an accurate manner. VGSim is reported to accurately deal with most of the requirements of real-time mobility dynamics of VANETs. Key among these requirements that VGSim is reported to solve are the closed-loop integration of real-life vehicular traffic and a wireless communication simulation module.

The developers of VGSim showed that this model has high flexibility, and more resourceful in comparison to similar models and is capable of easily adopting several mobility models.

To obtain realistic results from the simulation of VANETs, a mobility model that mimics realistic VANET networks needs to be developed. A mobility model could be described as a tool that defines the set of rules that describes the movement patterns of network nodes used by network simulators to create random topologies based on nodes position and perform some tasks between the nodes. Different types of mobility models have been used in VANET simulations. In this work, these models are classified based on the level of details that they generate.

One problem found in mobility models used for the simulation of VANETs is the lack of coherence in the mobility model when operating at both the Macroscopic and Microscopic levels [28]. Mobility models are generally constrained by factors like streets, lights, roads, buildings, cars, vehicular movements and inter-vehicle behavior. These constraints can be classified into two folds: the mobility part of the node which includes streets, lights, roads, general infrastructure etc. and is classified as Macroscopic, whereas the mobility of nodes and their features are classified as Microscopic. Mobility models can also be viewed as, those that incorporates a traffic generator and a motion generator. Constraints in motion are derived from the behavior of the vehicle, the vehicle operator habits and the behavior of pedestrians and describe the movement of a vehicle. The Traffic generator, on the other hand, generates stochastic topologies derived using maps and presents the character of the vehicle under some specified environmental conditions. Mobility models are also defined using the framework that includes topological maps such as lanes, roads, streets, obstructions in mobility, a model of communication, vehicular speeds derived from traffic densities present the way of altering the time in the simulation, vehicular distribution on roads and intelligent driving patterns. The illustration of this framework is given in Figure 5 [28].

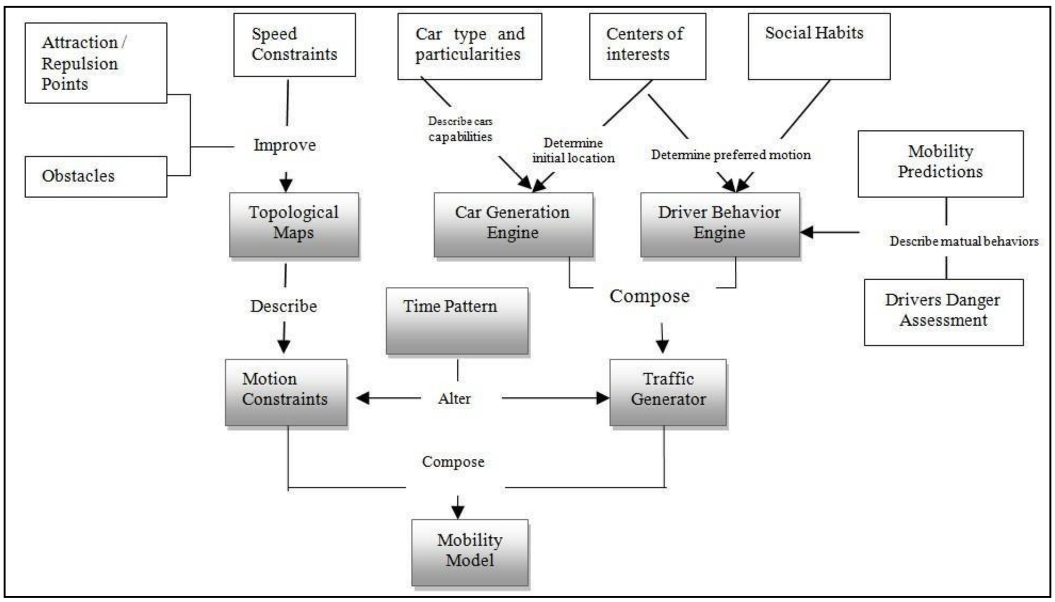


Figure 5 Mobility Model Framework

In order to conduct VANET simulation trials, the model used for mobility has to be developed. One method of obtaining a real-life model is to produce patterns with the use of traces in mobility. Several contemporary academics and network scientists have made some efforts to adapt already made mobility models so as to increase their likeness to real-life situations by the use of traces in mobility [29]. The key rationale behind these models is the use of existing measured parameters connectivity logs to develop synthetic traces which can be modeled using similar statistical characteristics of real-life vehicular traffic scenarios. The following subsections give some reported models that produce traces which are employed in mobility models.

2.4.1.1 Survey models

Survey models represent real-time human behavior in metropolitan mesh environments. The model mainly uses data collected from surveys done on human activities in urban environments. One of the large surveys presented by [30] is done for the department of labor in the US, conducted a survey by taking records of the way workers behave and their activities at lunch time, communication with workers pedestrians etc. the data obtained from this study was then used to create a generic mobility model for urban human behavior. The survey took records of human performance, tasks, and activities. For example, the UDel mobility model [31] is a tool for simulating urban mesh networks which incorporates obstruction in non-stationary nodes and produces a graph of the urban area. The behavior of the mobile nodes is then observed by putting them on the generated graph.

2.4.1.2 Event driven models

These models, also known as the trace models, can be used to check the way cars and pedestrians move, and use some analysis of their movement to generate their mobility pattern. In [28], a Wireless Local Area Network mobility model is presented, where the features of the network users were collected through measurements in an academic campus. In [32], the nature of the connectivity of users on a Wireless LAN connect with an infrastructure network was observed. These trace models may then be put together to generate a stochastic mobility model that reflects the real-time mobility of nodes on the map. This stochastic mobility model was then used to develop a discrete Markovian model, which considered the source, destination paths, and the present and past locations. The main shortcoming of this tracing technique in mobility is that only the features of moving vehicles or nodes having access points were taken into consideration, therefore, the inter-relation between nodes was considered. This problem makes probabilistic models unsuited for the ad-hoc mode of VANETs.

2.4.1.3 Software oriented models

A myriad of simulating tools like VISSIM [33], CORSIM [34] and TRANSIM [35] are capable of generating the traces in mobility of metropolitan microscopic traffic. VanetMobiSim [36] uses the Tiger database and Voronoi graphs to obtain the topologies of roads, maps, and streets and other details for the net-simulating tools. Issues with these software-oriented simulating tools are that they are capable of operating only at the traffic level and are incapable of generating real-life traffic details.

2.4.1.4 Synthetic models

Several studies have been conducted in the field of synthetic modeling. All models in this class employ rigorous statistical analysis to generate real-life mobility models. The performance of these statistical methods is then evaluated by a comparison with realistic models. This evaluation is used to authenticate the validity of the model. From [37] these models can be further classified into five folds:

- Stochastic model: works by considering an entirely stochastic mobility.
- Traffic Stream model: evaluates the feature in the mechanics of the mobility models.
- Car Following model: checks the nature of the inter-vehicular interaction.
- Queue model: models vehicles as being in queues with the streets being buffers.

- Behavioral models: checks how mobility is impacted by environmental interaction.

If the movement of a node is observed within a given area, it is observed to be directed in an unchanging or a stochastic path. In a Weighted Way Point (WWP), the target is chosen based on the present position and time while in Random Way Point (RWP), the target is chosen in a random manner. The mobility method then computes the mobile trace of a vehicle by establishing some mathematical relations. These statistical methods impose some limitations like not including a realistic pedestrian behavior. This makes it difficult to develop random topologies with this model.

2.4.2 Evaluation of VANET Simulators

Several VANET simulators have been reported but none presents a wholesome solution for the simulation of VANETs. This is mainly due to the fact that, VANET relies on the traffic simulation and the network simulation to function properly. Traffic simulators are employed in the engineering of transport and traffic systems. Network simulators, on the other hand, are employed for the evaluation of network protocols and applications in a variety of conditions. These simulators operate in an independent fashion. To be able to mimic a realistic VANET, a solution that incorporates both network and traffic simulators is needed. Several proposed traffic and network simulators have tried to thoroughly conduct the simulation of VANETs with each solution having its unique advantages and disadvantages. A thorough interaction is needed between traffic and network simulators in order to effectively address the problems presented in VANETs. There still remain the problem of why traffic and network simulators seem incompatible in operation. The main issue that comes to mind is the unmatched format of these tools. In many cases, the format of mobility models generated by the traffic simulator cannot be processed by the network simulator. For example, network simulators such as NS-2/3 cannot directly accept trace files from other traffic simulators.

Various commercial traffic level simulators such as AIMSUN [38], VISSIM [33], CORSIM [34] present a somewhat comprehensive graphical user interface and supports several traffic level characteristics. This makes them expensive and due to their proprietary nature, access to their source code is difficult and hence constraining the modifications needed for effective research. Also, these tools produce some details that are not yet used by conventional network simulators. This review focuses on free software simulators since they are mostly available and hence could be appropriately modified to meet research goals.

Numerous mobility models like the Gauss-Markov model, Random walk model, Car Following model, Platoon, Random Waypoint model have been employed to produce node mobile characteristics like alterations in speed, stochastic dynamics in a topology boundary on so on. Among all these models, the Random Waypoint model has seen wide usage but the mobility patterns generated by this model does not mimic a realistic node behavior. Therefore, researchers tend to focus on other projects, normally beginning with the simple classes to more sophisticated mobility patterns. These projects, however, seem to be more focused on traffic issue, with the network side receiving a very small research attention as described in [29].

To satisfy the criteria of a VANET simulating model, candidate models need to qualify in dealing with traffic and motion level issues. The traffic level is normally handled by components such as roads, the blockade in lines of communication, lights and vehicular densities. For the tool to meet the criteria at the traffic level, it should have maps, beginning and end positions, a trip through different positions, selection of track, vehicular speeds and so on. After all the details at the traffic level have been satisfied, the motion level criteria are adopted to create topologies between the nodes, and node feature is then analyzed based on the information gathered at the traffic level. It also incorporates the monitoring of heavy traffic situations. Models might be obtained using mathematical relations which can generate all predictable node behavioral patterns. Several models fall within this class. One model that has found wide usage is the “Car Following” model. This model is used to capture the situation of cars following one another on the same lane. This model is widely selected [29] among reported traffic models like Krauss Model (KM), General Motors Model (GM), Gipps Model (GP), Intelligent Driver Model (IDM).

VANET simulators supporting a Graphical User Interface (GUI) are normally favored over command lines. Also, during the simulation of real-life complex networks, simulators should also find a way of integrating radio obstructions, found in wireless communication media, in the simulation. Moreover, VANET simulators must have the ability to produce trace files for other simulators such as NS-2/3 or QualNet. Simulators such as; MOVE [39], Trans [38], VanetMobiSim [36], NCTUns [40] satisfy the discussed traffic level and motion level criteria.

A Simulator like CanuMobiSim [41] was made to solely produce traffic level details but is limited in its ability to produce motion level details, unlike MOVE and NCTUns simulators. NS-2/3, GloMoSim simulators generate details at the network level.

2.4.2.1 Mobility Model Generator for Vehicular Networks (MOVE)

MOVE [39], is a Java-based program developed on SUMO (Simulation of Urban Mobility) with a graphical user interface (GUI) support. MOVE has better visual features and focuses mainly on traffic level details. In this program, custom and randomly developed graphs described by the users are supported. The movement of nodes in a stochastically developed graph is restricted to grid mobility. This simulator is made up of a Map editor and a Vehicular Mobility editor. The Map editor generates topology maps for different network instances and the vehicular mobility editor creates mobility patterns in an automatic fashion or employs the patterns already defined by the user within the editor. The simulator is also able to create its own mobility model. However, result gotten from this simulator is not very comprehensive in comparison to conventional mobility models. Its limitation being the lack of support of networks with numerous nodes. (i.e., the ratio at which packets are delivered decreases with an increase in the number of nodes.).

Furthermore, it doesn't support networks with several radio interfaces. In the process of creating traces of movements, MOVE considers micro-mobility. The micro-mobility property does not include any changes in lanes or obstacles. Intersections are managed using simple random models, hence stochastic mobility of nodes within a topology is not taken into consideration. MOVE makes use of the federated approach, where communication is done through a parser. A trace obtained using traffic simulators are passed to the parser for translation, and then processed by the network simulator. Update of files from the network simulator is then sent back to the traffic simulator using the parser. The limitation with this method is that, inter-simulator interactions are done within the specified time.

2.4.2.2 Traffic and Network Simulator (TraNs)

This simulator [38], is a Java based program having advanced visual tools which are built to include both SUMO and NS-2 to carry out VANET simulations. SUMO does the translation of traffic files into a certain kind of dump files which are then utilized in the network simulator. A lighter version was developed by the authors called the TraNs-Lite which is employed for purposes of creating mobility models alone without the integration of the NS-2 network simulator. TraNs-lite is a scalable program having the capability of simulating a maximum of 3000 nodes and is capable of extracting mobility traces with the use of a Shapefile which is a vector map, with points, polylines, and polygons. These graphs may be edited by the developer based on his specifics of his design. The disadvantage of the TraNs architecture is that, the outputs generated using NS-2 can't be sent back to the SUMO i.e., NS-2 produces its outputs in "file.out" file and this file cannot be sent back during VANET simulations so as to regenerate traces. Hence, the uncoupled simulators are not able to give scenarios that mimic real time situations.

2.4.2.3 VanetMobiSim

This simulator was developed by extending the CanuMobiSim simulator. Due to the limitation scope of CanuMobiSim that they can only be employed in special fields, VanetMobiSim is capable of producing higher levels of information on some special scenarios. Hence CanuMobiSim was remodeled to obtain higher levels of real-time scenarios with VanetMobiSim. Designers of VanetMobiSim incorporates vehicle-to-vehicle and vehicle-to-infrastructure instances. Hence it has a combination of stop-signs, traffic-lights, and activity based macro mobility with pedestrian movement dynamics. It is capable of extracting a road topology using a stochastic and a customized topology. The simulator also makes it possible for developers to develop a trip using their own assumption(s) and can reconfigure the source to destination path using Dijkstra's algorithms, road speed shortest, or density speed shortest. This simulator is composed of a parser to obtain a topology which can be employed by a network simulator. The chief limitation of the method used by this simulator is that a trace produced can't be passed back to the network simulator or a trace produced by a network simulator can't be used as an input to VanetMobiSim. The main criteria for an effective VANET simulation are the corporation between simulators to generate realistic results which are not met by VanetMobiSim since it doesn't operate effectively with network simulators.

2.4.2.4 National Chiao Tung University Network Simulator (NCTUns)

The NCTUns simulator [40] was developed using C++. Embedded within it, is a graphical user interface tools that could be easily used by the developer. It is capable of simulating all variants of IEEE 802.11 standards (i.e., 80.211a, 802.11b, 802.11g, and 802.11p). It has the capability of simulating a myriad of wireless interfaces within a single node which includes 802.11p. It also has an unused space of a shadowing path-loss model, Rayleigh, and Ricean fading models. The simulator can also steer an antenna in one direction, in two directions, and at rotational directions. The SNR computation is done cumulatively while the signal power is obtained from the perspectives of both the sender and the receiver. The simulator is also able to implement blocks of objects and therefore introduces obstructions in the path of wireless signals. Wall-like objects could obstruct a wireless signal or can cause signal attenuation at specific values. Objects of obstruction produce a somewhat better simulating scenarios where the effect of multi-hop wireless networks could be observed. In simulations, every node is allowed to transmit either a UDP or TCP segment. However, NCTUns has an inherent demerit though. In several network simulators, numerous versions of TCP/IP like Tahoe and New Reno are allowed in a single simulator, but in NCTUns only one version of TCP/IP is allowed. NCTUns allowed for the cooperation of traffic and network simulators in one simulating module with an excellent feedback which supports VANET simulations. As stated previously, for an effective VANET simulation, feedbacks between the traffic simulator and the network simulator must be accomplished in time efficient way. Therefore, this simulator is the only one which deals with the disadvantages of the above-mentioned simulators like MOVE, TraNs, and VanetMobiSim. However, NCTUns is capable of only supporting up to 4096 nodes within a single simulation scenario.

Table 4, summarizes the major characteristics of traffic level and mobility level features for SUMO, MOVE, TraNs, VanetMobiSim, and NCTUns. In conclusion, Figure 6 highlights the strengths of the above-mentioned simulators in a pictorial form.

Table 4 Characteristics of SUMO, MOVE, TranNs, VanetMobiSim, and NCTUns

Attribute	SUMO/MOVE/ TraNs	VanetMobiSim	NCTUns
Custom Graphs	Supported	Supported	Supported
Random Graphs	Grid Based	Voronoi Graph	Shape Files
Graphs Using Maps	TIGER-database	GDF	Bitmap image
Multilane Graphs	Supported	Supported	Supported
Start/End position	AP, Random	AP, Random	Random
Trip	Stochastic Start - End	Stochastic Start - End	Stochastic
Path	Random Walks, Dijkstra	Random Walks, Dijkstra	Random Walks
Velocity	Road-Dependent, Smooth	Road-Dependent, Smooth	Road-Dependent, Smooth
(a) Traffic level			
Human Patterns	Car Following Models	IDM, IDM with intersection management, IDM Lane changes	IDM with car following, IDM with Lane changing, IDM with intersection management
Intersection Management	Stochastic turn	Traffic-light and road signs	Traffic light
Lane changing	Not Supported	MOBIL	Supported
Radio Obstacles	Not Supported	Supported	Supported
(b) Motion level			
Supports GUI	Supports	Supports	Supports
Output	NS-2, GloMoSim, QualNet	NS-2, GloMoSim,	NS-2
Other features	Federates / Integrates	Separates	Integrates

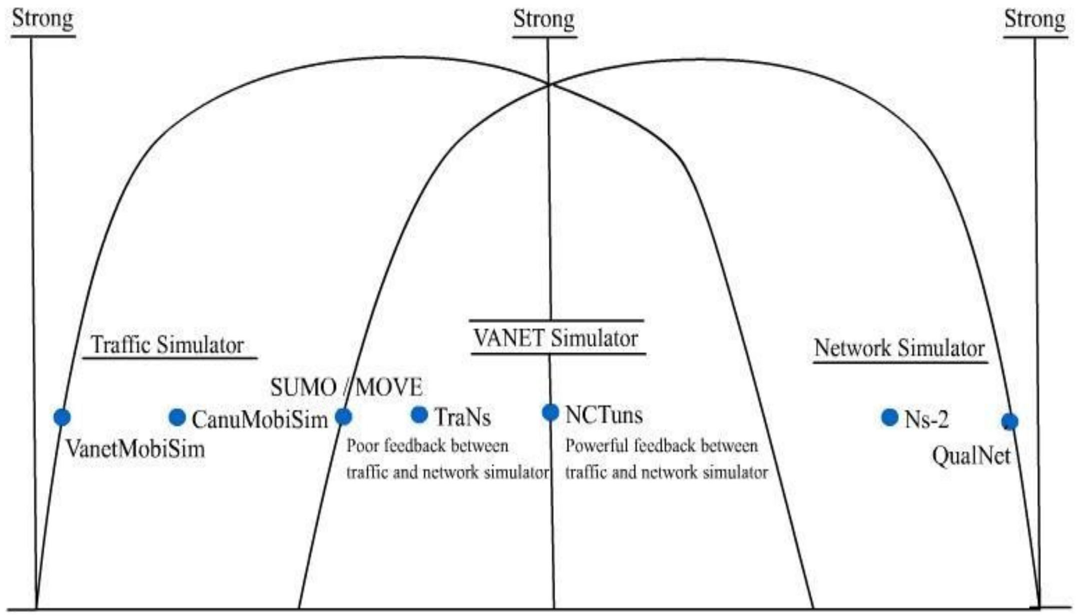


Figure 6 Comparison of Advantages of Traffic, VANET and Network Simulators

2.5 Summary

In this chapter, we have presented a comprehensive state of the art about VANETs, its issues, and challenges. Without this knowledge, it would become very difficult to propose any protocol or algorithm that can work with all the dynamic environment of VANETs.

We have started with VANET architecture and its layered approach to differentiate it from the OSI model. Then we highlighted different challenges faced by VANETs such as Mac and PHY layer challenges of IEEE 802.11p, power management issued, routing issues, message dissemination, frequency spectrum allocation, security and simulation issues.

Then we presented the classification of VANET applications and mainly focus on the requirements of online gaming application over VANET. Finally, we have presented different simulation tools and mobility models used by VANET researchers.

CHAPTER 3

LITERATURE REVIEW

In VANET, to extend the reach of vehicles beyond their transmission range, we use multi-hop communication via V2V or V2I. In this case, the routing protocols play a key role in selecting the best path from source to destination. However, the performance of communication in VANET is highly dependent on the performance of its underlying network routing protocols. Thus, in this chapter, we have literature reviewed the most commonly used MANET and VANET routing protocols, their issues and challenges.

3.1 Mobile Ad-hoc Network Routing

Hundreds of routing protocols for ad-hoc networks have been reported in the literature. Since VANETs share many characteristics of MANETs, we preferred to focus on MANET routing protocols first. In MANETs no static or fixed network topology is employed. Hence, mobile nodes employ any runtime topology due to their own dynamic behavior.

In MANETs, the wireless communication is such that the network nodes are not fixed and are mobile. Therefore, this type of network facilitates a somewhat ubiquitous interconnectivity between nodes within its communication range, such that the mobile nodes can interconnect at any point in time. Successful delivery of data among various nodes is impossible without the use of routing protocols. Thus, routing protocols for MANET is one of the challenging areas due to its dynamic and ad-hoc nature.

Many routing protocols have been developed so far to compete with sudden changes that may arise due to nature of these networks. Route discovery, route maintenance and sudden change in the topology are the major barriers for routing protocols in MANET. Due to these problems, several routing protocols have been developed that can meet the dynamic nature of such ad-hoc wireless networks. There are many different categories of MANET routing protocols and in this section, we mainly focus on the commonly used category, namely topology based routing protocols, as they are extensively used in the literature.

3.1.1 Topology Based Routing

A myriad of MANET applications reported has adopted the topology based routing to determine the best path to route packets. Topology based routing protocols generally make use of link information in a network to route data packets from source to destination. Topology based routing protocols can further be classified into three folds as depicted in Figure 7. These classes are [42], the proactive, reactive and hybrid routing protocols. The following subsections give a brief overview of these classes.

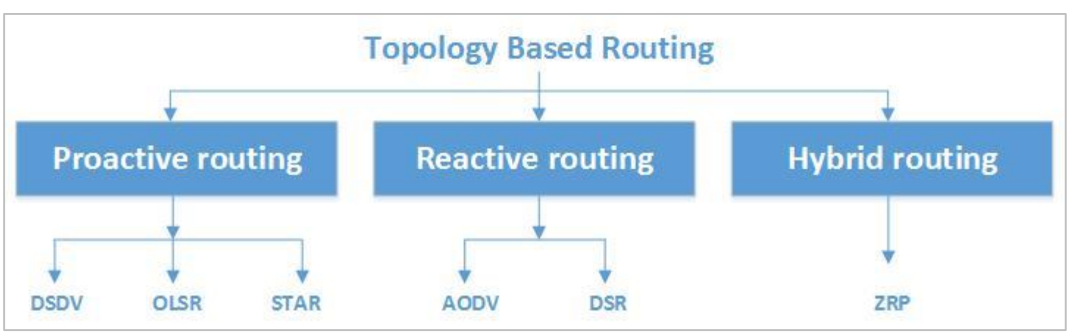


Figure 7 Topology Based Routing

3.1.1.1 Proactive Routing

Most proactive routing protocols make their routing decisions based on the shortest path algorithm [43]. These protocols build tables at each node, containing routing information of all connected nodes. Each node in the network then broadcasts its constructed table to its neighbors. Each node updates its table at every instance of network change. Strategies implemented in proactive routing are link state for routing protocols like OLSR and distance vector for routing protocols like DSDV. In the literature, OLSR and DSDV are the most popularly proactive routing protocols. Details of the routing operations of these algorithms are expounded below.

- **Destination Sequence Distance Vector Routing (DSDV)**: This algorithm [44, 45] uses the infamous distance vector shortest path routing algorithm which guarantees shortest routing paths without loops. In this algorithm, two types of packets are sent; the "full dump" packet and the "incremental" packet. In full dump packets, all the routing information is sent, whereas, in incremental packets, only updates are sent. Bandwidth utilization is reduced by transmitting only updates instead of the whole routing information. However, there is still an increase in packet overhead when dealing with incremental packets. The frequency of transmission of these packets makes them unsuitable for large networks.
- **Optimized Link State Routing (OLSR)**: In this scheme, routing information is maintained through the sending of routing information. This task is carried out using the Optimized link state routing (OLSR) [46]. In dynamic topologies, nodes within the network exchange update every time there's a change in network topology. This ensures that an update is received by every node only once. Also,

only a selected group of nodes can retransmit their updates. Nodes that cannot retransmit only read updated routing information.

- **Source-Tree Adaptive Routing (STAR)**: Another link state routing protocol reported in the literature is the Source-Tree Adaptive Routing (STAR) [47]. In this scheme, destination routes from every node are saved in each router. This reduces overhead in the network by eliminating periodic updates and therefore updates are only sent in response to events [43]. It implies that this routing scheme is well suited for large networks but requires higher memory and processing capabilities to cope with and maintain the large trees of the network.

Proactive based routing protocols may not be suitable for high mobility nodes because distance vector routing requires a significant bandwidth to share routing information with neighbors. Also, for link state routing operating in large networks, large memory, and processing speed is needed for the huge routing tables. From the above-stated limitations, proactive routing would not be suitable for VANET for large scale deployment due to tables update and heavy bandwidth utilization.

3.1.1.2 Reactive Routing

Reactive routing protocols were proposed to curtail for the areas where proactive routing fall short, i.e., high overhead, processing speed and memory demands. This class of routing schemes deals with these drawbacks by maintaining only the active routes at an instant [43]. Route discovery and maintenance are done using the nodes currently transmitting information from source to destination.

In reactive routing, routes are discovered by sending RREQ (Route Request) from a node when that node requires a route to send the data to a specific destination. After sending the request (RREQ), the node then awaits an acknowledgment packet referred to as the RREP (Route Reply). If the RREP is not received in a specified time interval, the source node assumes the packet or route either does not exist or the route is unavailable. On the other hand, if these information exchanges using the RREQ and RREP are successful, then by using unicasting, the routing information is transmitted to the source node so as to ensure that route is available for information exchange.

Reactive routing can be either a source routing or hop-by-hop routing. In source routing, the complete routing data from a source node to a destination node is added to the data packets. When these data packets are forwarded to other intermediate nodes in the network, each node takes the route information from the data packet and stores it. As a result, every intermediate node does not have to keep an update of all route information in order to transmit the data packet to the particular destination.

The main disadvantage of source routing is that it may not be well suited for large scale networks with highly mobile nodes with time-varying topology changes such as VANETs. As a result of a large number of nodes found in large Ad-hoc networks and the increase in the number of intermediate nodes, there is a high chance of an exponential increase in data packet overhead and hence route failure.

Hop-by-hop reactive routing is better than on-demand source routing [48] as every data packet used in this routing scheme contains the respective addresses of the next hop and destination. Hence, intermediate nodes linking source and destination nodes contain the routing table information needed to send a data packet to the desired destination. This can be quite helpful for accommodating sudden changes in the network topology. Thus when topology changes, nodes receive fresh routing table information and selects new routes accordingly. As a result, these selected routes are now used to send data packets to the destination. These types of routing protocols constantly keep updating their routing information and send this information to their neighboring nodes. These features of the hop-by-hop reactive routing scheme make it favorable for networks with highly mobile nodes such as VANETs.

Several reactive routing schemes have been reported in the literature [42, 49]. In this section, we describe two of the most commonly used reactive routing schemes, namely Ad-Hoc On-Demand Distance Vector Routing (AODV) [50] and the Dynamic Source Routing (DSR) [51]. The suitability of these routing protocols for VANET applications is also discussed.

- **Ad-Hoc On-Demand Distance Vector Routing (AODV)**: This protocol is a class of purely reactive routing scheme. It is classified as a multi-hop type reactive routing. AODV operates mainly when demanded and when the network requires it, which is executed using constituent nodes found in the multi-hop network. Discovery and maintenance of routes are done also when demanded. The protocol eliminates the requirement of continuous update of routes at each node all the time. That is, the protocol initiates the discovery and maintenance of routes only at instances where nodes are ready for the exchange of data. It employs a somewhat high efficiency in the methodology of routing by the reduction of the network load through the broadcasts of routes discovery mechanisms and through a dynamic routing update information at every intermediate node. Topological changes and routes without loops are attained with the use of recent data route between successive nodes through the use of Destination Sequence Numbers of DSDV.

- ***AODV Route Discovery***: is a key for an efficient operation of almost all protocols in wireless communicating nodes. This stage is crucial because, if a node intends to exchange packets with another node in the network, it must choose an appropriate path with minimum cost to route its packets. In this protocol, route discovery is done through the broadcast of route request (RREQ) packet to all its neighbors. This RREQ packet is composed of the address of the sending node and the receiving node, in order to know the nodes involved in the information exchange. The request packet is also comprised of the sequence number of the source and the destination nodes, so that routes information between these nodes can be maintained. Also, RREQ has a field containing the broadcast ID and a counter value. The counting value keeps the count of the number of times requests are generated from a particular node. When a source node broadcast a RREQ to its neighbors it acquires RREP either from its neighbors or that neighbor(s) rebroadcasts RREQ to their neighbors by an increment in the hop counter. If a node receives several route requests from same broadcast ID, it drops repeated route requests to avoid routing loop. RREQ is generated from one source towards different destinations so as to reach a specific destination. If the source node does not receive a RREP, it automatically sets up a reverse routing path to the destination node. A reverse path is obtained only when each node keeps the routing information of its neighbor from which it gets in the RREQ. Reverse path is used to send a reply to the source node if any intermediate node does not satisfy the RREQ. Also, the opposite route is agreed upon only for the specific amount of time. All intermediate nodes stored the particular destination sequence number information make a comparison with the RREQ destination sequence number. If RREQ sequence number is more than or equal to the saved sequence number of the intermediate node, then a RREP is generated and sent to the source node following the same route from the destination node to source node. This method is also known as the forward path discovery [50]. This mechanism allows for route discovery for two nodes seeking to communicate with each other.

- ***AODV Route Table Management****:* In AODV, routing table management is required to avoid those entries of nodes that do not exist in the route path from source to destination at a particular routing instance. Managing routing table information in AODV is carried out with the use of destination sequence numbers. The presence of this management scheme in AODV is crucial in preventing routing loops. The following are the required features needed to maintain the route table for each node:
    - IP address of the particular destination.
    - A total number of hops between a source and a destination node.
    - Next hop: It contains information of the nodes that are used to forward data packets by using the current route.

- Destination sequence numbers.
- Active neighbors: Nodes currently utilizing the active route.
- Expiration time: It contains information for the entire time that route is the best route.

- ***AODV Route Maintenance****:* At the point when hubs in the system distinguish that a course is not substantial any longer for correspondence, it eradicates all the related sections from the steering table for those invalid courses and after that transmit the RREP to its present dynamic neighbors indicating that course is not legitimate any longer for correspondence. AODV keeps up just the circle free courses, when the source hub gets the connection/disconnection warning, it either begins the procedure of rebroadcasting the RREQ or the source hub quits sending information through the invalid course. Besides, AODV utilizes the dynamic neighbor's data to continue following the presently utilized path.
- ***AODV Features****:* AODV reduces few issues that happened in proactive routing conventions. AODV give support by responding at on interest requirements for correspondence for such especially ad-hoc networks with vast quantities of nodes. This can help when a sudden change in topology happens. AODV redesigns the data of dynamic nodes in the routing table. This component can assist keeping up the routing tables with the related number of sections and nodes just have the data of presently dynamic courses for communication. AODV lessens flooding of messages in the system when contrasted with proactive routing conventions so AODV

diminishes the system overhead. AODV likewise minimizes the course repetition and expansive memory necessities. AODV eliminates the loop-free routes by using destination node sequence numbers [50]. In the event that the route gets to be invalid for a specific packet exchange, then the source node resends the RREQ with the more prominent destination sequence number keeping in mind the end goal to reconstruct the route. Another value of AODV is that it utilizes the broadcast route discovery component to control the system overhead. Response to a link failure in the network is also one of the crucial properties of AODV. Link breakage is maintained by keeping the information of the neighbors that are using the currently active route. When link failure happens, neighboring nodes response to affected source nodes for the local movement and provides a fast response for the new route. Another important characteristic of AODV is that it can be applicable for the large scale ad-hoc networks in comparison to proactive and hybrid routing protocols.

- **Dynamic Source Routing (DSR)**: This Routing protocol as in [51], is specially designed for routing in multi-hop wireless ad-hoc networks. DSR consists of two operations Route Discovery and Route Maintenance. These two operations make DSR self-configuring and self-organizing. DSR routing protocol manages the network without any centralized administrator or infrastructure. In DSR, data packets store the routing information of all intermediate nodes in its header to reach a particular destination. Routing information for every source node can then be changed at any time in the network and DSR updates it after every change occurs

[52]. Intermediate routers do not need to have routing information to route the passing traffic, but they save routing information for their future use. The main goal behind the design and development of DSR was to reduce the overhead on the network and produce a self-organizing and a self-configuring routing protocol to support MANETs.

- ***DSR Route Discovery****:* In DSR route discovery, when a node is ready to send a packet to another node it formats the routing information in the header of the packet. The routing information in DSR is in the form of a sequence of nodes. Every node in the network learns this routing information. If no routing information is available, the source node uses the route discovery operation to discover the appropriate route to a particular destination. The whole process to find the route is called route discovery. An example of the route discovery mechanism in DSR routing protocol is shown in Figure 8. The node labeled “A”, starts a discovery process to find the route to node E. So in this example, node A is the initiator of communication and node E is the target. At the beginning of the route discovery process, the initiator sends a discovery request to nodes that are within its communication range.

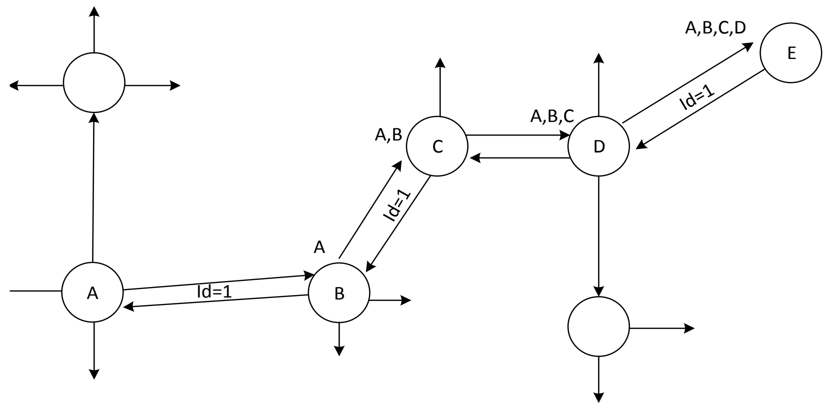


Figure 8 DSR Route Discovery

The discovery request contains the identity of the initiator and target as well as contains the route information. At start, route record is set to null by the initiator. When any node receives the discovery request, it checks the target information. If current node hosting the discovery packet is not the destination or target, it adds its information to the route record and forwards the discovery request to all nodes in its communication range. But when the target node receives the discovery requests it sends the request reply with final route information containing the complete intermediate path. The target node can send the request reply using its route cache or by reversing the order or discovery request. Thus in this way DSR discover the route from source to destination.

- ***DSR Route Maintenance****:* In this routing scheme, when any node sends a packet using source route, it also has the responsibility for its delivery confirmation. If we consider the above scenario again, we can explain route maintenance mechanism as follows; if node A transmits a packet to node E, through nodes B, C and D. Node A will retransmit the packet until it receives a delivery confirmation from packet C. Similarly, like A, node B will retransmit until it receives a confirmation from C, C will retransmit until it receives a confirmation from D and D will retransmit until it receives confirmation from E. This process continues if there are more intermediate nodes until the target node is reached or, the retransmission process continues for a limited number known as the maximum number of attempts. In case, a node retransmits a packet for a maximum number of attempts and there is no acknowledgment received, the node will send an error message to the source node. Then source node can use another route from route cache to send a packet or it can start the route discovery again. This simple mechanism is used in DSR to maintain the routing operation.

- ***DSR Features****:* The two most important features of DSR protocol are route discovery and route maintenance that make this protocol self-configuring and self-maintaining. In DSR protocol, periodic updates about neighbors or link state information are not needed like in some routing schemes. The absence of periodic updates in DSR helps to minimize the overhead transmitted over the network. Hence the operations used in accomplishing routing in DSR are on demand basis [51]. A node may store more than one route to the same destination. In DSR this can be carried out by listening to a passing traffic, or by saving the additional routes during attempts for single route discovery. This feature allows the routing scheme to utilize the cached route in case a particular route breaks down. Hence, there is no need reinitiate a new process of route discovery since alternative routes are already available to the destination [52]. Another important feature of DSR routing protocol is that a packet using this routing protocol can reach its destination even when the intermediate nodes are using different types of network. DSR make it possible for nodes with different network types can participate in ad-hoc networks hence allowing for flexibility in the routing process [52].

3.1.1.3 Hybrid Routing

Hybrid routing combines characteristics of both reactive and proactive routing protocols to make routing more scalable and efficient [53]. Mostly hybrid routing protocols are zone based, i.e. the number of nodes in the network is divided into several clusters or zones to make route discovery and maintenance more reliable for MANET.

- **Zone Routing Protocol (ZRP)**: In [54], they proposed the infamous Zone routing protocol, ZRP. The need for hybrid routing schemes arose to address the deficiencies and limitations of proactive and reactive routing and there is a demand of such protocols that can resolve on-demand route discovery with a limited number of route searches. ZRP limits the scope of proactive routing strategies to neighboring hubs locally, however, ZRP utilizes responsive routing to seek the craved hubs by questioning the particular system hubs in the whole system as opposed to sending the inquiry to every hub in the system. ZRP utilizes intra-zone and inter-zone routing to give adaptable route discovery and route support in numerous situations. Inter-zone routing performs route discovery through responsive routing convention all around, while intra-zone routing, in view of proactive routing, keeps routing data locally inside its own particular routing range [56]. The general norm for ZRP is that it decreases the system overhead that is brought about by proactive routing and it additionally handles the system postpone that is created by receptive routing conventions and performs route discovery more effectively. The main disadvantage of ZRP is that it is not designed for such environments in which the nodes behavior is highly dynamic and rapid changes in topology such as VANET. In other words, we can say that this routing protocol is specifically designed for such networks where nodes are not highly mobile and network size depends on a limited number of nodes. Pure proactive or reactive routing protocols can be suitable to some extent in a highly dynamic environment like VANET as compared to hybrid routing.

3.2 Vehicular Ad-Hoc Network Routing

As discussed in earlier sections, VANETs inherit many characteristics from MANETs. Due to high mobility, continuous topology change and constrained link lifetime possess additionally difficulty in choosing routing protocols [44, 45, 55]. A few different variables such as street design, city or highway environments make routing more challenging in VANETs. In contrast to topology based routing, VANET routing protocols utilize the position of nodes to make routing decisions. In this section, we detail the most commonly reported category of VANET routing protocols, namely position based routing.

- **Position Based Routing**: The dynamic and highly mobile nature of VANET, where nodes move very fast and change their location frequently, require a routing method that can deal with this dynamic network environment. These demands have led some researchers to use positions of network nodes in order to provide successful communication from source to destination. Such methods where geographical positions of network nodes are used to perform data routing from source to destination is called position based routing. Position based routing assumes that each node has knowledge about its physical/geographic position with the help of GPS or by some other position determining services. In these position based schemes, each node also has the knowledge of source, destination, and other neighboring nodes. As compared to topology based routing, position based routing utilizes the additional information of each participating node to accomplish routing decisions. In VANETs, that additional information is gathered through GPS. Position based routing provides hop-by-hop communication to vehicular networks [55]. A position based routing protocol consists of many major components such as beaconing, location service and servers and recovery and forwarding strategies [43].
    - ***Beaconing***: Here, a node forwards a packet with its current geographical position and its unique identity (IP Address). If a node receives a beacon from its neighbor, it then updates its information in a location table. Thus beaconing is used to gather information of node’s one-hop neighbor or node’s next hop neighbor.

- ***Location service and servers****:* When a node does not contain the current physical position of a specific node in its location table or want to know the current physical position of any specific node then a location service is invoked to assist in finding the current position of a particular node [56]. To trace the current physical position of the desired node, the requesting node sends location query with the unique ID of the desired node, sequence number and a total number of hops. The neighbors reply this message until the desired node is found and if the desired node is within the fold of the near neighbors of the requested node then it replies with a packet containing its current geo-position [55]. In this way originating node updates desired node physical position information in the location table.
- ***Forwarding and recovery strategy****:* Forwarding and recovery strategy are used to forward data from source to destination node. Position based routing protocols uses three types of forwarding methods for VANET in order to forward data packets from source to destination [55]:
    - Restricted directional flooding.
    - Hierarchal forwarding.
    - Greedy forwarding.
- ***Restricted directional flooding***: In this method, data packets are sent into the geographical area of the specific node and the part of the geographical area known as the forwarding zone. This method does not require information of neighboring nodes. The forwarding zone is created between source and destination nodes and the source node flood packet into the

forwarding zone so as to send the packets towards the destination. Network overhead might enlarge if a large number of packets are sent to the forwarding zone by source node that may result in expanding the area of forwarding zone. These issues can be overcome by adopting efficient flooding method such as Distance-aware timer-based suppression method [55]. Restricted directed flooding uses broad-based protocols such as the Mobility-centric data dissemination algorithm for vehicular networks (MDDV).

- ***Hierarchal forwarding***: Another forwarding strategy for position-based routing protocols is hierarchal forwarding in which protocols' hierarchy is used to forward data packets. The hierarchal forwarding performs routing for neighboring nodes and also for nodes at greater distances. Forwarding strategy for hierarchy routing use geodesic packet forwarding (GPF) and anchored GPF.
- ***Greedy forwarding***: Another efficient forwarding strategy for position based routing is the greedy forwarding in which a node sends a packet to nodes closest to the destination. The sending node calculates the minimum number of hops for sending a packet to the destination. In the case of a failure, where there is no node closest to the destination, a recovery strategy is used to overcome this kind of situation. Greedy Perimeter Stateless Routing (GPSR) is an example of greedy forwarding strategy.

Unlike topology based routing, position based routing does not require any route maintenance. The route determined only when there is a need for forwarding packet. Another advantage of position based routing is that it contains information of source, destination and their neighboring nodes. The aforementioned characteristics make position based routing suitable for VANET. Several routing protocols have been proposed by many researchers that make use of nodes' position information for routing decisions. Although these routing protocols are most suitable for the vehicular communication, still some challenges exist. We will discuss some of the recently suggested protocols and the issues in these routing protocols. Furthermore, we will also investigate which recent advancement has been carried out to overcome these issues.

3.2.1 Greedy Perimeter Stateless Routing (GPRS)

Greedy Perimeter Stateless Routing (GPSR) [59] is one of the best examples of position based routing. GPSR utilizes nearest neighbor's data of destination while keeping in mind the end goal of forwarding the packet. This strategy is otherwise called voracious sending. In GPSR, every node knows about its current physical location and the position of its neighbors. The information about node positions gives better routing and furthermore gives knowledge about the destination. Then, again neighboring nodes additionally helps to settle on sending choices more effectively without the utilization of the topology data. All data about nodes position is acquired by utilizing GPS gadgets. GPSR convention is typically contrived into two forms; "Greedy forwarding", that sends information to the nearest nodes to the destination and "Perimeter forwarding", that is utilized in areas where there is no nearer node to destination [57]. In other words, perimeter forwarding is used where greedy forwarding fails. Further, we will see in detail how these forwarding strategies work and what their weaknesses are.

- **Greedy Forwarding**: In this sending strategy, information packets know the physical position of their destination. As the originator knows the position of its destination node, the greedy regions/hops are chosen to forward the packets to the nodes that are nearer to their destination. This procedure rehashes until the packet is effectively conveyed to the destination. Closest neighbor's physical position is accumulated by using beaconing calculations or basic signals. At the point when a neighboring node advances packet to the nearer region to the destination, the sending node gets a signal message that contains IP address and position data. At that point, it upgrades its data in the table. On the off chance that sending node does not get reference point from its neighboring node inside a particular time period, it accepts that either neighbor neglects to forward the packet to an area nearer to the destination or the neighbor is not in its radio reach. So it expels its entry from the location table. The significant point of preference of greedy sending is that it holds the current physical position of sending node [59]. Accordingly, by utilizing this procedure, the aggregate separation to destination turns out to be less and packets can be transmitted in a shorter time period. Other than its focal points there are a couple of disadvantages of this methodology; there are a few topologies utilized as a part of it that restrains the packet to move to a particular range or separation from the destination. Likewise, this methodology comes up short when there are no nearer neighbors accessible to the destination.

- **Perimeter Forwarding**: Perimeter forwarding is utilized where greedy forwarding fizzles. It implies that, when there is no next bounce nearest neighbor to the destination then perimeter forwarding is utilized. Perimeter forwarding utilizes nodes as a part of the void regions to forward packets towards the destination. The perimeter forwarding utilizes the right-hand standard. In this run, the void regions are abused by crossing the way in a counterclockwise manner, keeping in mind the end goal to reach a particular destination. At the point when a packet is sent by a source node, this packet is sent in counterclockwise heading including destination node until it again came to at the source node. As per this administer every node included to forward packet around the void district and every edge that is crossed are called perimeter. Edges may cross when the right-hand rule discovers perimeter that is encased in the void by using a heuristic methodology [59]. This heuristic approach likewise has a few downsides in spite of the procurement of a most reach route capacity to the destination. The downside is that it evacuates without thought of those edges which are rehashed and this may bring about system allotments. To evade this disadvantage, another system depicted underneath is used.
- **Planarized Graph**: When two or more edges cross each other in a single graph, the resulting graph is known as the planar graph. Relative Neighborhood Graph (RNG) and Gabriel Graph (GG) [57] are the two types of planar graphs used for the removal of crossing edges. RNG occurs when two edges intersect with a radio range of each other and share the same area. For example, as shown in Figure 9, X and Y are the two edges that share the area of two vertices X and Y. The edges X and Y are removed by using RNG since another edge from X towards V is already

available. GG is used to remove only those crossing edges which are in between the shared area of two nodes having the same diameter as the other nodes have. Figure 10 depicts the Gabriel Graph. Figure 10 shows that the midpoint diameter is less than the diameter of node X or node Y. Thus the edge from the X, Y cannot be removed. So there is less network disconnection in the GG as compared to RNG.

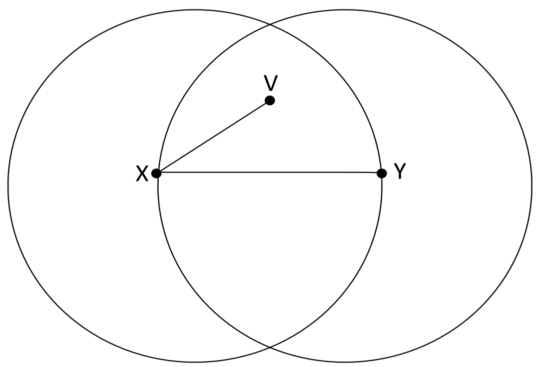


Figure 9 Example of Relative Neighborhood Graph (RNG)

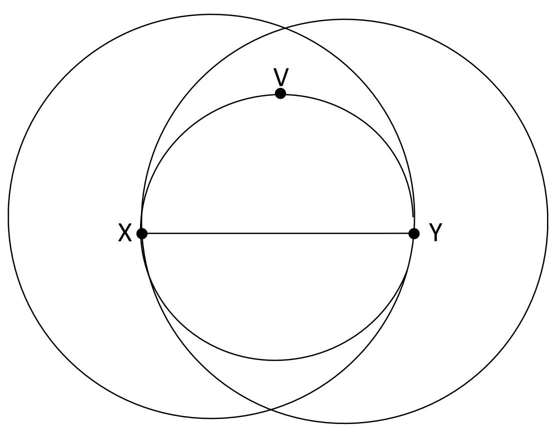


Figure 10 Example of Gabriel Graph (GG)

- **Features of GPSR**: GPSR joins the greedy forwarding with the perimeter forwarding to giving better routing choice on both full and planarized system chart by keeping up neighbor's data in the area table. For the forwarding choices in perimeter mode, GPSR packet header incorporates the following unique attributes [57].
    - GPSR packet header has the flag identity that is utilized to distinguish whether the packet is in greedy forwarding or in perimeter forwarding.
    - It contains destination node physical address.
    - GPSR packet header likewise contains an area of the packet in the perimeter mode and the area of the new face to take a choice whether to hold the packet in the perimeter mode or to return it to the greedy mode.
    - GPSR additionally have the record of sender and beneficiaries address of the packet when the edge's crosses in the new face.

GPSR additionally have a few particular qualities that are, if the packet is in perimeter mode then its area address is contrasted with sent node address and if separation to area and destination node is not as much as packet it changed to greedy mode to forward packet towards the destination. GPSR toss those packets that are over and over sent as a destination for such packets are not in extent. The packets in perimeter mode never send twice through the same connection if the destination is in extent. General GPSR is a productive case of the position based routing that uses the geographic area of nodes and decreased utilization of routing state on every node. Besides this, it gives maximum robustness in exceptionally dynamic wireless ad-hoc networks.

- **Issues in GPSR**: Other than GPSR certain attributes, it experiences a few downsides. Greedy forwarding measured as unacceptable for the vehicular networks where the nodes are very versatile and the node will most likely be unable to keep up its next hop neighbors' data as the other node may have left the wireless communication range because of high mobility. This can lead to information packets loss. The second issue may happen amid beaconing system that references points that may have lost because of channel annihilation or bad signal. This issue can lead to the expulsion of neighbor data from location table. GPSR utilizes planarized charts as its repair system where greedy forwarding comes up short. In any case, these diagrams perform well in the roadway situation because of their distributed calculations. These charts do not perform well in such environments of vehicular communication where a lot of radio snags are found, in addition to this their distributed nature may lead to the partitioning of the network and might make packet conveyance incomprehensible. Consequently, there is need of such position based routing protocols, which blend position data with the road topological structure keeping in mind the end goal to make conceivable vehicular correspondence in in presence of radio obstacles.

3.2.2 Geographic Source Routing (GSR)

Due to deficiencies of GPSR in presence of radio obstacles, network demanded new routing strategies that can compete with challenges occurred due to radio obstacles. Therefore, Geographic Source Routing (GSR) is proposed. It deals with high mobility of nodes on one hand, and on the other hand, it uses road's layout to discover routes. GSR finds the destination node using Reactive Location Service (RLS). GSR combines both geographic routing and road topology knowledge to ensure promising routing in the presence of radio obstacles. In city areas, there are buildings and trees *etc.* that may create problems in direct communication among nodes. Hence, previously proposed protocol GPSR for highways may not perform well in a city environment. The motivation for new routing protocol for the city is stated below in details.

- **Frequently Network disconnection**: Due to building and trees in the city area, pure greedy position-based routing, and its recovery mechanisms do not fully apply [58]. Nodes that can directly connect in free space cannot communicate in city area due to radio obstacles. As greedy position based routing uses the position of the nodes to find destination and planarization methods uses the distance between nodes as a connecting factor, that may not be applicable in the city due to unavailability of direct communication.
- **Multiple hops**: In planarized connectivity, the node sends a packet to neighboring nodes until it reaches its destination. In the city area, planarized connectivity graph can increase delay due to a large number of nodes.
- **Routing Loops**: Routing loops can occur in packets while using perimeter method due to mobility. Participation of a node in the network when the mobility is high can create routing loops. In the city area, when there are many nodes participating in the communication at the same time, there are more chances of routing loops.
- **Incorrect route selection**: In high mobility and excessively numerous hops, perimeter routing strategy can choose a long route utilizing the right-hand rule. The likelihood of selecting expected route is expanded when there is more than one route accessible.

High mobility and the excessively large number of hop in city zones may lead to wrong route choice.

GSR routing was proposed to deal with challenges faced by GPSR in a city environment. There are two main issues in the city environment, one is dealing with high mobility issue in the city and other is topology structure of a city. In GSR, position based routing has been used, that support the city map too. Vehicles have navigation system installed, so getting a map of the city is normal. GSR use reactive location service to find the physical location of the node.

Reactive Location Service (RLS) is used for position discovery in reactive position based routing. In RLS a source node broadcast position request with some identification for the required node. When the node with that identification receives the position request, it responds with position reply containing its current physical position. The sender node reaches the destination by utilizing the road topology map and the above data. At the end of the day, in GSR, the source node finds the briefest way to the destination on the chart utilizing basic diagram calculations and imprint the packet with destination's location. For this situation, the packet heads out through junctions to reach the destination. GSR use to switch back to a greedy method for local recovery. After a packet reaches its local maximum, it switches back to greedy forwarding.

Anchor-based Street and Traffic-Aware Routing (A-STAR) is position based routing protocol. The development of A-STAR was in consideration with city environment. In the city area, almost all roads and streets are covered by big buildings and there are close ends in the streets and so frequent stop signal, turns and speed breakers make routing more challenging [59]. Problems faced by the position based routing protocols in city environment defined earlier in GSR. The capability of A-STAR protocol to overcome these problems will be defined here. A-STAR is anchor based routing protocol. In anchor based routing, before transmitting the packet, source node address is added in the header of packet and information of all intermediate node junction that packet must travel to reach the destination. To use city maps and road information of town, Spatial-Aware Routing is commonly used. Spatial awareness is used to get topology information and different nodes position in the network. Mostly anchor based routing and spatial aware routing used together.

In position based routing, every node sends its current position by beaconing messages and every node knows its neighbor nodes. When a source sends a message to the destination it uses the geographic location of the destination. The challenges in city environment can be better understood by the following example. A source node wants to send a packet to the destination. There are buildings between source and destination and there is no node closer to the destination. Two separate paths are available to the destination; one is shorter than the other. But when this situation occurs in GPSR, it will select the route according to its right-hand rule. So GPSR will not look for the shortest path, it will look for the right-hand rule and the packet will traverse hop-by-hop until it finds a node nearer to the destination. This takes much longer time and processing. The Modus Operandi of the A-STAR is same like GSR, A-STAR was proposed for a city environment. Both GSR and A-STAR compute the number of junctions to reach the destination, but A-STAR additionally utilize movement data and road mindfulness in path discovering [61]. In road awareness, A-STAR gets the grapple data as per the road map. A-STAR has two new elements that make it contrast from GSR in operation. A-STAR utilizes statically and powerfully evaluated maps to locate the number of junctions. In actually appraised maps, A-STAR utilizes timetable of transports to guarantee the high availability e.g. a few roads are served by general city transports their availability can be high because of the nearness of city transports. In powerfully appraised maps, A-STAR gathers the most recent data of movement to discover the grapples/junctions to compute the way e.g. a few roads are more extensive than others so there is more activity. It implies that connection is high on more extensive roads with high activity (more vehicles). Utilizing this activity data, A-Star doles out the weight to the road e.g. more vehicles less weight and fewer vehicles more weight. This dynamic process helps this protocol to calculate anchors more accurately [59].

Both the recovery techniques of GPSR i.e. perimeter mode and GSR i.e. switch back to greedy are deficient in city situations of VANET. A-STAR uses another recovery strategy. At the point when a packet face issues to go from an intersection, that intersection is set apart as "out of administration" so different packets are limited to cross that intersection until that intersection changed to "Operational" state. At the point when any intersection is out of request every node in the system is educated about that intersection and overhauls their routing data and city maps by denoting that put in out of request. In this way, no node will utilize that intersection as a stay to navigate to achieve destination. At the point when the out of request intersection gets to be operational, every node mindful about the utilization of that intersection and may adopt that intersection for forwarding the packet towards the destination. In this way contrasted with other position based routing conventions, A-STAR adopts higher connectivity stay based ways to discover the route towards the destination in expansive city situations.

3.3 Relevant Proposed Studies

A substantial amount of work has been made by researchers to evaluate the effectiveness of VANET using different routing schemes (proactive, reactive or position-based) and the scenario was either city, highway or the sparse environment. Also, some works assume GPS device in each vehicle which somehow a valid assumption nowadays but the results are strongly dependent on the accuracy of the GPS device.

For instance, in [60] the authors describe the use of VADD (Vehicle-Assisted Data Delivery) routing protocol in VANET. It makes use of "carry and forward" strategy in which vehicles carry the packets when there are no routes available to the destination node. This routing protocol suits VANET applications where delay can be tolerated under sparse VANET environment.

The authors in [61] analyzed yet another category of MANET routing protocols namely Distance-based. They used NS2 network simulator and VanetMobiSim as the mobility generator. In addition, they have used the IEEE 802.11p wireless standard for both city and highway scenarios. The accuracy of their results was based on the assumption of a GPS device and an infrastructure support.

Researchers in [62] have performed a VANET simulation study using realistic vehicular traces files. In their work, they showed that the performance of the routing protocols is highly affected by the mobility model. They have used the IEEE 802.11b wireless network technology which was not designed for VANET environments.

Another related work is as described in [63]. In this work, they conducted performance analysis of MANET routing protocols (AODV, DYMO, LAR and DSR) in urban scenarios using their own proposed methodology. In their work they have shown that LAR shows better results under different configurations.

In [64], the authors proposed a geographic routing protocol known as Groovenet. In addition, due to the dynamic topology and fast speed of vehicles in VANET, the authors pointed out that some VANET applications prefer broadcast routing protocol strategy over unicast or multicast strategy.

Also in [65] the authors presented a performance comparison between reactive routing protocol (AODV) and hybrid routing protocol (GRP) using the IEEE 802.11n wireless standard and OPNET simulator. In their work, they showed that GRP outperforms AODV under dense population of nodes.

To the best of our knowledge, no attempt has been made to present a simulation study on the use of MANET routing protocols in VANET using the latest IEEE 802.11p wireless technology in a multi-hop networks, considering the case of a highway scenario as being presented in this paper—especially studying the impact of varying key system parameters. MANET routing protocols were inherently not designed to cope with the dynamic nature of VANET, and with some modifications and an assumption of a GPS device could yield promising results.

Our work will also aid system designers and researchers to develop practical applications while satisfying the requirements and the constraints of MANET routing protocols.

3.4 Summary

Despite the different categorization of routing protocols in Ad-hoc wireless networks, in this chapter we mainly focus on MANET (Topology Based) and VANET routing protocols. The rationale behind selecting MANET is that VANET is a subclass of MANET with many similar characteristics being inherited. However, VANETs have some unique characteristics such as fast speed of nodes and frequent topology change that distinguished it from MANET.

MANET routing protocols are mainly classified into proactive (table driven), reactive (on-demand) and hybrid. Proactive routing protocols are based on Distance-Vector and Link state routing methods. In this case, every node has information about its neighboring nodes saved in tables. It has a good startup time due to updated tables maintained at each node. The main drawback is the periodic updates that affect the network bandwidth. DSDV is considered as pure proactive and many other flavors have been proposed to reduce the periodic updates and enhance bandwidth. They are not suitable for large-scale network size

Reactive routing protocols, on the other hand, are designed to support large scale network size in a highly dynamic environment. In this case, unlike periodic updates of proactive routing, the update is on demand i.e. whenever the node wants to send data to the destination, discovery process takes place to figure out the route to the destination. Pure reactive protocols such as AODV and DSR are best suited for large-scale networks despite the high startup time during route discovery prior to sending data to the destination.

Hybrid routing protocols tried to solve the issues of both proactive and reactive routing protocols by using different zones. Within the zone, it makes use of proactive routing due to the small scale of the zone and across zones, it uses reactive routing. The main issue with this routing is the clustering of zones and their size.

The second category of routing protocols that we have addressed in this chapter is the VANET routing protocols. More specifically, we focused on the commonly used routing protocols category namely Position based routing. Two prominent proposed routing protocols that fall under this category are GPSR and GSR. Unlike topology based routing, position based routing uses the real-time location of nodes (with the help of GPS) to make its routing decisions in VANET. Although these routing protocols seem ideal for VANET, there are still some issues regarding the accuracy of the GPS and the environment such as city or highway.

GPSR uses a greedy forwarding technique to forward packets to the closest node to the destination. In case no node closest to the destination found, then it uses perimeter forwarding using right-hand rule to reach the destination. Some of the issues that still need to be enhanced are multiple hops, routing loops, routing decisions in a city environment.

GSR is yet another position based routing protocol that combines node positions and road topological information to make its routing decisions. Unlike GPSR, GSR collect information about node locations using Reactive location services (RLS) and then this along with geographic maps of streets layout are used to locate the destination. Thus, many issues exist in position based routing and need testing in different VANET environment before being nominated as reliable routing protocols. On the other hand, MANET routing protocols are well established and tested as well as being approved by IETF for deployment by many network simulators.

CHAPTER 4

PERFORMANCE EVALUATION OF ROUTING PROTOCOLS

Efficient communication between vehicles in VANET mainly depends on the performance of its underlying network routing protocols. Many routing protocols have been proposed in the literature for VANET such as topology based, position based etc., but their performance depends on the scenario (city or highway) and the need of the application in terms of throughput, delay and packet loss. Also, some researchers assume GPS device in each vehicle which is somehow a valid assumption nowadays but the results are strongly dependent on the accuracy of the GPS device. Thus, there is no single routing protocol that can fit and handle all the dynamics of VANET, and the selection of the best routing protocol depends on the scenario and application requirements. In this chapter, first, we present a detailed performance evaluation of using MANET routing protocols in VANET environment. Secondly, we present a multihop performance evaluation of MANET routing protocols to give insight into how far the online gaming can go within its bound constraints. These performance evaluations have been conducted to fulfill our research objective of selecting the best MANET routing protocol in a VANET highway scenario within the constraints of real-time applications such as online gaming.

4.1 Performance Evaluation of MANET Routing in VANET

In this work, we have decided to use MANET routing protocols because VANET inherits many characteristics from MANET. In addition, these protocols are matured enough, being tested for different environments, approved by IETF (Internet Engineering Task Force) and ease of availability of its source code by most of the VANET and network simulators. Here we present a detailed performance evaluation of using MANET routing protocols (AODV, DSDV, and DSR) in VANET and select the best one that suits the requirement of online gaming in terms of delay and packet loss percentage.

4.1.1 Simulation tool

In this work, we have used NCTUns (National Chiao Tung University Network Simulator) version 6.0 which is considered as both a network simulator and mobility generator in one single package. In contrast to other simulators, which usually connect the mobility generators and the network simulation in a loosely coupled manner such as NS2/NS3, NCTUns integrates tightly the simulations of a road network (mobility generator) and a communication network simulator. It is a GUI based high-fidelity network and traffic simulator and emulator capable of drawing network topologies, configuring protocol modules in a node, movement of mobile nodes, plotting network performance graphs, constructing road structure and animation view of the data transmission during simulation. It uses a novel kernel re-entering simulation methodology, which means that it directly uses the real-life Linux's TCP/IP protocol stack to generate high-fidelity simulation results, instead of simulating the whole stack. NCTUns is an open source architecture that helps developers to create their own protocols and test it easily. NCTUns 6.0 is currently supported by Linux Red Hat with the flavor fedora 12 and this simulator is purely written in C++. NCTUns 6.0 is the last non-commercial version released in 2010 after that due to its success and award-winning title in network simulators, it has become a commercial simulator since 2012 and licensed under EstiNet Software Company. Statistics indicate that more than 16,164 people around the world have used NCTUns 6.0 software since its first public release 2010. Some features of NCTUns 6.0 are as follows:

- High-Fidelity Results.
- It uses real-life application programs.
- It can be switched into an emulator.
- Repeatable and faster simulation results.
- Highly integrated GUI environment.
- Full support for VANET and the IEEE 802.11p standards.
- Provides maximum support for wired and wireless networks such as (optical, mobile, WiMAX, satellite etc.

NCTUns supports various VANET standards i.e. IEEE 802.11(a/b/p) to allow V2V and V2I communication in the Intelligent Transportation System (ITS). Many other simulation tools like NS2/NS3, OPNET, OMNET++, TRANS etc. are available in the market but we have decided to choose NCTUns because of its full support for VANET, and the tight integration between both the mobility generator and the network simulator, as well as it's easy to use GUI interface for changing parameters.

4.1.2 Simulation setup

To evaluate the performance of MANET routing protocols in VANET we have considered a real-world scenario of a highway road network between Dammam and Riyadh in Kingdom of Saudi Arabia (KSA). The reason for choosing a highway scenario was because we proposed our online gaming for highway scenario in which a group of vehicles is moving towards their common destination. Also in this scenario, the connectivity between vehicles could be maintained if drivers adjust their speed or through cruise control. As shown in Figure 11, the road design consists of four lanes in each direction with two traffic lights on either side. The highway is deployed with varying vehicle density with each equipped with a wireless technology (802.11p standard) moving with different node speeds. To reflect realistic mobility, vehicles move in a restricted pattern alone road design captured from Google map and follow the traffic rules of the speed limit, traffic lights, and lane-switch. Vehicles travel a distance of 3600 meters and use V2V with multi-hop data forwarding to reach their destination. Seven road side units (RSUs) have been deployed along the road design to reflect the infrastructure support. The detailed simulation parameters used in our study are listed in Table 5.

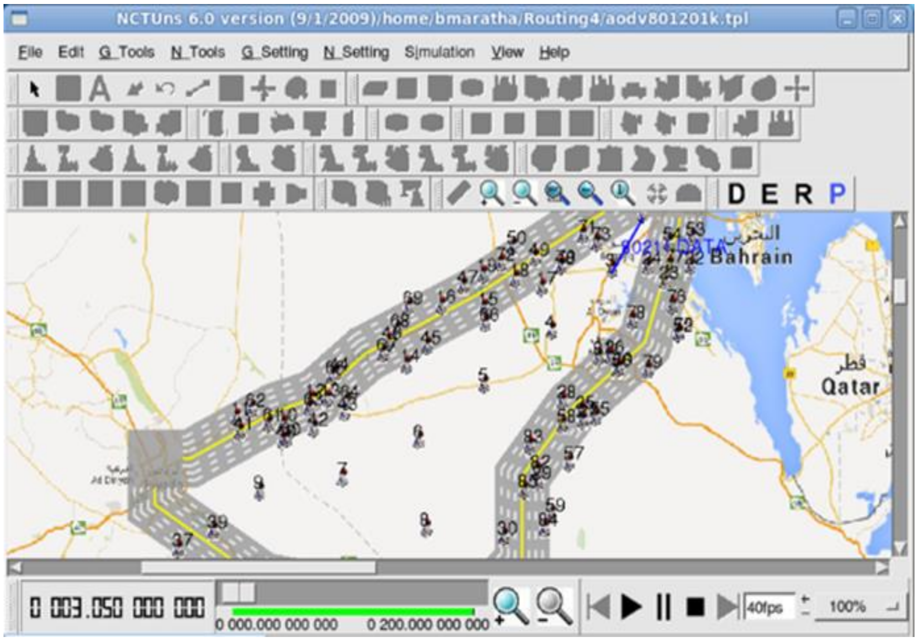


Figure 11 Real-World Highway Road Scenario

Table 5 Simulation Parameterization

Parameter	Value
Simulator Name	NCTUns 6.0
Simulation time	200 s
Routing Protocols	AODV, DSDV, DSR
Simulation Distance	3600 m
Number of vehicles	30, 50, 80
Speed of vehicles	80, 100, 120 Km/h
Transport protocol	UDP
Packet size	1KB to 10KB
Vehicle type	802.11p (Agent Controlled)
Data rate	6, 11, 27 Mbps
Propagation Model	Two-Ray Ground/Free Space.
Fading effect	Rayleigh, Ricean
Transmission Range	550m
Road type	4 Lane per direction
Traffic Lights	2
Road Side Units	7

The simulation was setup to evaluate the performance of the MANET routing protocols (AODV, DSDV and DSR) under varying vehicle speed (80, 100 and 120 Km/h), node density (30, 50, 80), data rates (6, 11, 27Mbps) with multi-hop forwarding, and different propagation models (Two Ray ground, Free space and shadowing) and fading effects (Rayleigh and Ricean). These routing protocols are already implemented in NCTUns 6.0 simulator with source code available in C++ programming language for modifications. The performance of the routing protocols was measured with respect to key metrics which include the throughput, packet drops, packet collisions and end to end delay. Each scenario was run for a simulation period of 200s and the trace and log files are analyzed and recorded. The simulation period was good enough to show the dynamics of the selected routing protocols.

The configuration parameters have been carefully selected to reflect real-world scenarios. For example, the speed of the vehicles has been varied to reflect the actual speed of vehicles in a real highway road which is usually 120 Km/h. Also, the payload size has been selected wisely to incorporate simple chatting applications as well as a more complex gaming and multimedia applications. In addition, the reason for selecting data rates of 6, 11 and 27 Mbps was first, to analyze how routing protocols will behave under different data rates (bandwidth usage, drop packets, etc.) and secondly to compare it with the old 802.11a/b technologies. The maximum data rate for 802.11p is 27 Mbps while for 802.11b is 11Mbps. The data rate for the 802.11p standard can be adjusted as per the application requirement and environment conditions. Lower data rates represent dense vehicle population in which there are many routes available to reach the destination. Higher data rates represent the sparse environment in which the chances for other routes are very low and whenever there is a route, data should be sent very fast with the highest data rate.

4.1.3 Vehicles Profiles

In NCTUns 6.0 simulator, each vehicle can be configured with different auto-driving behaviors. These driving behaviors are defined by a Car Profile which may include some characteristics such as Maximum speed, Maximum acceleration, Maximum deceleration, etc. The vehicles are mapped to these Car Profiles either manually or randomly. In NCTUns version 6.0, only five Car Profiles are provided for mapping and one can specify what percentage of vehicles should use a given Car Profile. To reflect real-world scenarios in terms of mobility of vehicles, different driver behaviors were introduced via Car Profiles. In our simulation study, 20% of vehicles randomly used Profile1 and another 20% of vehicles used Profile 2 and so on. As shown in Table 6, to reflect vehicle speed of 80 Km/h, the five profiles were configured as such: (Profile1=12m/s, Profile2=13m/s, Profile3=14m/s, Profile4=15m/s, Profile5=16m/s). The experiment was run for ten times with different Car Profiles randomly and the average metrics were reported. The reason for running the experiment ten times was to avoid any bias in mobility of vehicles and reflect the different behavior's that driver may demonstration on road. The main concern was how to reflect a vehicle mobility from both macroscopic and microscopic point of view that closely resembles real-world scenarios. The use of a single road design has no much effect on the results because, in a highway scenario, vehicles usually move at speed of 100 -120 Km/h and mostly in straight lines, what really matters here is the speed, node density, driver behavior, etc.

Table 6 Vehicles Profile

Profiles	Max. Speed(m/s)	Max. Acceleration(m/s^2)	Max. Deceleration(m/s^2)
Profile 1	12/26/31	1	4
Profile 2	13/27/32	3	5
Profile 3	14/28/33	10	3
Profile 4	15/29/34	3	1
Profile 5	16/30/35	10	20

4.1.4 Evaluated Metrics

NCTUns 6.0 simulator outputs the results in trace files. We have used AWK script language and excel formulas to compute the average results for throughput, packet loss, and end-to-end delay. The average results for these performance measures were computed according to the following formulas:

$$Throughput(t) = \frac{Number\ of\ \ received\ bits(t)}{t} \qquad (1)$$

$$E2E = \frac{\sum_{j \in received\ \ pkts} (recieved\_array[j] - sent\_array[j])}{Number\ of\ \ received\ \ packets} \qquad (2)$$

$$Packet\ lost = No.of\ \ pkt\ sent - No.of\ \ pkt\ recieved \qquad (3)$$

4.1.5 Simulation Results

In this section, we report and discuss the simulation results and graphs obtained from NCTUns 6.0 simulator. The results are primarily reported for the key performance metrics of average throughput, packet loss, the number of packet collisions, and average end-to-end delay. Figure 12, Figure 13 and Figure 14, depicts the effect of varying vehicles speed on the performance of the routing protocols in terms of throughput, packet drops, and packet collisions. We have deployed 30 vehicles moving at average speeds of 80/100/120 Km/h with a default data rate of 11Mbps and a payload size of 1KB. In terms of throughput, DSDV routing protocol shows better performance than AODV and DSR for the whole simulation time of 200s. Also, it is observed that DSDV has fewer disconnections compared to AODV and DSR. The reason for that is due to the routing table maintained in each node by sending periodic hello packets. Thus whenever there is a better path from source to the destination it will be picked up immediately without waiting for a source to disconnect from a selected path first. DSDV shows slight fluctuation in the results compared to AODV and DSR which are almost stable. The packet drop and collision for DSDV are much higher compared to AODV and DSR due to the periodic updates. It is usually expected that when the speed of the vehicle increases, the chances of getting disconnected becomes higher, and consequently will increase the packet drops. In fact, increasing the speed of vehicle sometimes enhances the drop because it may catch the platoon and have better node density around it. Thus, in our results, there is a variation in packet drops with respect to vehicles speed and lower node density distribution.

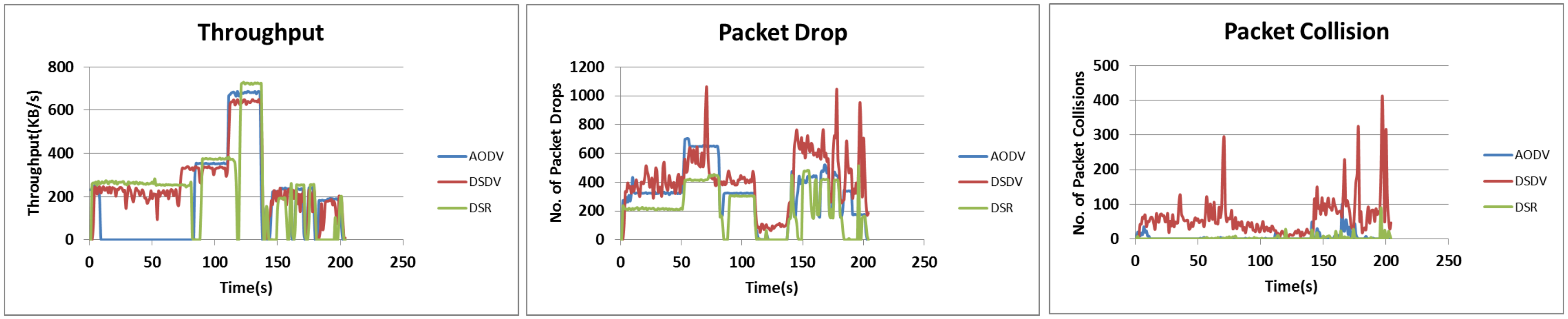


Figure 12 Effect of varying speed with nodes=30 and speed=80Km/h

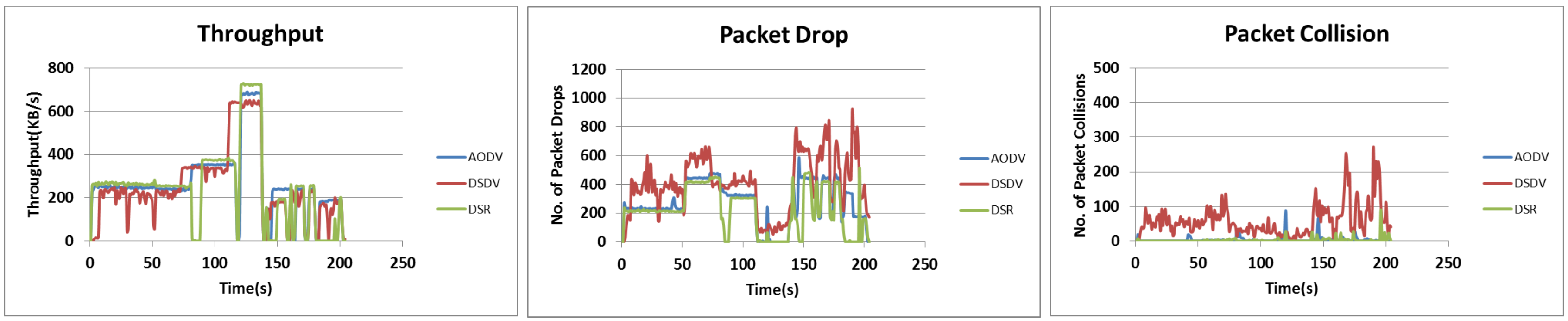


Figure 13 Effect of varying speed with nodes=30 and speed=100Km/h

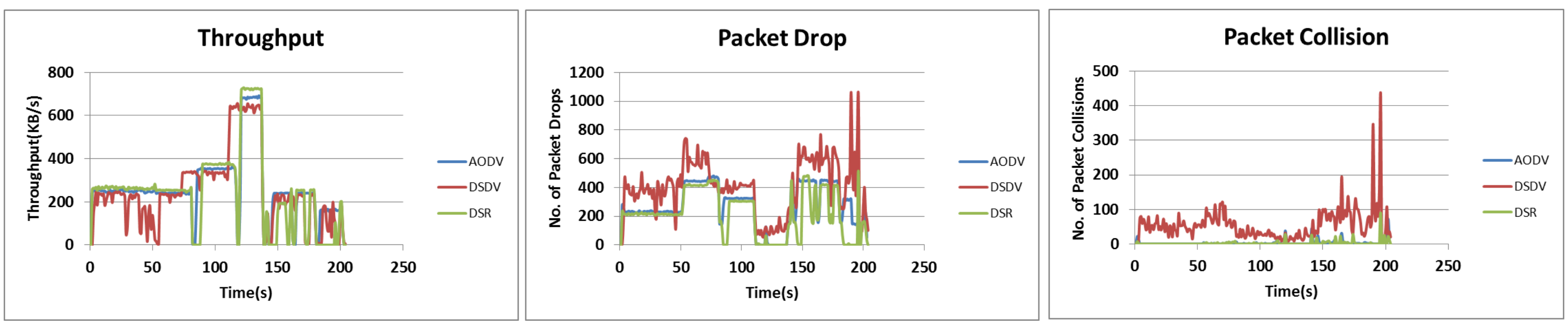


Figure 14 Effect of varying speed with nodes=30 and speed=120Km/h

Figure 15, Figure 16 and Figure 17, shows the effect of varying vehicles speed on the performance of routing protocols but with 50 vehicles deployed. Here the effect of fast vehicles speed increases the probability of getting disconnected very fast and consequently try to hook up with other vehicles. Due to this reason we see a lot of fluctuation of DSDV in terms of throughput compared with AODV and DSR which are more stable. AODV and DSR perform better than DSDV in terms of packet drop and collision and this is due to the periodic updates that have increased with node density. As mentioned earlier, the effect of vehicle speed on packet drops is dynamic, sometimes it increases the packet drops due to lack of sufficient intermediate nodes or picking nodes in the opposite direction, and sometimes decreases the packet drop by picking up better routes.

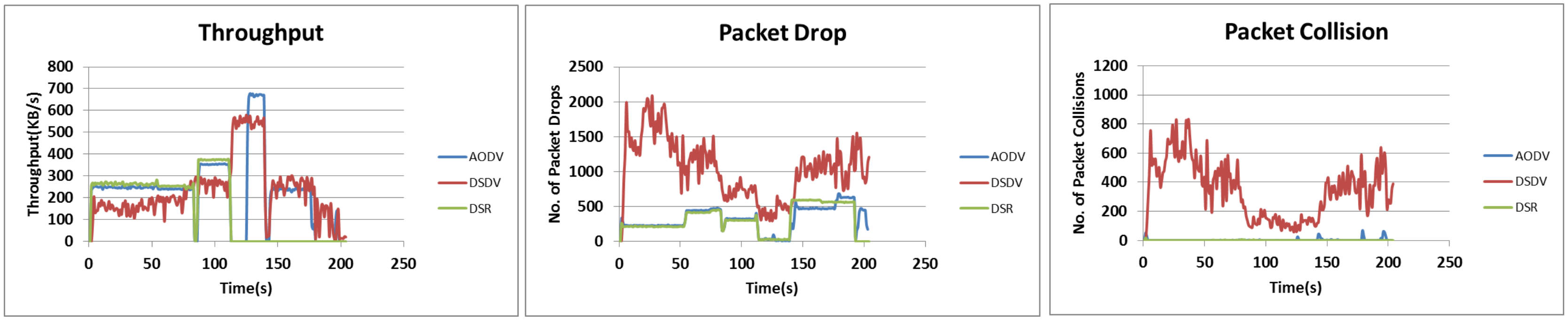


Figure 15 Effect of varying speed with nodes=50 and speed=80Km/h

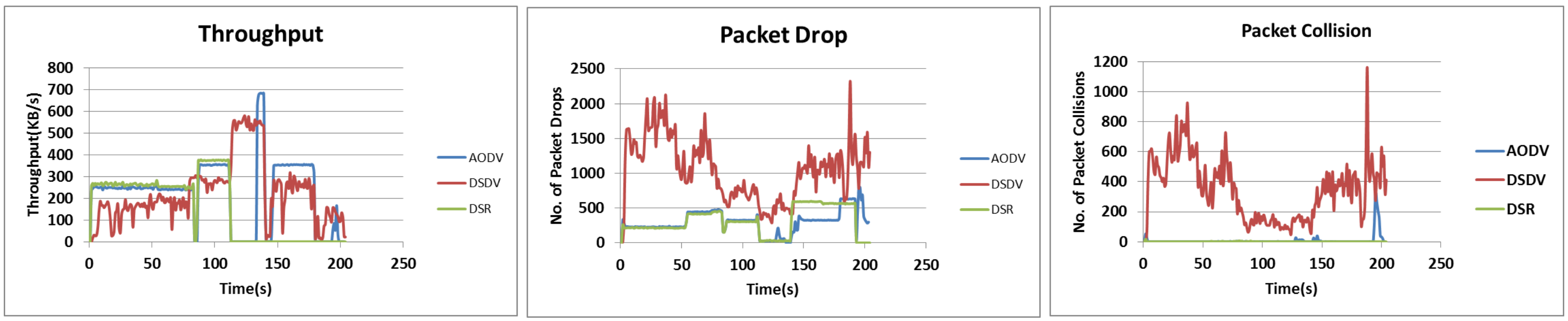


Figure 16 Effect of varying speed with nodes=50 and speed=100Km/h

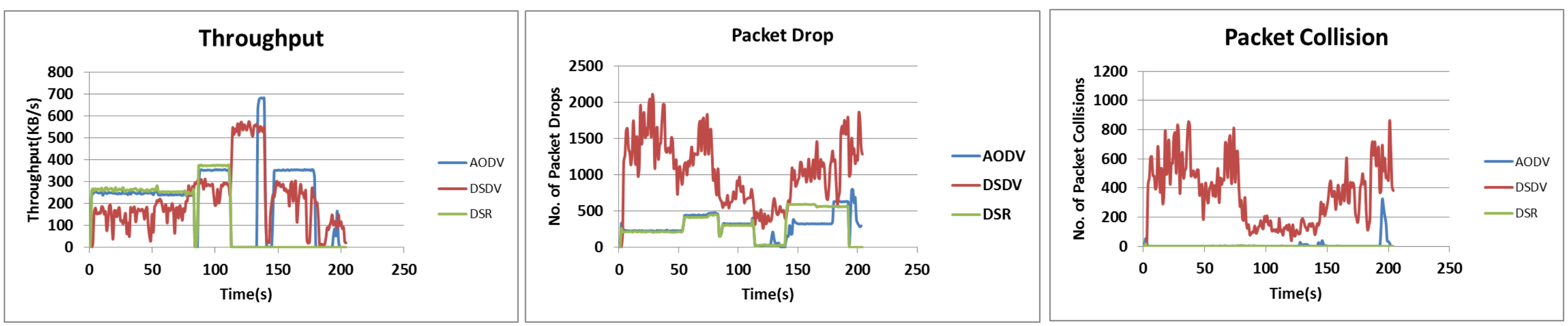


Figure 17 Effect of varying speed with nodes=50 and speed=120Km/h

The last effect of varying vehicles speeds on the performance of routing protocols but with 80 vehicles deployed are illustrated in Figure 18, Figure 19 and Figure 20. Here the connectivity of AODV protocol has enhanced due to the availability of intermediate notes and it shows fewer disconnections compared with the low vehicle density scenarios. The packet drops and collisions of DSDV is worst compared to both AODV and DSR due to the periodic updates, which has increased drastically for node density of 80 vehicles. Also, there is a no much enhancement in packet drop for both AODV and DSR with respect to vehicle speed, because the distribution of nodes did not help to select better routes and keeps using the same routing path.

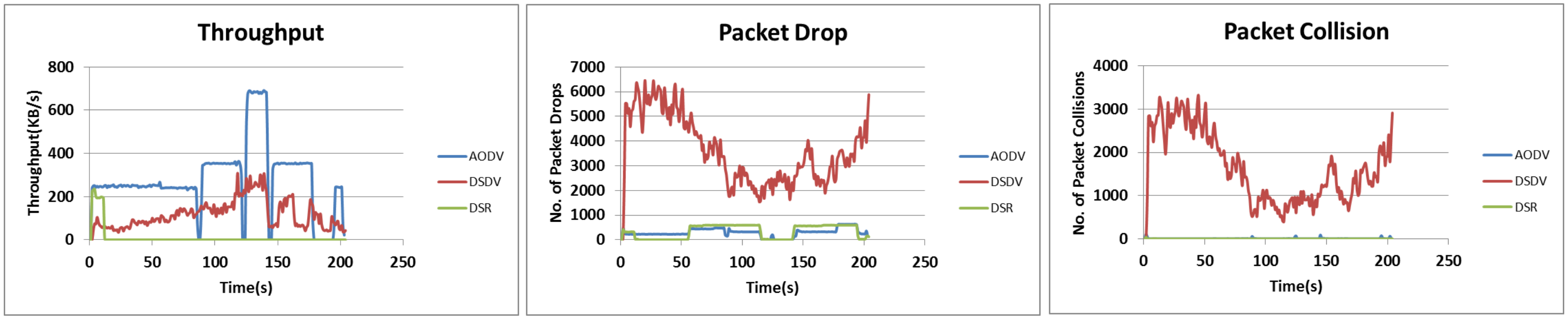


Figure 18 Effect of varying speed with nodes=80 and speed=80Km/h

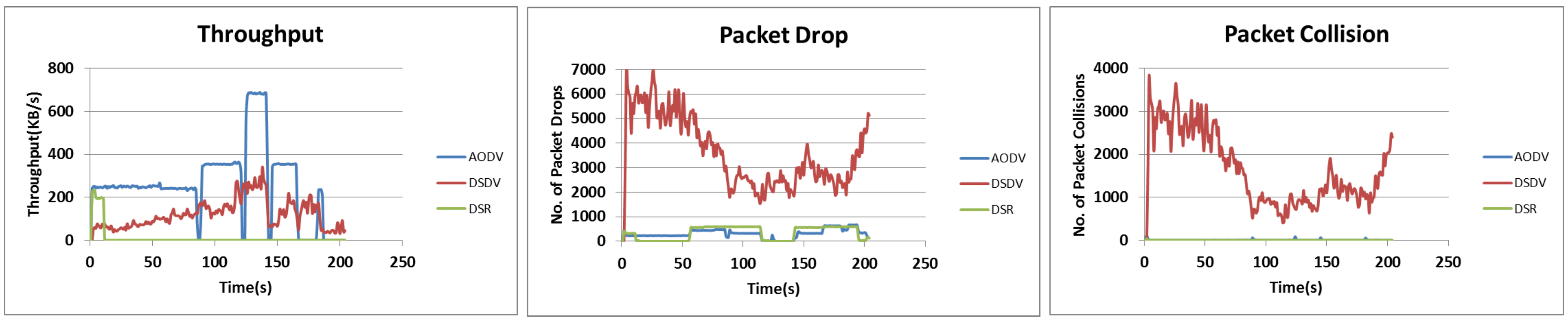


Figure 19 Effect of varying speed with nodes=80 and speed=100Km/h

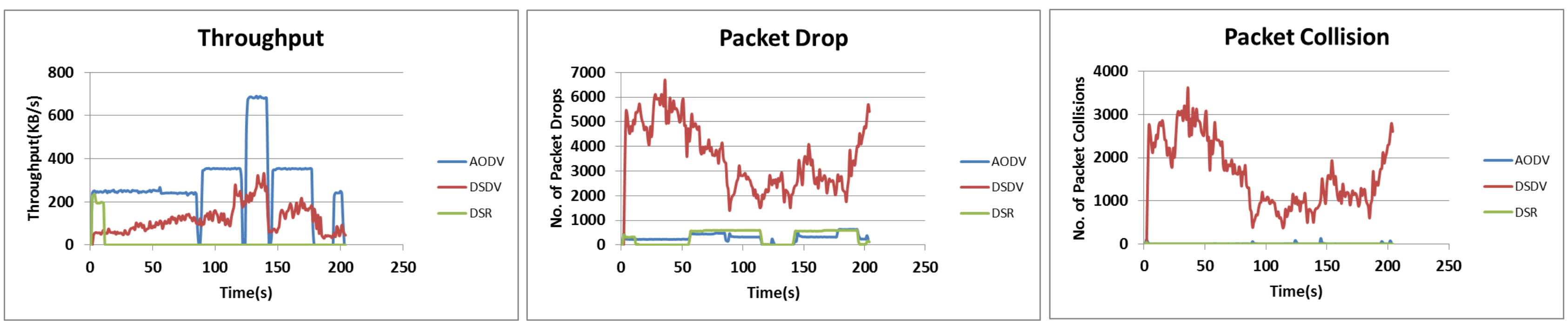


Figure 20 Effect of varying speed with nodes=80 and speed=120Km/h

Figure 21, Figure 22 and Figure 23 demonstrates the effect of increasing the node density from 30 to 80 nodes while keeping the average speed at 80Km/h with a default data rate of 11Mbps and a payload size of 1KB. For lower vehicles density of 30 and 50 vehicles, DSDV outperforms both AODV and DSR in terms of throughput with some fluctuation in its output. But as the vehicles density increases from 30 to 50 nodes, the period update overhead of DSDV start affecting its performance in terms of packet drop and collisions while for AODV and DSR it's being enhanced. For higher node density of 80 nodes, in terms of throughput AODV outperforms both DSDV and DSR. Here DSDV is heavily affected by node density compared to AODV, but DSR gives the worst performance for throughput. This can be attributed to the fact that the source node is the only node responsible for sending the data and these losses good opportunities while trying to get to the source node. For higher node density, DSDV yields the worst performance in terms of packet drop and collisions. This can be attributed again to the periodic updates. Also it has been noted that, there is a slight enhancement in packet drop for both AODV and DSR due to the increase in the probability of finding better intermediate nodes for routing.

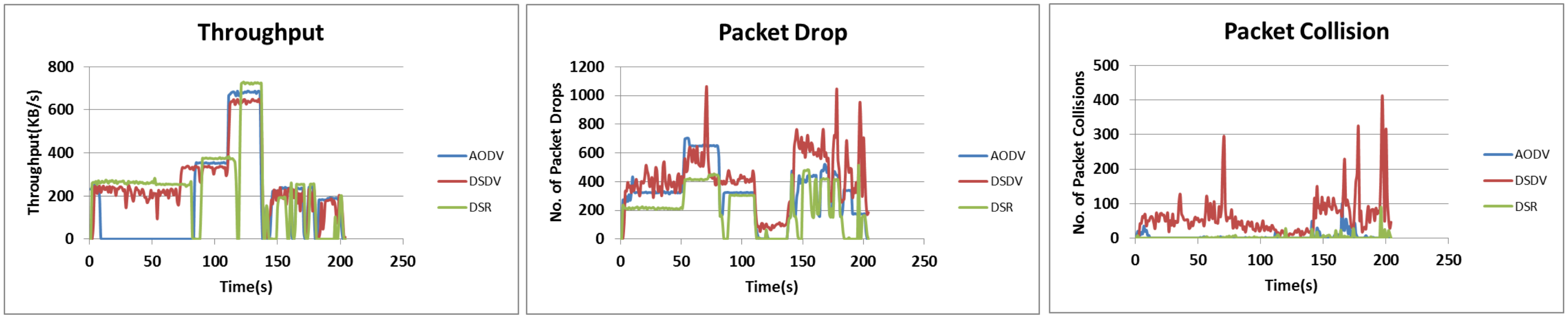


Figure 21 Effect of vehicle density with nodes=30 and speed=80Km/h

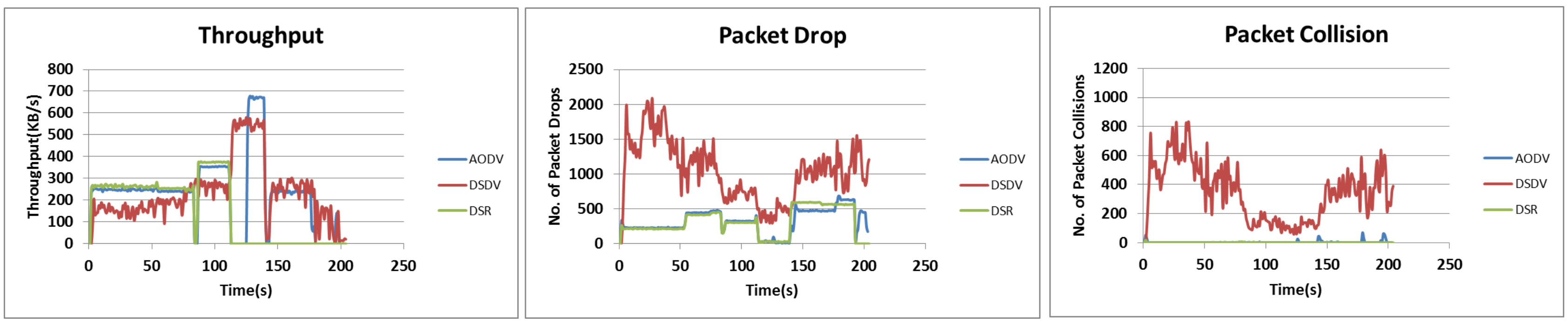


Figure 22 Effect of vehicle density with nodes=50 and speed=80Km/h

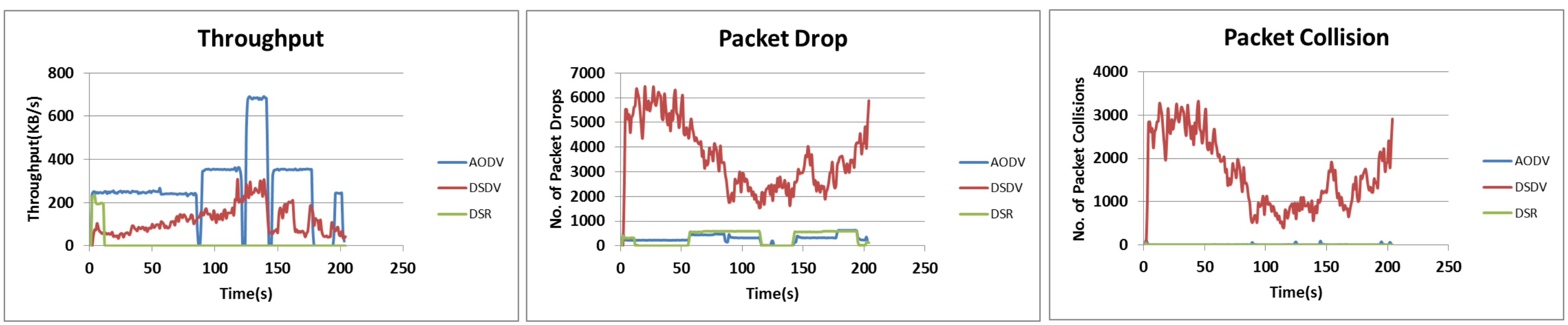


Figure 23 Effect of vehicle density with nodes=80 and speed=80Km/h

Figure 24, Figure 25 and Figure 26, shows the effect of node density at a vehicle speed of 100Km/h. For the throughput, no much noticeable change has occur compared to a vehicle speed of 80Km/h, with DSDV performing better at lower node density and worst at higher node density. At higher node density, AODV slightly outperforms DSR in terms of throughput. Again, DSDV is worst in terms of packet drops and collisions compared to both AODV and DSR which is attributed to the periodic updates. The packet drops of AODV and DSR were slightly enhanced due to finding better intermediate routing paths.

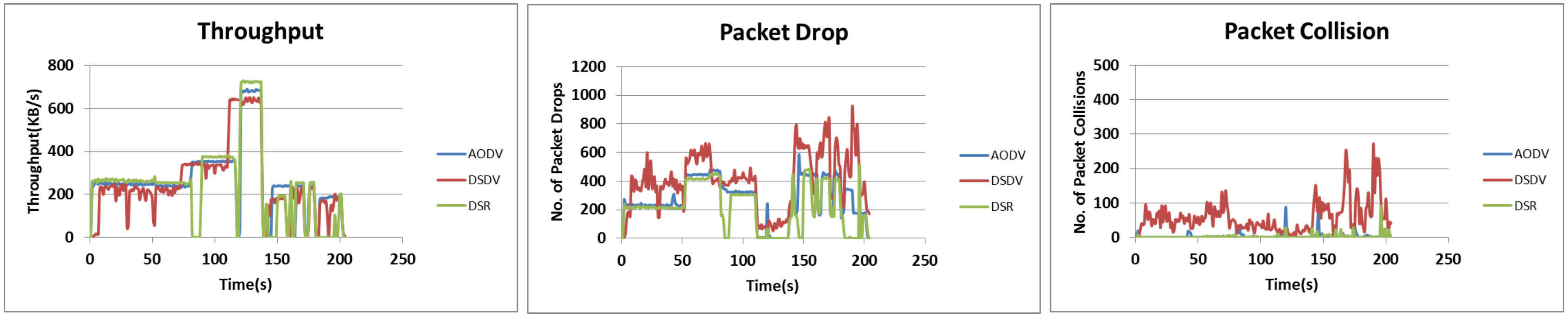


Figure 24 Effect of vehicle density with nodes=30 and speed=100Km/h

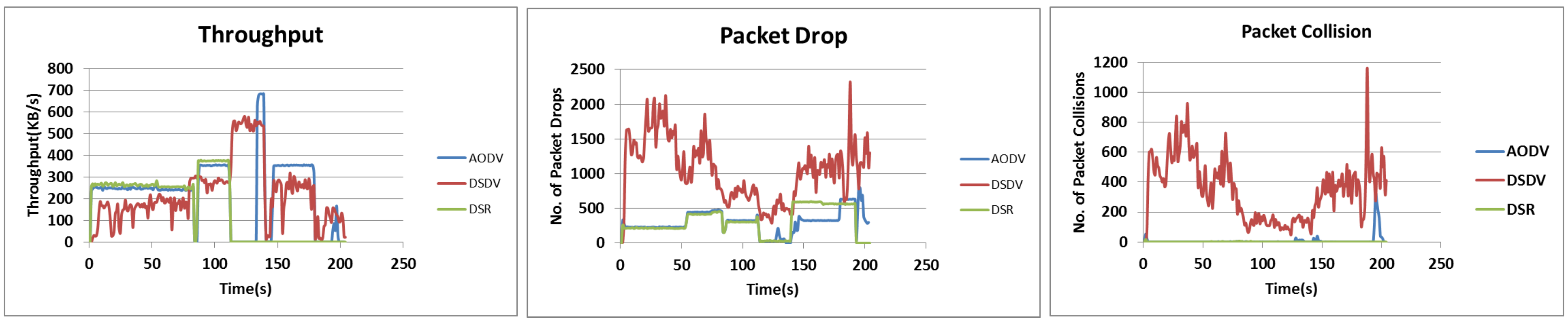


Figure 25 Effect of vehicle density with nodes=50 and speed=100Km/h

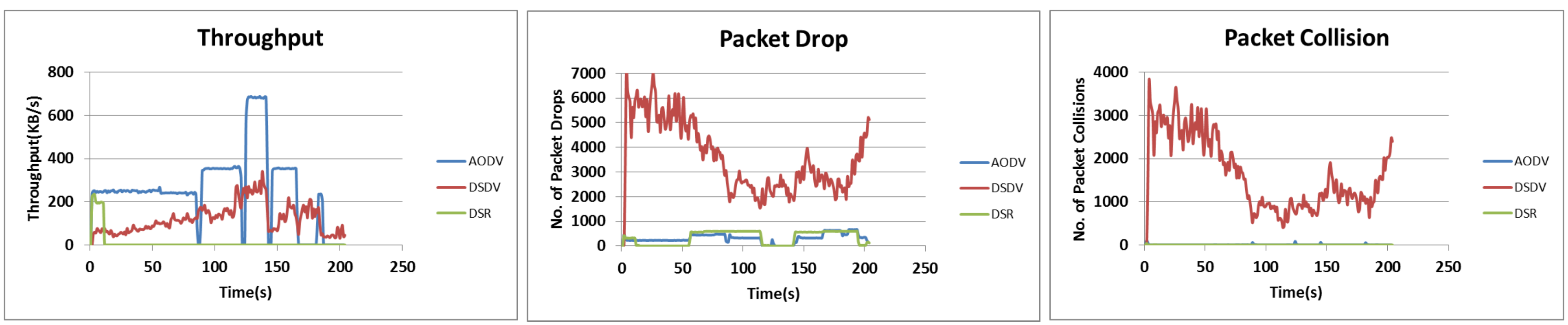


Figure 26 Effect of vehicle density with nodes=80 and speed=100Km/h

Figure 27, Figure 28 and Figure 29, shows the effect of node density at a vehicle speed of 120Km/h. It has been noticed that by increasing the speed from 80 to 120Km/h, a lot of disconnection takes place for node density of 30, but it has improved as the node density is raised to 80. With the increase in node density, DSDV shows worst performance in terms of packet drops and collisions, while AODV and DSR getting enhanced.

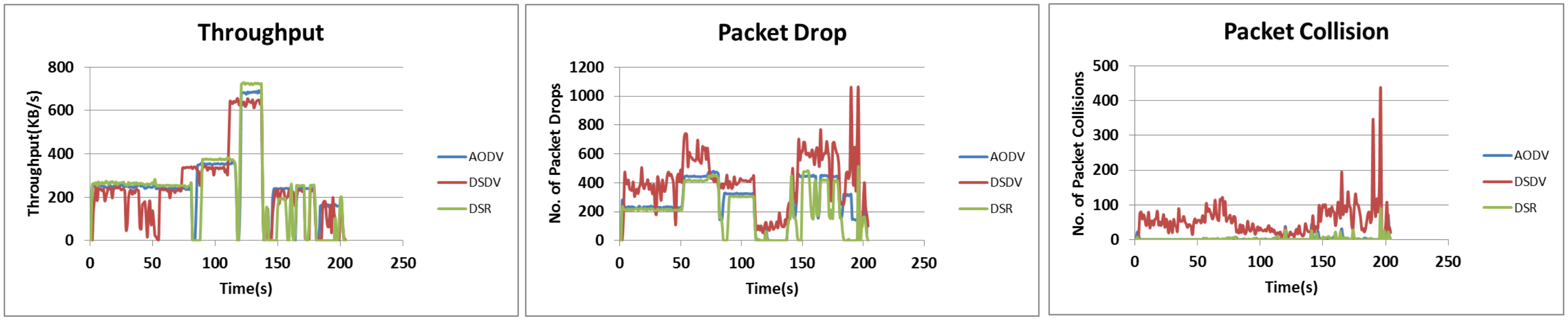


Figure 27 Effect of vehicle density with nodes=30 and speed=120Km/h

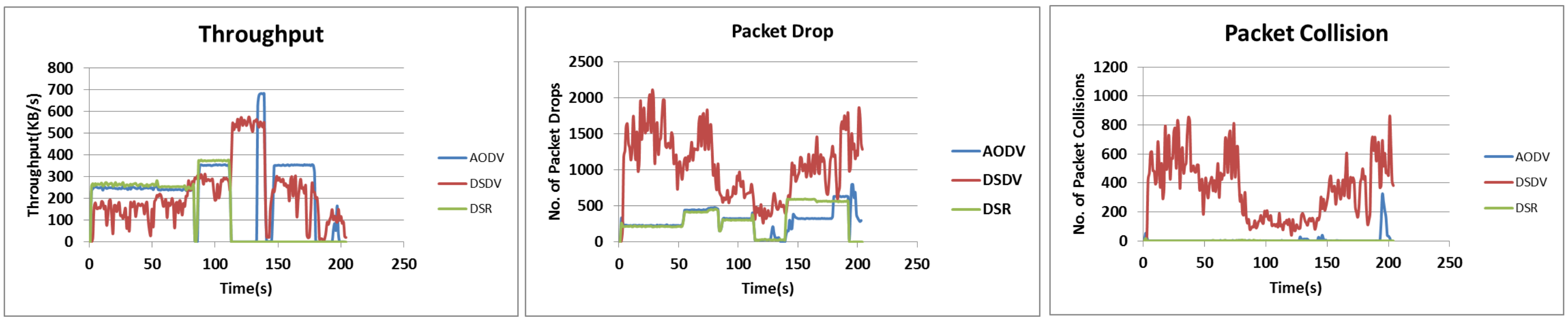


Figure 28 Effect of vehicle density with nodes=50 and speed=120Km/h

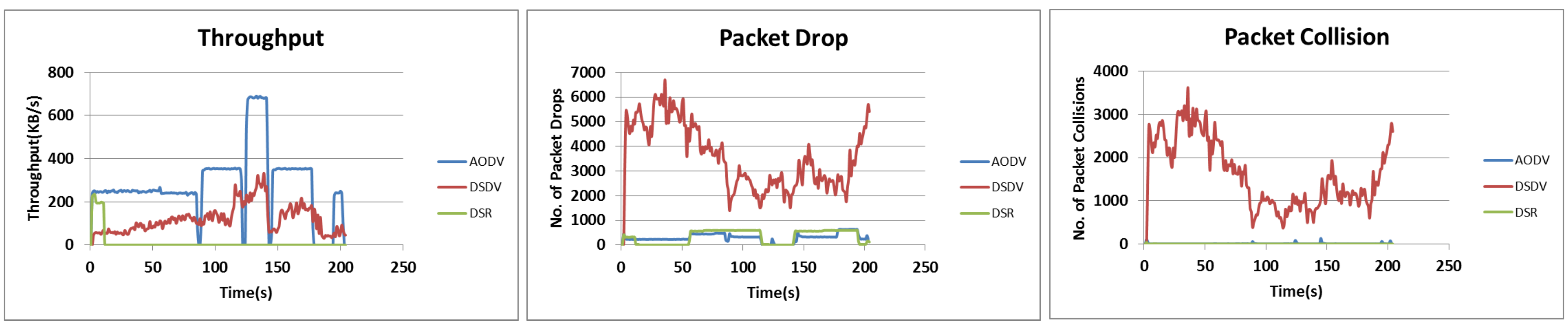


Figure 29 Effect of vehicle density with nodes=80 and speed=120Km/h

Figure 30, Figure 31 and Figure 32, demonstrates the effect of using different data rates (6/11/27) Mbps on the performance of routing protocols at node density of 50 and speed of 120Km/h. Increasing the data rate from 6Mbps to 27Mbps has increased the throughput of all routing protocols, while DSDV still worst in terms of packet drop and collisions. Also, the packet drop and collision of DSR are showing better performance than AODV. A remarkable increase in throughput has been noticed by increasing the data rate to its maximum (27Mbps) for the IEEE 802.11p standard. Very slight increase has been observed in packet drop and collision when compared to data rates of 6 and 11Mbps, and this is attributed to the buffer size that cannot cope with fast data rate of 27Mbps and hence some packets has been dropped.

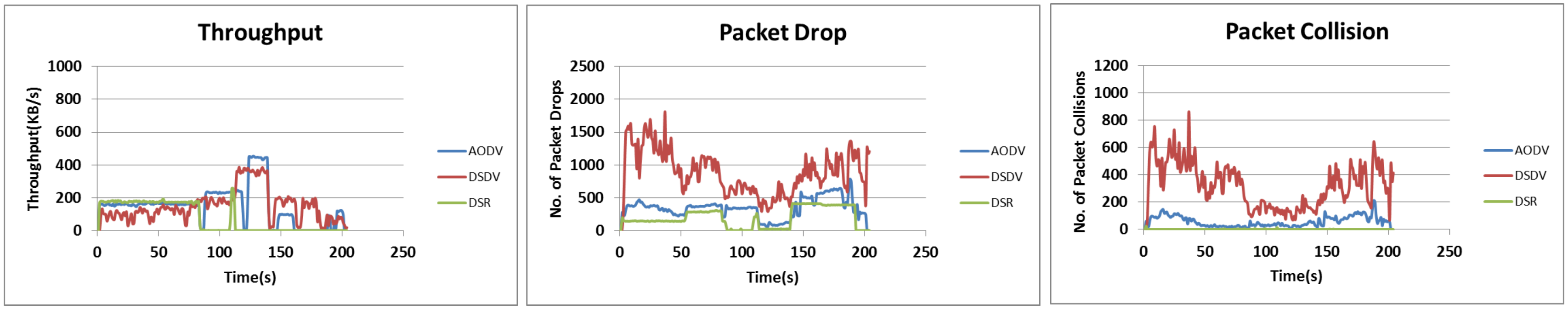


Figure 30 Effect of data rate with nodes=50, speed=120Km/h and data rate=6Mbps

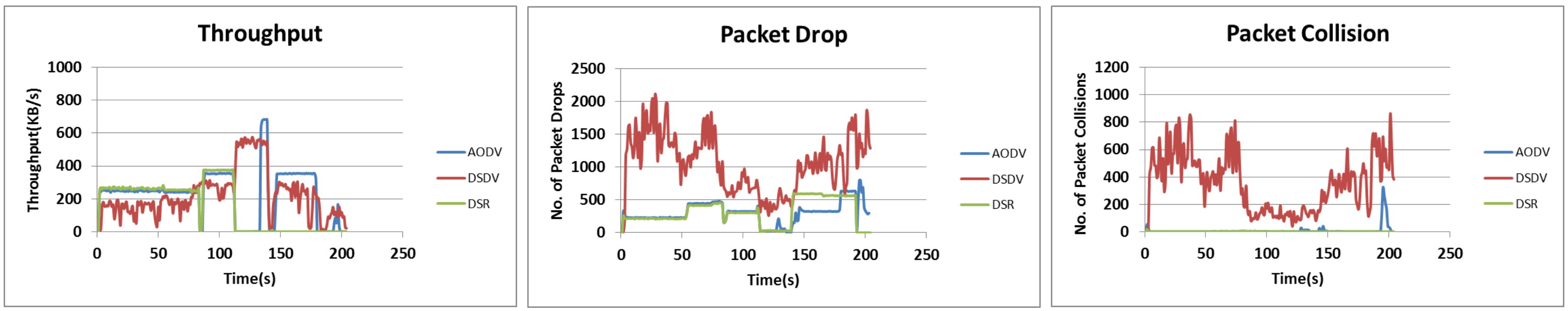


Figure 31 Effect of data rate with nodes=50, speed=120Km/h and data rate=11Mbps

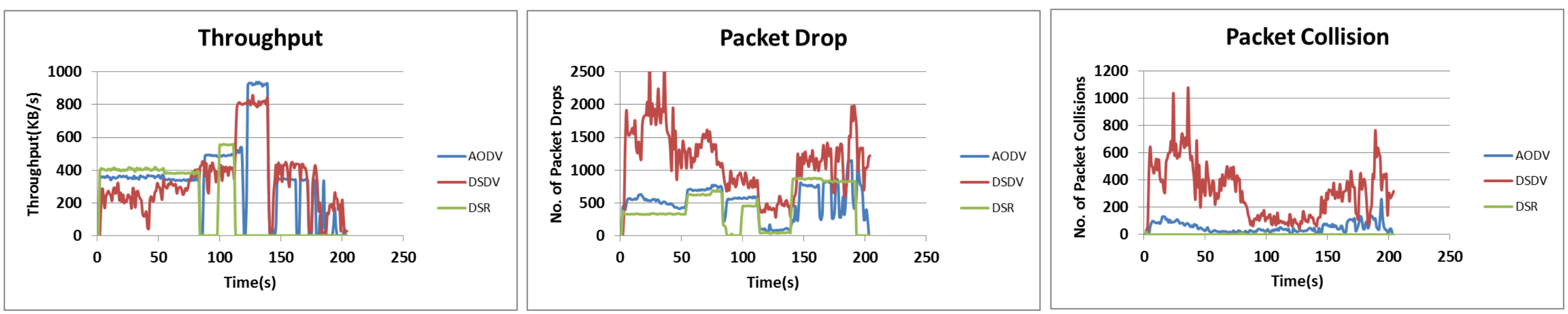


Figure 32 Effect of data rate with nodes=50, speed=120Km/h and data rate=27Mbps

The impact of increasing the payload size with a node density of 50 and a speed of 120Km/h is shown in Figure 33, Figure 34 and Figure 35. At higher payload size (10KB), DSR shows better performance in terms of throughput than AODV and DSDV. This is due to the fact that, at higher packet size, a lot of segmentation takes place and since DSR sends path information along with the data, the chances of reaching the destination are higher compared to AODV and DSDV. However, DSDV is still worst in terms of packet drop and collisions. In terms of packet drop and collision, no much change has been noticed in the results due to the fixed number of nodes and the vehicle speeds, and thus increasing the payload size increases the possibility of segmentation while following the same routing paths.

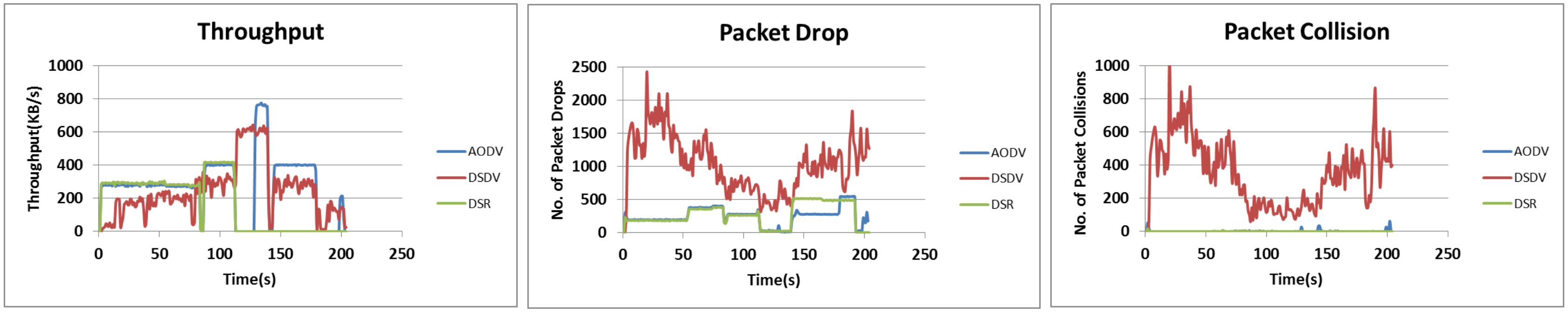


Figure 33 Effect of payload with nodes=50, speed=120Km/h and payload 4KB

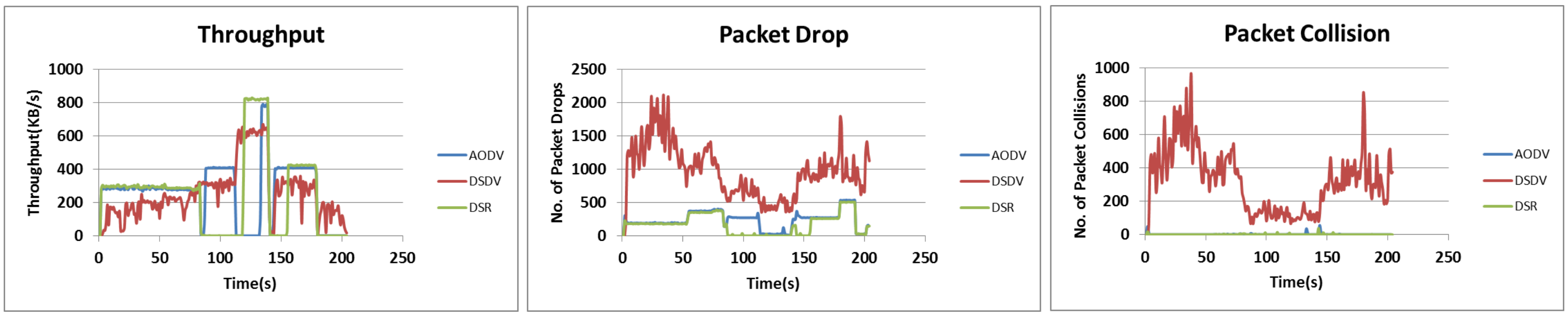


Figure 34 Effect of payload with nodes=50, speed=120Km/h and payload 7KB

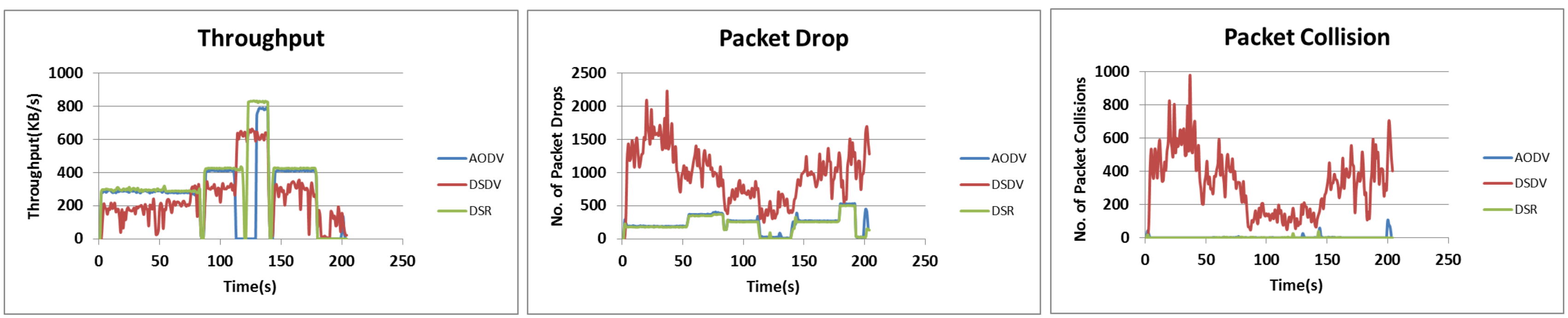


Figure 35 Effect of payload with nodes=50, speed=120Km/h and payload 10KB

The effect of increasing the buffer size from 50 packets to 100 packets is shown in Figure 36 and Figure 37. There is always a trade-off between selecting the optimal buffer size and the selected performance metrics. Increasing the buffer size does not always yields a better performance and hence should be experimentally evaluated. The default buffer size in NCTUns 6.0 is 50 packets. There is a noticeable effect on the throughput of DSDV routing protocol compared with the other two routing protocols, and this is due to the periodic updates that stack in longer queues. Regarding the packet drops and collisions, DSDV is the worst performed compared to AODV and DSR. The packet drops for both AODV and DSR has increased slightly at buffer size of 100 due to the congestion in long queues and as mentioned earlier the size of the buffer should be experimentally evaluated for optimal performance.

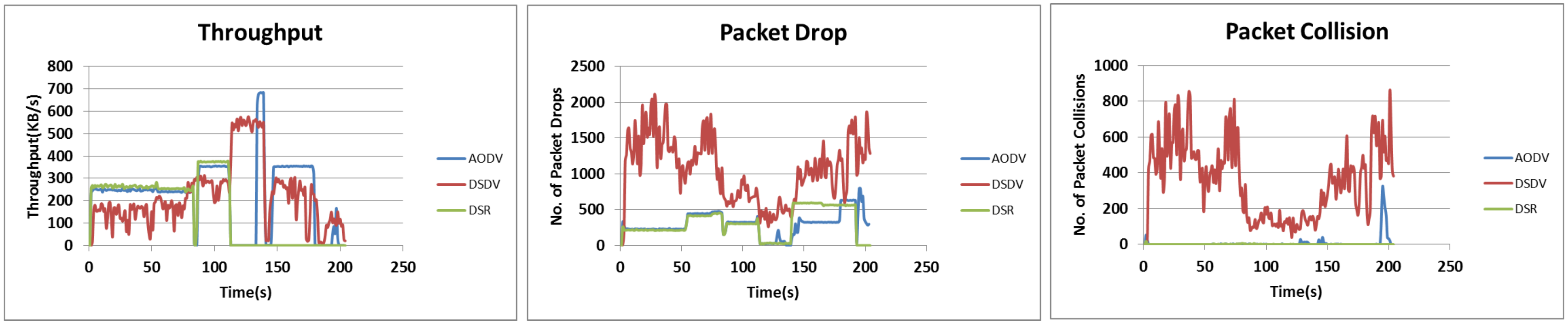


Figure 36 Effect of buffer size with nodes=50, speed=120Km/h and Buffer size=50 pkts

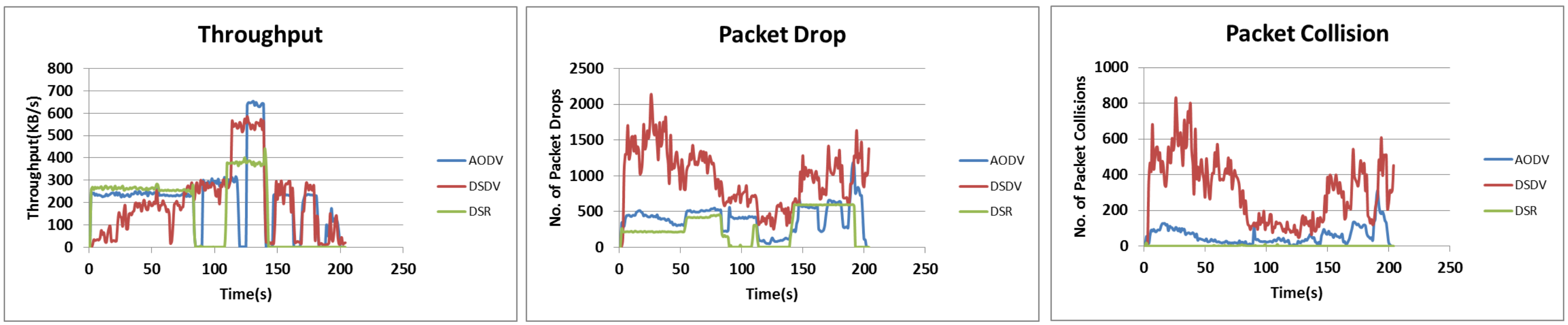


Figure 37 Effect of buffer size with nodes=50, speed=120Km/h and Buffer size=100 pkts.

The main purpose of these experiments were to select the best parameters for our online gaming applications and produce better results. The impact of path loss model on the performance of routing protocols is shown in Figure 38 and Figure 39. The two path loss models used were Two-Ray ground and Free space and shadowing. In terms of throughput, the performance of routing protocols is greatly affected by free space and shadowing model compared with the Two-Ray ground model. The packet drop and collision for DSDV have drastically increased with less fluctuation compared to the Two-Ray ground model. AODV shows lesser packet drop for the Two-Ray ground model, but with a higher degree of the collision. With respect to the free space and shadowing model, DSR shows slightly fewer packet drops and collisions.

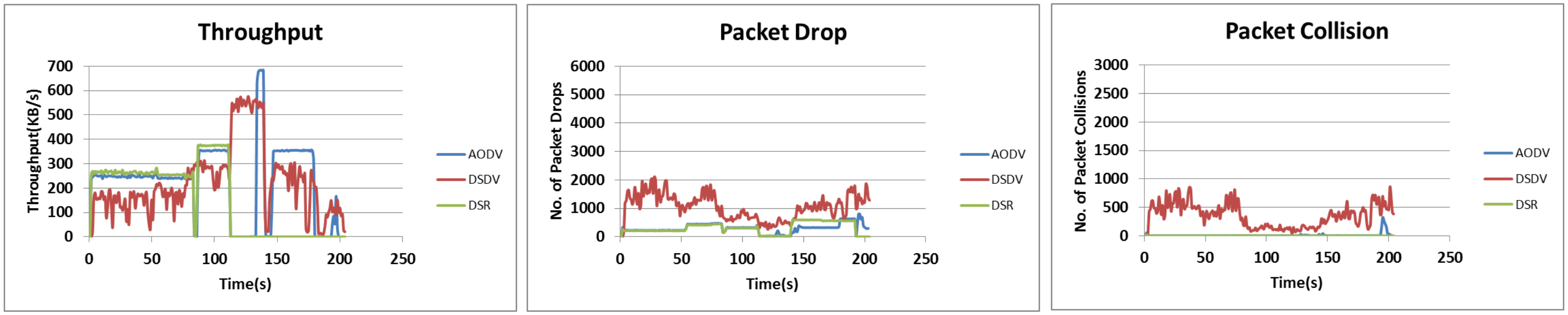


Figure 38 Effect of path loss model with nodes=50, speed=120Km/h, and Two ray ground Model

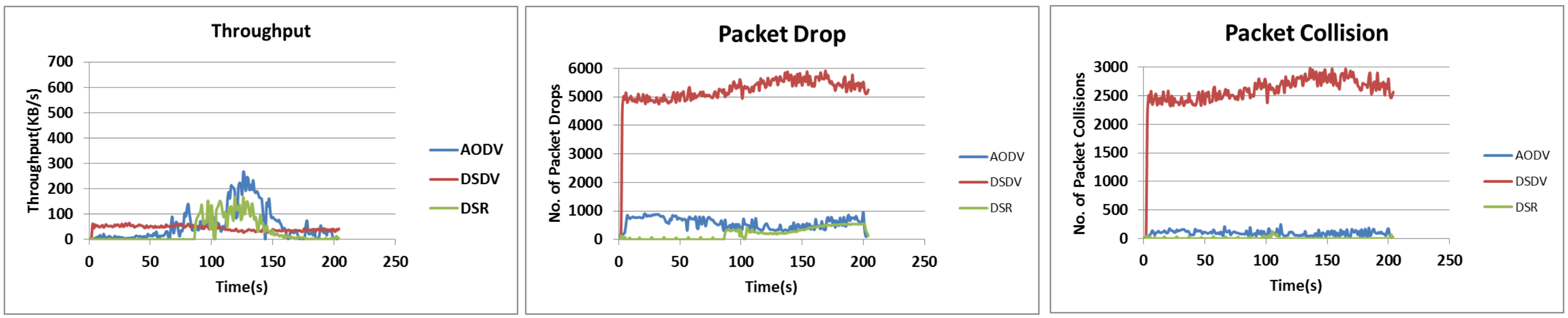


Figure 39 Effect of path loss model with nodes=50, speed=120Km/h and Free space and shadowing model

The effect of Rayleigh and Ricean fading model on routing protocols is depicted in Figure 40, Figure 41 and Figure 42. Rayleigh fading model has a considerable and obvious impact on the routing protocol performance in terms of throughput. DSDV is still worst in terms of packet drop and collisions. Rayleigh fading is more applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. Since in our highway scenario, there is a dominant line of sight, thus Ricean fading is more applicable in this case. The goal of this experiment was to select the appropriate fading model for our online gaming application.

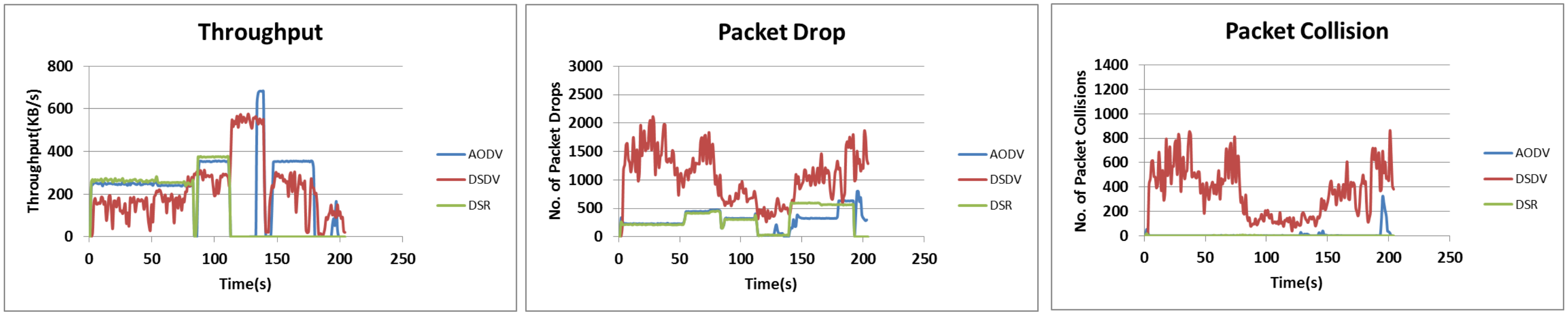


Figure 40 Effect of fading model with nodes=50, speed=120Km/h and No fading model

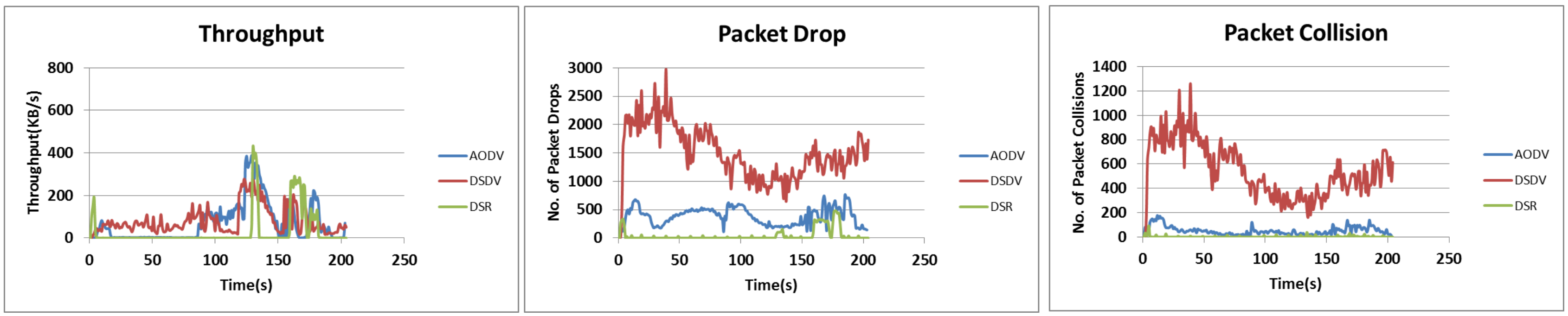


Figure 41 Effect of fading model with nodes=50, speed=120Km/h and Rayleigh fading model

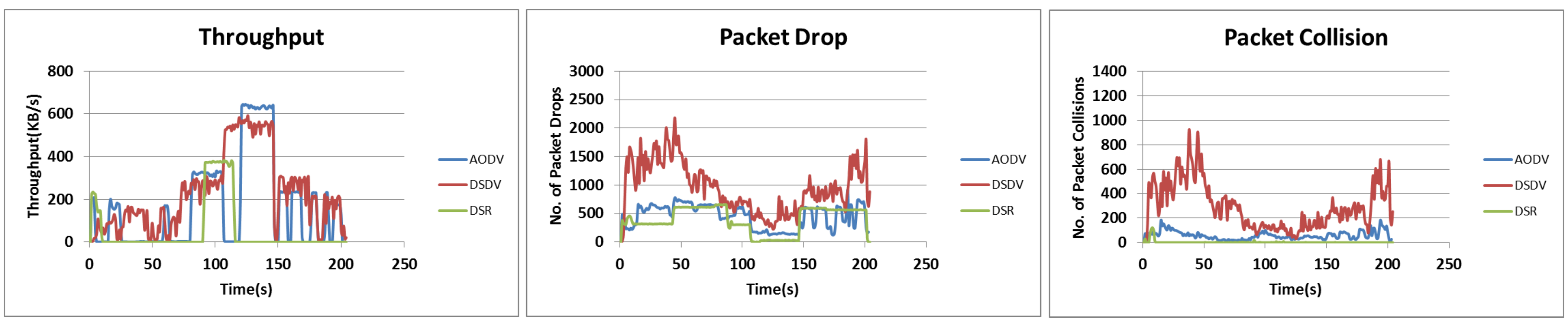


Figure 42 Effect of fading model with nodes=50, speed=120Km/h and Ricean fading model

The effect of infrastructure support is illustrated in Figure 43 and Figure 44. As it is expected that, the existence of infrastructure will increase the probability of multi-hop connectivity between vehicles and thus increase the throughput and reduce the packet drops. In terms of throughput, DSDV outperforms both AODV and DSR for no infrastructure support, while for packet drops and collisions, it still shows the worst performance. With infrastructure support, the packet drops has been enhanced for both AODV and DSR.

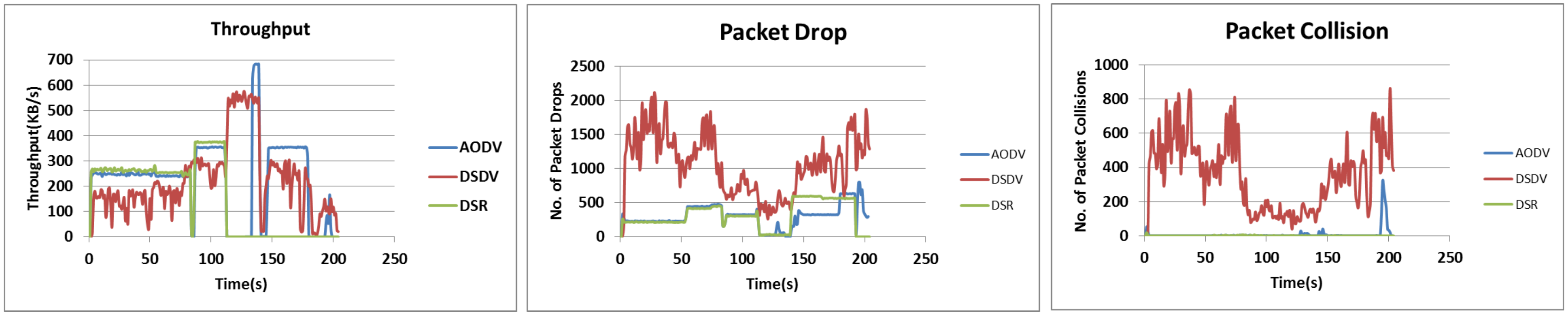


Figure 43 Effect of infrastructure support with nodes=50, speed=120Km/h and infrastructure support

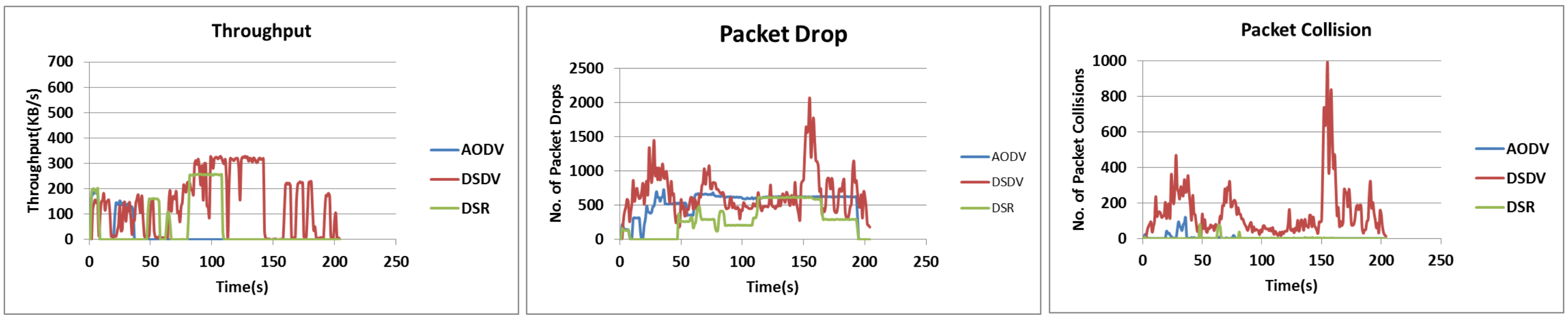
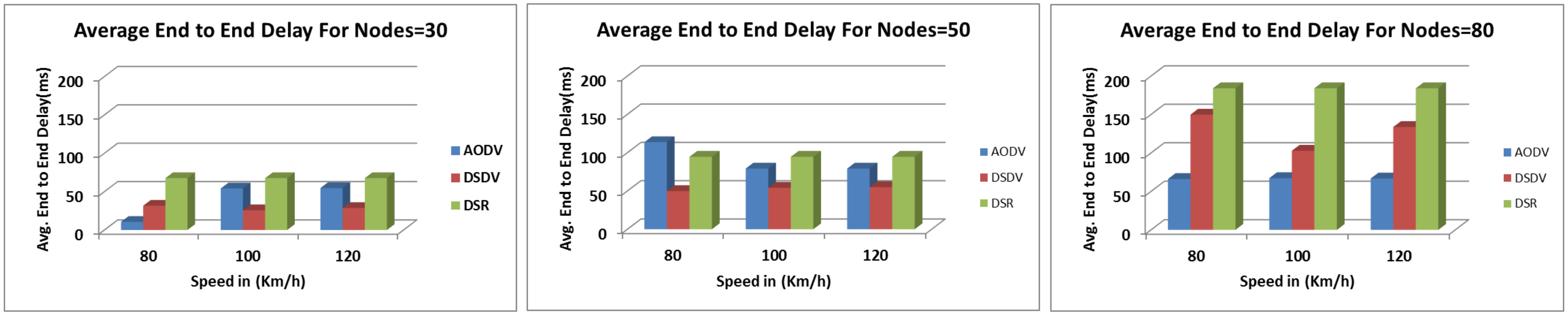


Figure 44 Effect of infrastructure support with nodes=50, speed=120Km/h and no infrastructure support

Finally, the average end-to-end delay for different node densities is shown in Figure 45. For a node density of 30 vehicles and speeds of (100 and 120Km/h), DSDV shows lower average end-to-end delay compared with AODV and DSR. DSR shows the least performance for average end-to-end delay when compared to AODV and DSDV. For a node density of 50 vehicles, DSDV outperforms both AODV and DSR. At a higher node density of 80 vehicles, AODV outperforms both DSDV and DSR. The detailed information about data exchange between nodes for a node density of 30 vehicles and speed of 120Km/h are shown in Figure 46. DSDV shows the poorest performance in terms of drop (DROP), packet retransmission (RTX), broadcast transmission (BTX) and broadcast receive (BRX) of data and acknowledgment packets. AODV shows better performance than DSR with respect to (DROP, RTX, RX and TX) of data and acknowledgment packets. However, DSR is performing better than AODV in terms of BRX and BTX of data and acknowledgment packets.

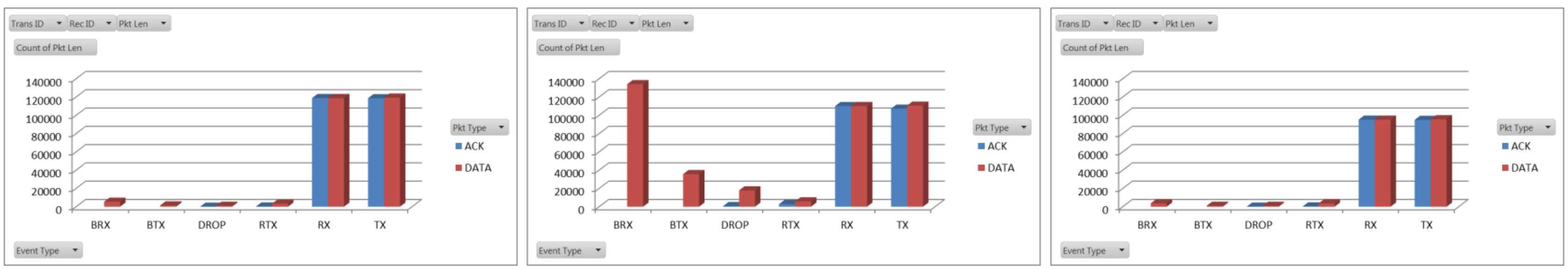


	Nodes=30		
	80	**100**	**120**
AODV	10.573	54.101	54.643
DSDV	31.609	25.738	28.65
DSR	67.571	67.571	67.571

	Nodes=50		
	80	**100**	**120**
AODV	113.582	79.165	79.159
DSDV	49.738	54.109	54.875
DSR	94.509	94.509	94.509

	Nodes=80		
	80	**100**	**120**
AODV	66.081	67.265	66.811
DSDV	149.806	102.825	133.738
DSR	184.103	184.103	184.103

Figure 45 Average end-to-end delay



Event Type	ACK	DATA	Grand Total
BRX		5473	5473
BTX		1371	1371
DROP	8	996	1004
RTX	236	3318	3554
RX	118873	118879	237752
TX	118643	119302	237945
Grand Total	**237760**	**249339**	**487099**

Event Type	ACK	DATA	Grand Total
BRX		134034	134034
BTX		35636	35636
DROP	641	17868	18509
RTX	2871	5848	8719
RX	110027	110119	220146
TX	107247	110519	217766
Grand Total	**220786**	**414024**	**634810**

Event Type	ACK	DATA	Grand Total
BRX		3651	3651
BTX		1006	1006
DROP	64	1026	1090
RTX	257	3676	3933
RX	95206	95208	190414
TX	94950	95684	190634
Grand Total	**190477**	**200251**	**390728**

Figure 46 Detailed information of routing protocols at nodes =50 and speed = 120Km/h

4.2 Multi-Hop Delay of MANET Routing in VANET

To gain more insight into how routing protocols behave and how far it can go while keeping the delay within the bounds of online gaming applications, we have conducted a performance evaluation of Multi-hop delay of MANET routing protocols over VANET. In order to have a baseline for comparison, we have first considered the case when all vehicles are static and then we considered the real scenario when all vehicles are moving in a highway scenario. The static scenario was considered, in order to have a better understanding of the results in a multi-hop dynamic.

4.2.1 Static scenario

A group of six static vehicles laid down on a highway road scenario with 300m distance apart. This distance has been carefully selected to allow Multi-hop to take place between the sender and receiver. Node 1 was selected as a sender and transmitting a constant UDP traffic of 1KB to the receiver for a simulation time of 200s. The receiver was kept dynamic i.e. first node 2 was considered as receiving node, thus allowing one hop communication, then node 3 acts as a receiving node allowing two-hop communication and so on. The scenario design and simulation parameters are shown in Figure 47 and Table 7 respectively.

Figure 48 illustrates the effect of Multi-hop communication on the throughput of the MANET routing protocols for the static scenario. For one hop and two hop communications, all three MANET routing protocols (AODV, DSDV, and DSR) shows stable behavior in terms of throughput with DSR slightly outperforms both AODV and

DSDV. This is attributed to the fact that for DSR, the data along with the path is sent to the intermediate nodes and the source node is the only node responsible for sending the data. For three, four and five hops communication, the fluctuations starts taking place with DSDV showing the worst performed routing protocols.

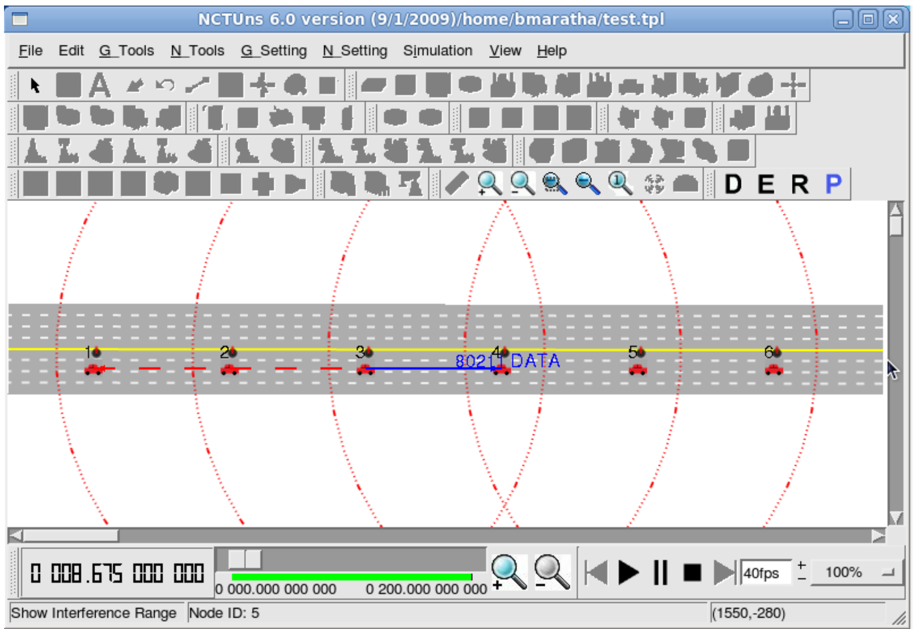


Figure 47 Static Multi-hop highway scenario

Table 7 Parameters for static Multi-hop scenario

Parameter	Value
Simulator Name	NCTUns 6.0
Simulation time	200 s
Routing Protocols	AODV, DSDV, DSR
Simulation Distance	2000 m
Number of vehicles	6
Transport protocol	UDP
Packet size	1KB
Vehicle type	802.11p (Agent Controlled)
Data rate	11 Mbps
Propagation Model	Two-Ray Ground.
Transmission Range	550m
Road type	4 Lane per direction
Traffic Lights	2

This is due to the periodic updates of DSDV protocol which keeps on disturbing the data transfer between vehicles and thus dropping the throughput for a while and picking from their up and so on. Also, it has been noticed that DSR has some spikes in its output compared to AODV and this is due to the time it takes for a source to get the path from intermediate nodes. The throughput decreases with the increase in the number of hops, with AODV showing more stability compared with DSDV and DSR.

Figure 49 shows the effect of Multi-hop communication on the packet drop of the MANET routing protocols for the static scenario. For one hop communication the packet drop is almost zero for all routing protocols, but for two and more hops the same pattern for throughput has been noticed with AODV the most stable and DSDV the most fluctuating.

Figure 50 illustrates the effect of Multi-hop communication on the packet collisions of the MANET routing protocols for the static scenario. In this case, DSR performs slightly better than AODV and DSDV. For the same reasons mentioned earlier, DSDV is worst in terms of packet collisions that reached 10 packets compared to AODV and DSR that does not exceed 3 packets.

Finally, Figure 51 shows the effect of Multi-hop communication on the average end to end delay of the MANET routing protocols for the static scenario. In this case, despite the high percentage of dropped packets and a higher number of packet collisions, DSDV outperforms both AODV and DSR in terms of average end to end delay for the whole simulation period. This is attributed to the tables maintained by DSDV during periodic updates which make faster route decision compared to AODV and DSR which react only whenever the user wants to send data and try to figure out the path on the fly. For one and two hops the delay is below 50ms, and for three and four hops it is below 250ms, while for five hops it is below 500ms. The detailed data are shown in Table 8, Table 9 and Table 10.

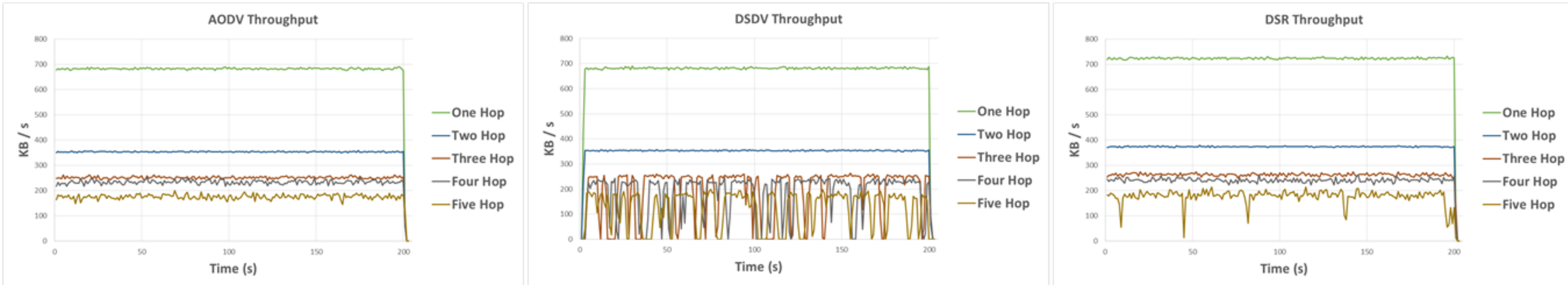


Figure 48 Effect of static Multi-hop on throughput of routing protocols

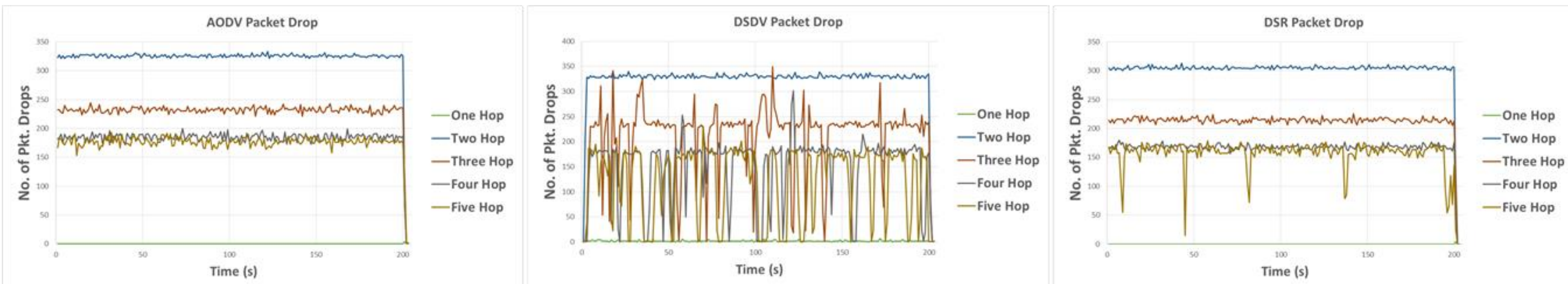


Figure 49 Effect of static Multi-hop on packet drop of routing protocols

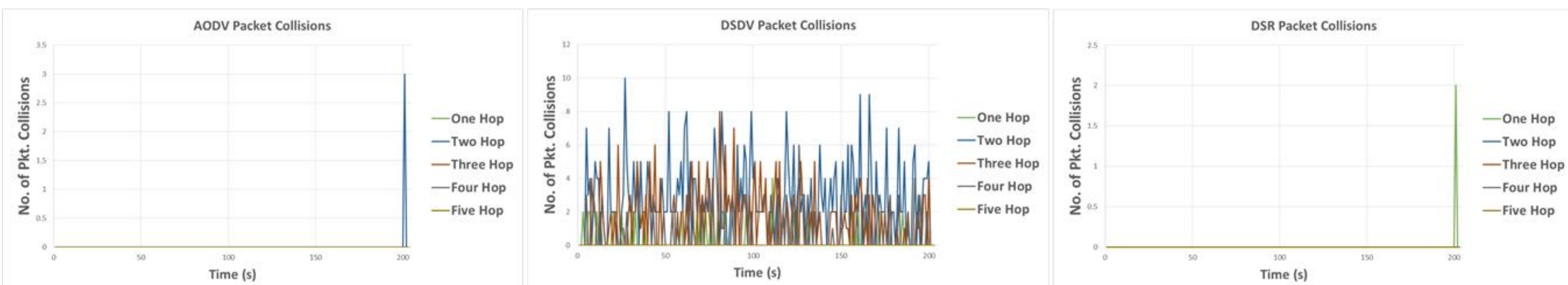


Figure 50 Effect of static Multi-hop on packet collision of routing protocols

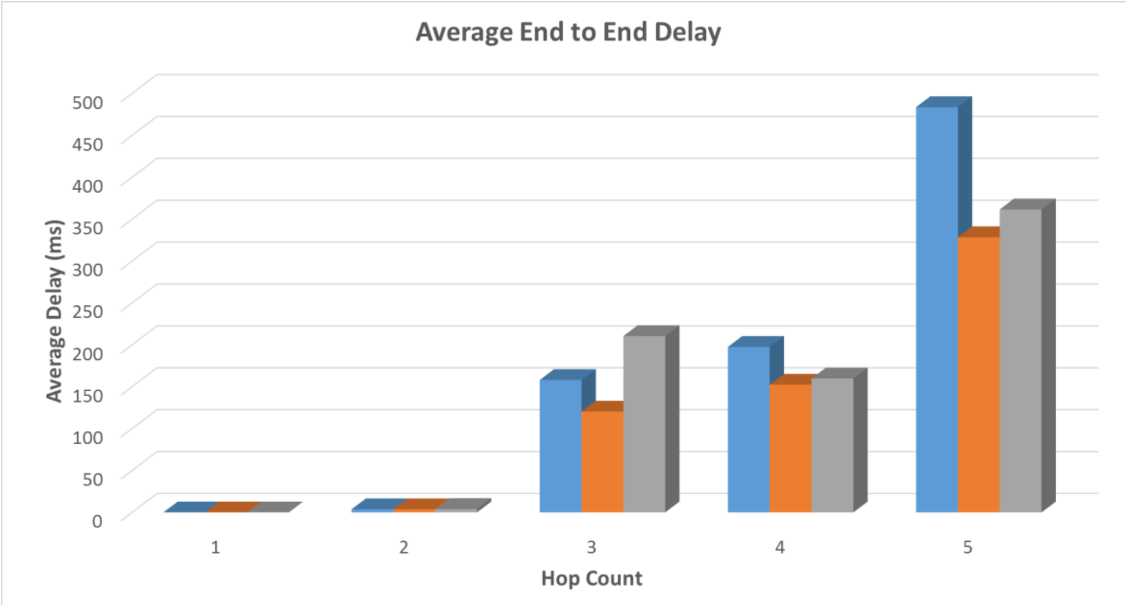


Figure 51 Average end to end delay for static scenario

Table 8 AODV performance metric for static scenario

AODV					
Metric/Hop Count	1	2	3	4	5
% Packet Loss	0	0.0031	1.6324	15.8354	33.4321
Average Throughput (KB/s)	638.6432	330.98752	235.40224	218.68544	164.55168
Avg. End to End Delay (ms)	0.001	3.722	158.041	197.519	483.695

Table 9 DSDV performance metric for static scenario

DSDV					
Metric/Hop Count	1	2	3	4	5
% Packet Loss	0	0	10.8039	17.6451	35.2444
Average Throughput (KB/s)	632.98048	328.07424	179.15904	171.66848	116.59264
Avg. End to End Delay (ms)	0.001	3.715	120.345	152.434	328.426

Table 10 DSR performance metric for static scenario

DSR					
Metric/Hop Count	1	2	3	4	5
% Packet Loss	0	0.0033	3.2693	16.4031	28.5961
Average Throughput (KB/s)	600.59648	310.60992	218.5984	200.48896	148.224
Avg. End to End Delay (ms)	0.001	3.983	210.406	159.802	361.591

4.2.2 Dynamic Scenario

In order to gain an insight on the effect of multi-hop communication on the performance of MANET routing protocols we considered the same group of six vehicles but this time moving at average speed of 110Km/h in a dynamic scenario. The Car Profile configuration for the different speeds are (Profile 1/2/3/4/5 = 28/29/30/31/32). We traced the generated log file using AWK scripting language to find out the period of time for which sender and receiver communicate using one hop, two hops and so on. The scenario design and simulation parameters are shown in Figure 52 and Table 11 respectively.

Figure 53 shows the effect of Multi-hop communication on the throughput of the MANET routing protocols for the dynamic scenario. AODV outperforms both DSDV and DSR in terms of average throughput while DSDV shows the poor performance. AODV and DSR show very close performance behavior during the whole simulation time. DSDV starts showing poor behavior after three hop counts.

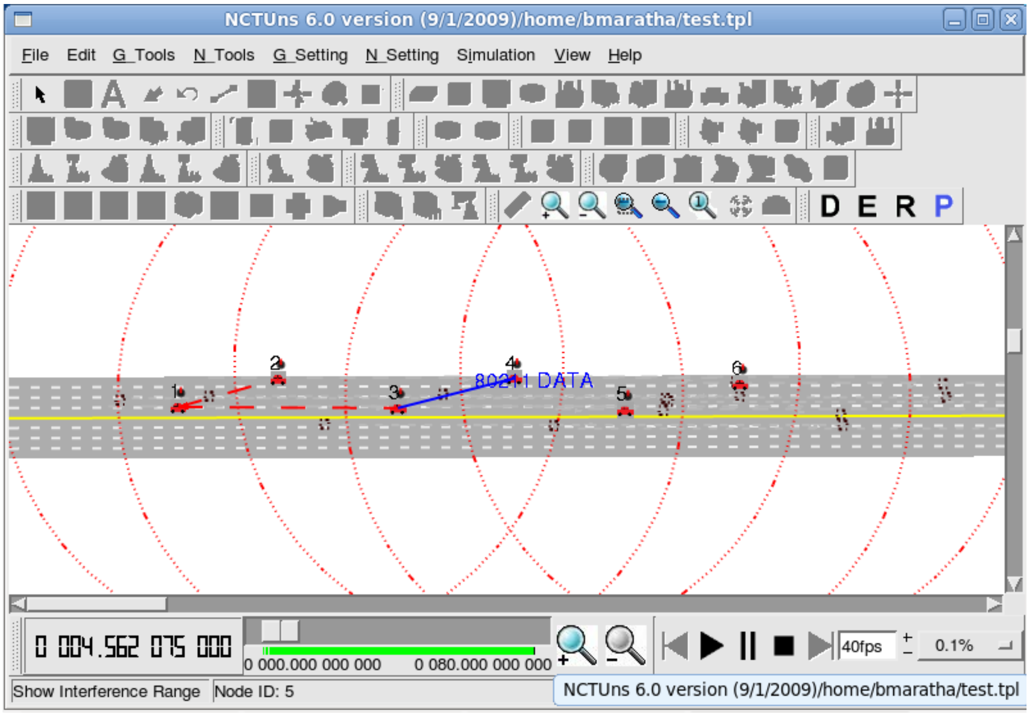


Figure 52 Dynamic Multi-hop highway scenario

Table 11 Parameters for Dynamic Multi-hop scenario

Parameter	**Value**
Simulator Name	NCTUns 6.0
Simulation time	80 s
Routing Protocols	AODV, DSDV, DSR
Simulation Distance	2000 m
Number of vehicles	6
Speed of vehicles	110 Km/h
Transport protocol	UDP
Packet size	1KB
Vehicle type	802.11p (Agent Controlled)
Data rate	11 Mbps
Propagation Model	Two-Ray Ground.
Transmission Range	550m
Road type	4 Lane per direction
Traffic Lights	2

The effect of multi-hop communication on packet loss ratio is shown in Figure 54. AODV shows better performance in terms of packet loss ratio up to four hop counts, after that DSR starts outperforming both AODV and DSDV. Here DSDV shows the worst performance for the whole simulation time. The reason for the packet drop is that, vehicles have different Car Profiles, each with different speeds (average is 110 Km/h), and they might get disconnected anytime they go outside the communication range of each other.

Finally, the average end to end delay is shown in Figure 55. In this case, DSDV outperforms both AODV and DSR. AODV shows the worst performance in terms of average end to end delay.

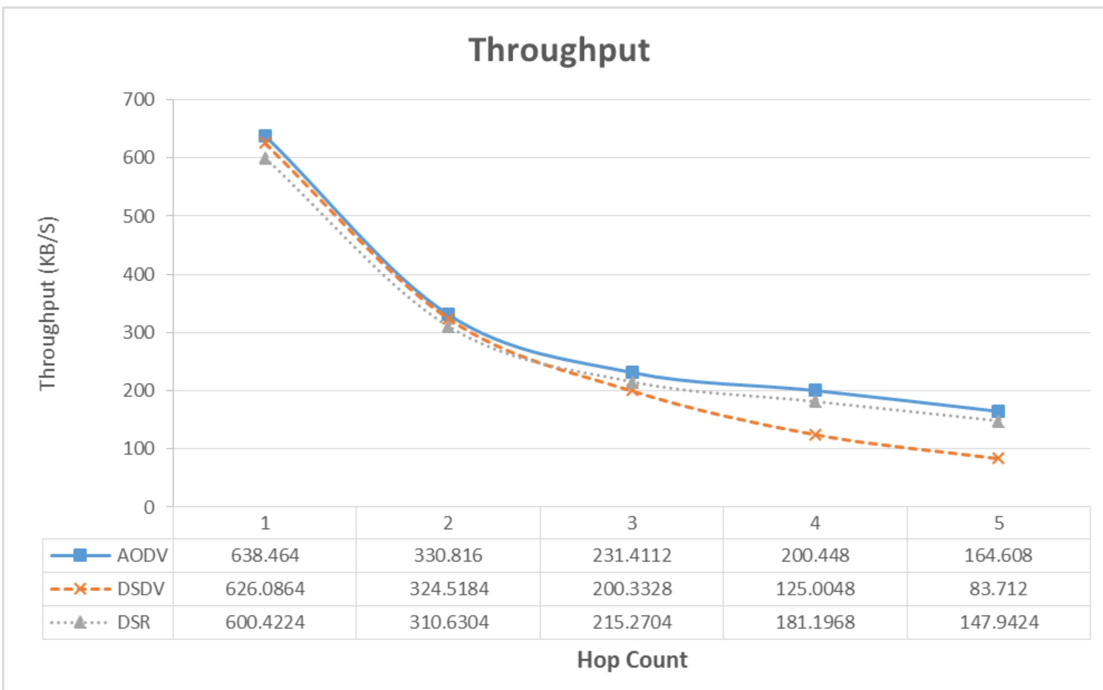
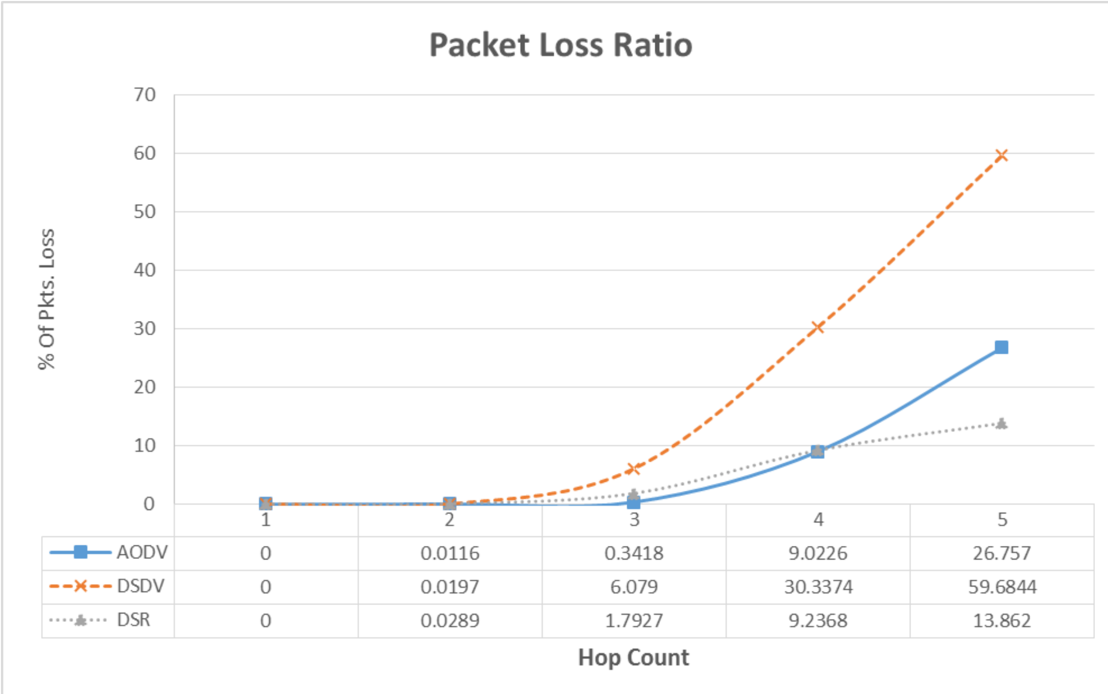
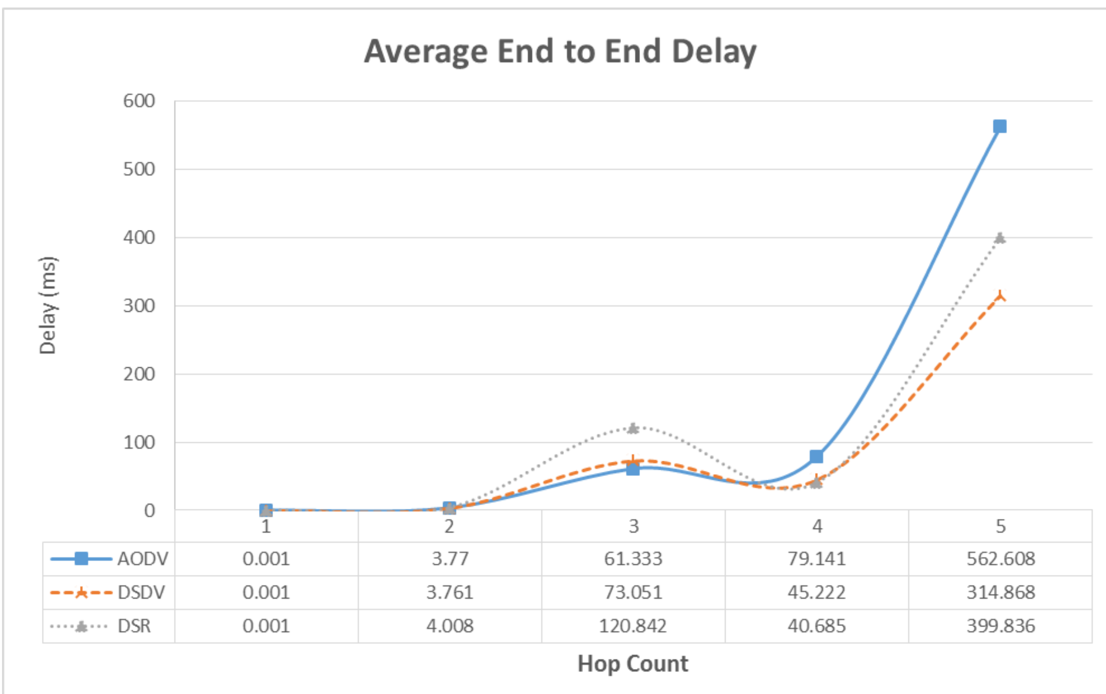


Figure 53 Effect of dynamic Multi-hop on throughput of routing protocols



	1	2	3	4	5
AODV	0	0.0116	0.3418	9.0226	26.757
DSDV	0	0.0197	6.079	30.3374	59.6844
DSR	0	0.0289	1.7927	9.2368	13.862

Figure 54 Effect of dynamic Multi-hop on packet loss ratio of routing protocols



	1	2	3	4	5
AODV	0.001	3.77	61.333	79.141	562.608
DSDV	0.001	3.761	73.051	45.222	314.868
DSR	0.001	4.008	120.842	40.685	399.836

Figure 55 Effect of dynamic Multi-hop on delay of routing protocols

4.3 Summary

In this chapter, we have presented an in-depth performance evaluation of MANET routing protocols (AODV, DSR, and DSDV) in VANET. The protocols were evaluated against each other using throughput, packet drops and packet collisions as performance metrics. Different simulation parameters were varied such as (vehicle speed, node density, packet size, data rate, propagation model and fading effects) to depict the behavior of MANET routing protocols in a VANET highway scenario. From the first part, it is clear that there is no one single routing protocol that will suit all requirements of VANETs. The choice of the best routing protocol depends on the type of application and the environment under study. Some applications can tolerate high delay while others have strict delay constraints. Results show that DSDV performs better at lower node density than AODV and DSR in terms of throughput and average end to end delay maintaining the packet drops and collision within a tolerable limit. For higher node density, AODV and DSR outperform DSDV and the reason is that DSDV suffers from periodic updates which affect its performance at higher node density. In the second part, we evaluated the performance of MANET routing protocols for the multi-hop delay in a VANET highway scenario. We considered two cases, one where all nodes were static and the other where all nodes are dynamic and moving at 110Km/h. Results show a lot of fluctuation in DSDV output for throughput, packet drops, and packet collisions compared to AODV and DSR which are more stable at three and more hops. In terms of average end to end delay, these protocols can go as far as four hops while maintaining the delay under 200ms. DSDV is better in terms of end to end delay compared to AODV and DSR. DSDV is a good choice for lower node density such as a group of 5 to 10 cars moving in a platoon while still keeping the delay within the limits of online gaming and tolerated packet drops and collisions. Thus, there a big trade-off between all the three metrics and selecting the best one depends on the application requirements.

CHAPTER 5

ONLINE GAMING OVER VANET

Many research works have been conducted to use VANETs for safety applications, but very few has focused on its use for entertainment applications such as online games. This is due to the fact that, playing games over VANET is very challenging due to the dynamic network topology and fast vehicle's speed. In addition, the absence of infrastructure support, the uncertainty of available intermediate nodes for multi-hop operation, frequent clustering of network and operating in a fully distributed environment (Peer to Peer) is what makes this task more complicated.

In order to have a good gaming experience, the duration of connectivity between vehicles should be maintained for a reasonable period of time, and this could be achieved in specific scenarios such as a group of vehicles (Platoon) co-operating with each other in a long travel. Moreover, gaming data should be exchanged very fast with constrained delay for satisfactory real-time gaming interaction between players. Online games can range from simple text-based environments to the incorporation of complex graphics and virtual worlds. The Internet online games are categorized as per acceptable delay requirement into:

- Shooter Games: First Person Shooter (FPS).
- Real-time Strategy Games (RTS Games).
- Role-Playing Games.
- Other games

Online gaming over VANET will require innovative approaches to designing the game and the underlying architecture, in order to cope with the following VANET characteristics:

- Very high, but predictable mobility.
- Small-scale partitioned network due to intermittent connectivity.
- Location-aware information can be obtained from Onboard sensors (e.g., GPS).
- Constrained movement due to roadway geometry.
- No significant constraints in terms of space, computation, and power as compared to other wireless networks (e.g., sensor and cellular).
- Two different environments can be considered, highway and urban.
- The most important challenge that has to be faced in order to enable games over VANETs is the end-to-end connectivity and the connection duration.

In this thesis, we have considered online gaming over VANET for a group of six vehicles co-operating with each other while traveling in a highway scenario towards their common destination. By doing so, we could maintain better connectivity between vehicles and reduce disconnections. From the outcomes of chapter 4, we have decided to use DSDV routing protocol because it performs well in terms of delay bound and lower node density of online gaming platoon. In addition, we have restricted the hop count to six, because beyond that the delay and percentage of packet loss are unacceptable for the online gaming experience.

5.1 CarAgent in NCTUns 6.0

In NCTUns 6.0, vehicles can move along a predefined path designed manually or move automatically following the traffic rules on road using a CarAgent software uploaded at each node. Thus, a CarAgent is an application software that runs on each node to control its mobility according to the traffic light rules and as shown in Figure 56, it consists of four main components, which are; (1) the agent logic, (2) a road map database, (3) socket interfaces, and (4) car/signal information APIs. The agent logic controls the automatic driving behavior of the vehicle node on which the CarAgent is run. The road map database stores the location/direction of roads. The socket interfaces provide TCP/UDP internet connections for vehicles to exchange their information on the road. The car/signal information APIs are the functions that the agent logic can call to access the car and signal information databases located in the Simulation Engine (SE). These API functions internally use TCP/IP IPC (Inter-Process Communication) connections to exchange information between the CarAgent and the SE. Therefore, the CarAgent in NCTUns 6.0 automatically controls the mobility of the vehicles and it is actually the driver of the vehicle following the traffic rules. It communicates through the socket API with the SE to get real time information about road, road obstacles, traffic light, neighboring vehicles, and speed limits and uses these information to drive the vehicle on road.

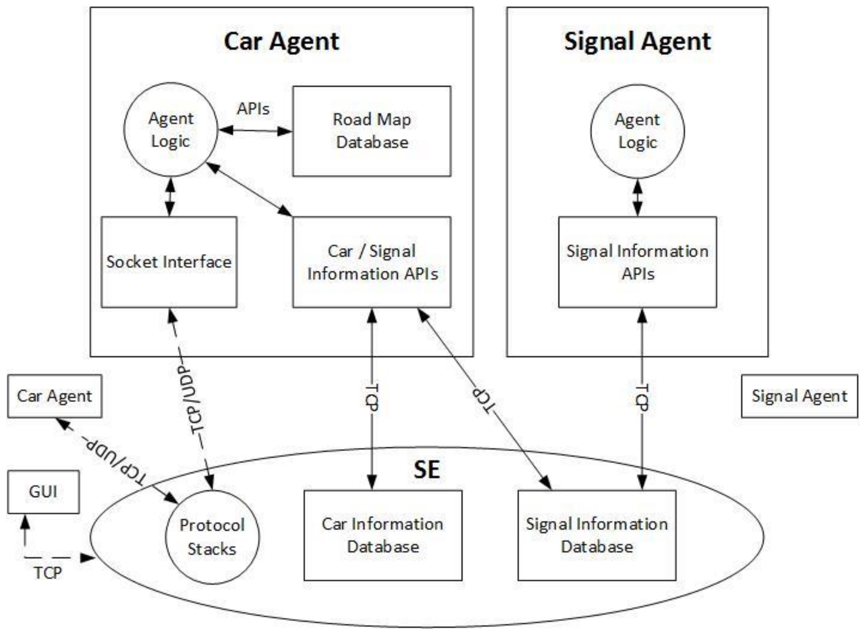


Figure 56 The integrated platform of NCTUns 6.0

As shown in Figure 57, the SE acts as a coordinator between two or more communicating CarAgents. The details of communication between two CarAgents are as follows:

1. The agent logic of the left CA uses the standard POSIX socket-interface API's (e.g., sendto(), write(), etc.) to write a segment of data into the socket send buffer in the kernel.
2. The data segment will first reach the TCP/UDP layer (which is defined as the transport layer in the OSI model). After being encapsulated with a TCP/UDP header, this TCP/UDP packet is then passed to the IP layer (which is defined as the network layer).
3. The TCP/UDP packet will be encapsulated again with an IP header and then be written into a tunnel interface.
4. Later on, the user-level SE will retrieve the IP packet from the tunnel interface.

5. The media access control (MAC) protocol (which is defined as the data link layer in the OSI model) and the physical (PHY) protocol (which is defined as the physical layer) are simulated in the SE. The fetched IP packet will be encapsulated again with a MAC header and then sent from the sending PHY to the receiving PHY under the control of the MAC protocol.
6. The MAC header of the MAC packet will be stripped off when the packet arrives at the receiving MAC. The SE then writes the packet into another tunnel interface in the kernel, which is associated with the right vehicle.
7. The kernel then delivers the IP packet from the tunnel interface to the IP layer. Although this packet is received from the (pseudo) tunnel interface, the kernel processes it in exactly the same way as it processes a packet received from a (real) network interface. The IP header of the IP packet is then stripped off at the IP layer, and then the packet is passed up to the TCP/UDP layer.
8. At the TCP/UDP layer, the TCP/UDP header of the TCP/UDP packet is stripped off and the remaining data segment is then stored into the socket receive buffer.
9. Finally, the agent logic of the right CA uses the standard POSIX socket-interface API's (e.g., recvfrom(), read(), etc.) to read the data segment from the socket receive buffer.

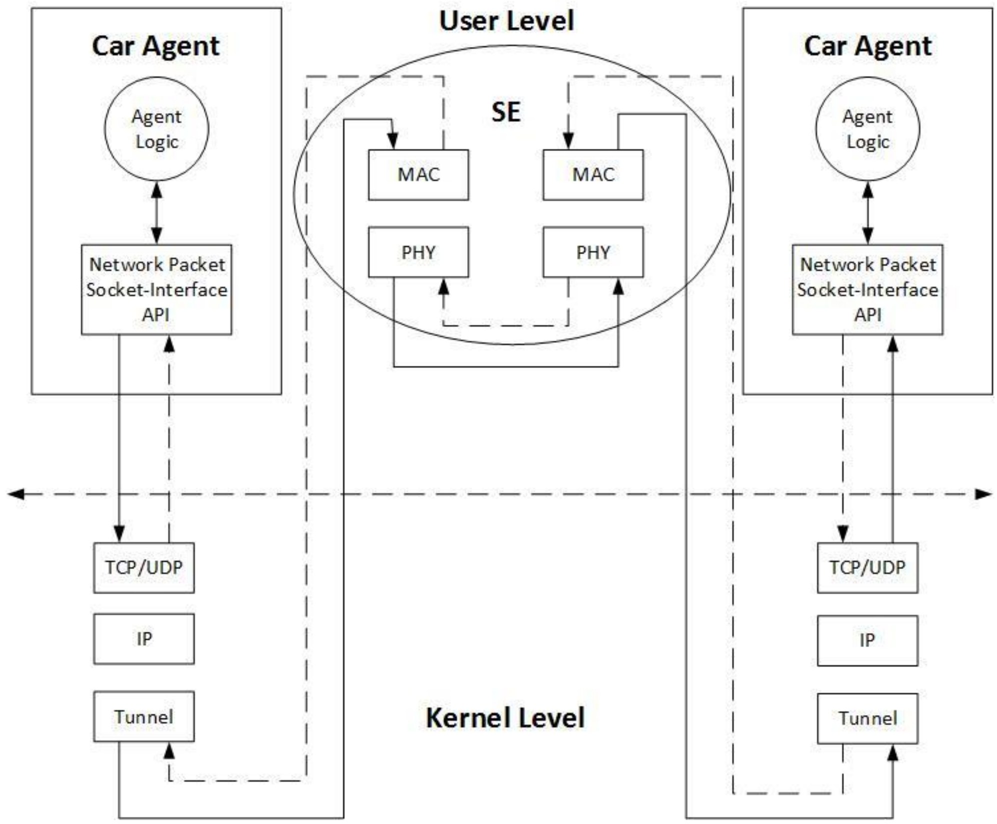


Figure 57 Communication among CarAgents

For online gaming scenario, we considered a group of vehicles moving towards their common destination and the default CarAgent mobility model does not suit its requirement because connectivity cannot be maintained for longer duration, but in reality, drivers can adjust their speed to catch the platoon and remain connected for better gaming experience. Thus in our thesis, we modified the source code of the CarAgent software to add an extra feature i.e. “Driver Behavior” to maintain longer connectivity between vehicles. The practicality of adding a driver behavior has been captured from real scenarios of online gaming, because a platoon or group of vehicles moving towards their common destination tend to move close to each other and adjust their speed to catch the platoon and this is known as catch up time in the literature i.e. the time required by the vehicle to catch the platoon and get connected. This is strongly dependent on driver behavior, and there are good motivations to do so if back seat player or kids want to get involved in an enjoyable gaming experience.

First, we present our proposed design for online gaming over VANET using the default mobility model included in NCTUns 6.0 called CarAgent. Then, we proposed our own mobility model by modifying the CarAgent and compare both results.

5.2 Online Gaming Scenario with Default Mobility

To evaluate the performance of online gaming in VANET, we have proposed a highway road network scenario in which a group of vehicles (1, 2, 3, 4, 5 and 6) is moving towards their common destination. As shown in Figure 58, the road design consists of three lanes in each direction with eight traffic lights. The highway is deployed with 60 vehicles each equipped with a wireless technology (IEEE 802.11p standard) moving with different node speeds. Vehicles travel a distance of 13000 meters and use V2V with multi-hop data forwarding to reach their destination. The requirements of online gaming has been captured from real trace files of “First Shooter” games which has a very stringent delay requirement of less than 150ms and %Packet loss of less than 2% and an average traffic load on the network i.e. packet size less than 2KB. These figures act as a basis for comparing the feasibility of our simulation results. The detailed simulation parameters used in this scenario are listed in Table 13.

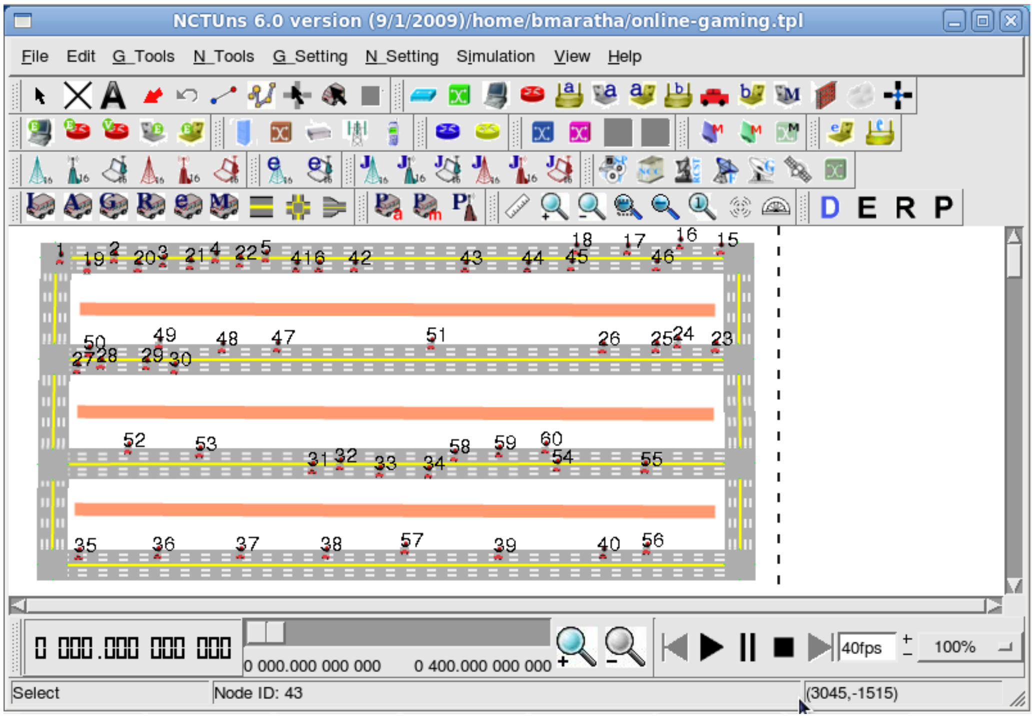


Figure 58 Online gaming scenario with default mobility

Table 12 Parameters of online gaming with default mobility

Parameter	**Value**
Simulator Name	NCTUns 6.0
Simulation time	400 s
Routing Protocols	DSDV
Simulation Distance	13000 m
Number of vehicles	60
Speed of vehicles	120 Km/h
Transport protocol	UDP
Packet size	1KB
Vehicle type	802.11p (Agent Controlled)
Data rate	11 Mbps
Propagation Model	Two-Ray Ground.
Transmission Range	300m
Road type	4 Lane per direction
Traffic Lights	8
Obstacles	3 (Block signal).

The format of the real trace file for the “First-Shooter” game that has been used in our online gaming is shown in Table 13. This file reflects the real traffic of online gaming application in terms of payload size and frequency of packet bursts sent over the network. NCTUns 6.0 has the capability of reading these real trace files and accurately configures its parameters based on the time-stamp associated with each packet. It has been tested with simple scenarios that the real trace files of the online gaming application are read accurately by NCTUns 6.0 and reflect all of its traffic properly.

Table 13 Online gaming trace file format

Field	**Example**	**Description**
Timestamp	12834907204	Unix Time in μsec
Protocol	UDP	Transport Layer protocol
Remote IP	1.0.1.6	IP address
Remote Port	7000	TCP/UDP port
Payload Size	1K	Packet size
Direction	Same	Same or opposite direction
Local Pos.	22,127,0	X, Y, Z position vector
Priority Level	2	Level 1 higher and level 5 Lowest

As shown in Figure 59, multi-hop count varies between source and destination, for higher hop count, DSDV start showing fluctuations in its results. Also, some spikes are noticed in the results and are mainly due to selecting vehicles moving in the opposite direction. The main point here is that the connectivity between vehicles cannot be maintained as vehicles are allowed to go as far as they wish, which consequently affects the duration for which the game could be played. The average throughput is 93.6KB/s, %loss is 31.7 and the average delay is 30ms. The high percentage of packet loss, which is unacceptable for online gaming requirements, is mainly due to the longer disconnection periods caused by lack of interaction among vehicles.

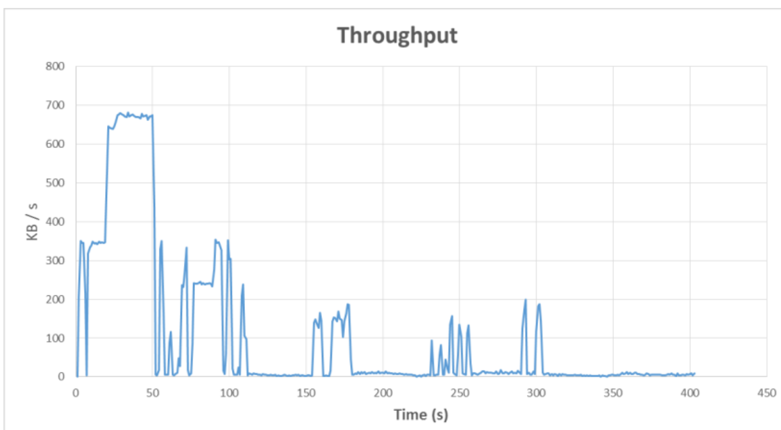


Figure 59 Connectivity duration of Online gaming with default mobility

5.3 Online Gaming Scenario with Proposed Mobility

Due to the poor performance of online gaming over VANET which is mainly due to the default mobility model in NCTUns 6.0 (CarAgent), which does not have any driver behavior interaction to adjust the speed of vehicles to catch the platoon also known as catch-up time. One way to enhance connectivity among vehicles is to use adjustable transmission power. This approach has a limitation of interference with the environment frequencies. In this work, we have proposed our own mobility model with driver interaction features by modifying the default CarAgent. Figure 60 depicts our proposed mobility model which restricts the number of hops to five. Beyond this, vehicles try to cooperate with each other either by increasing or decreasing their speed depending on sender and destination locations. This modification has been conducted with the assumption that each vehicle is equipped with a GPS device. This approach could be used by online gaming applications specifically designed for VANET, to warn drivers to adjust their speed if they want to catch the platoon and maintain a good gaming experience with the destination.

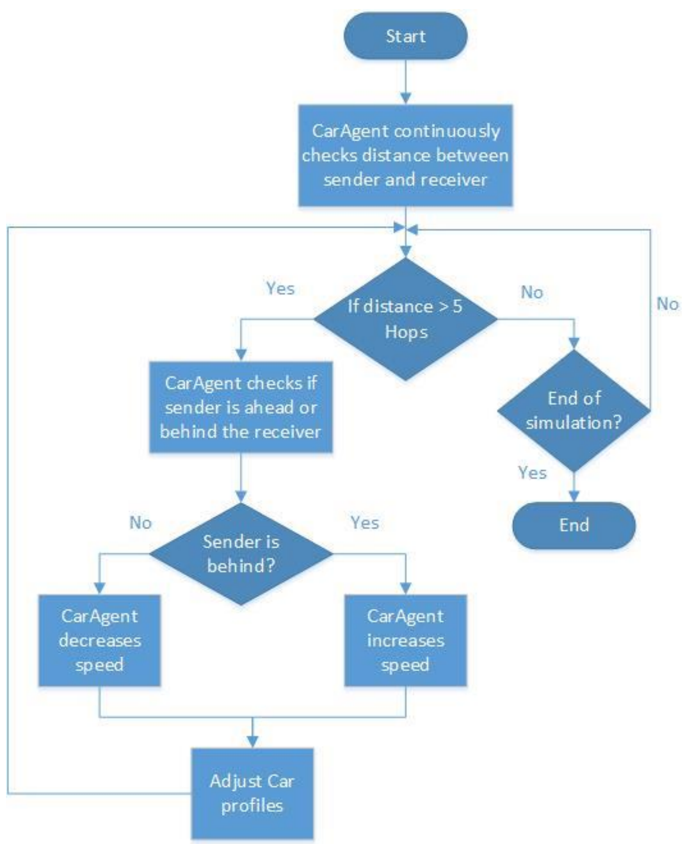


Figure 60 Algorithm for proposed mobility model

Figure 61 shows the effect of our proposed mobility model on the connection duration of online gaming experience. The disconnections noticed earlier has drastically enhanced, and most of the time vehicles are connected via one hop, two hops or a maximum of five hops. The average throughput is 312.20KB/s, %loss is 4.4 and the average delay is 6.2ms. The percentage of packet loss has enhanced but still slightly beyond the requirements of online gaming applications. This loss is attributed to the periodic updates of the DSDV routing protocol itself and needs to be enhanced.

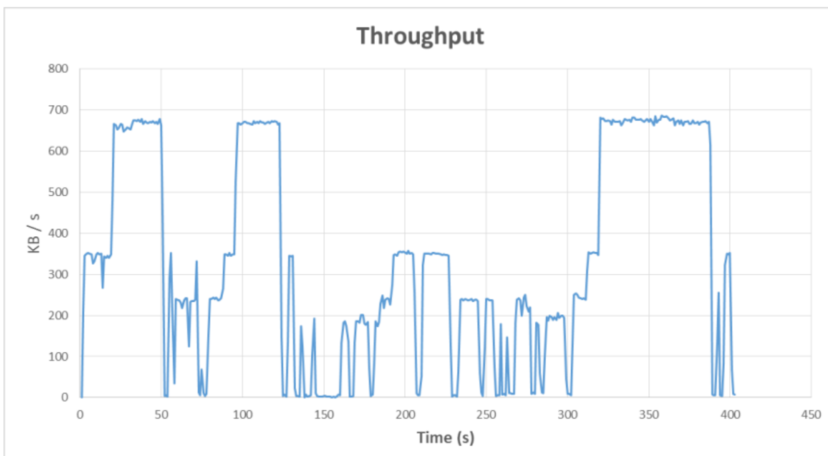


Figure 61 Connectivity duration of Online gaming with proposed mobility

5.4 Enhancement to DSDV for Online Gaming

Our proposed mobility model for online gaming has drastically enhanced the average throughput and end to end delay, but the percent packet loss is still beyond the requirements of online gaming which is in the order of 1% depending on the type of game. When analyzing the results we have noticed that the routing protocol used, namely DSDV losses good opportunities for connectivity due to vehicles moving in the opposite direction. Using vehicles in the opposite direction just lasts for short duration due to the fast increase in the relative distance which consequently appears as spikes in our results. One approach to solving this problem at the physical layer is to use steerable antennas. Due to the high cost of this approach, we tried to solve this problem at the network layer. If DSDV routing protocol has the capability of distinguishing vehicles in the same and opposite directions with the help of GPS, this could help in their routing decisions by constructing routing tables of nodes in the same direction and avoid picking up vehicles in the opposite direction. Our proposed routing enhancement for the DSDV routing protocol is shown in Figure 62.

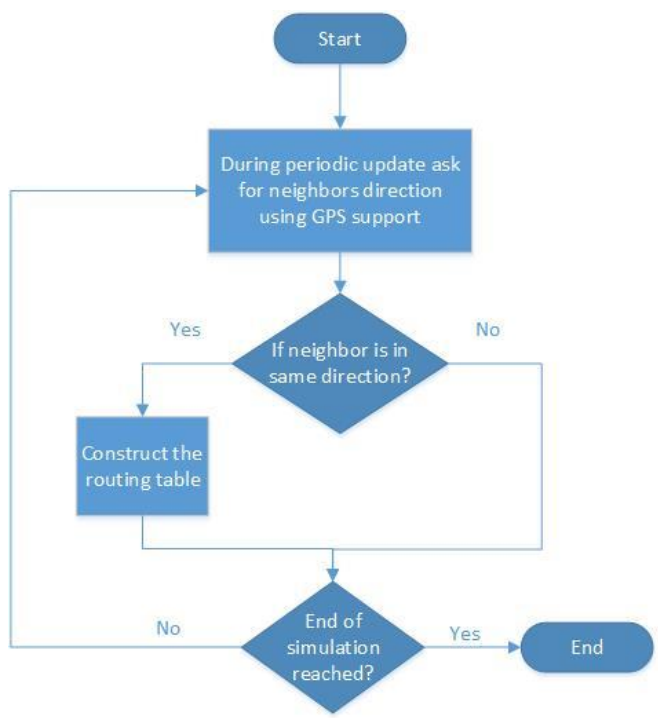


Figure 62 Enhanced DSDV routing proposal for online gaming

The same setup and simulation parameters were used to evaluate the performance of our enhanced routing protocol with the proposed mobility model. The results are quite promising for online gaming application over VANET but with limited scope. As shown in Figure 63, by excluding the vehicles in the opposite direction by our enhanced routing protocol, the connectivity lasts longer in this case compared with Figure 61. The performance metrics obtained in this case by AWK script are the throughput of 345.78, % packet loss of 1.64 and an average delay of 6.8ms. The results fulfill the requirements of online gaming applications.

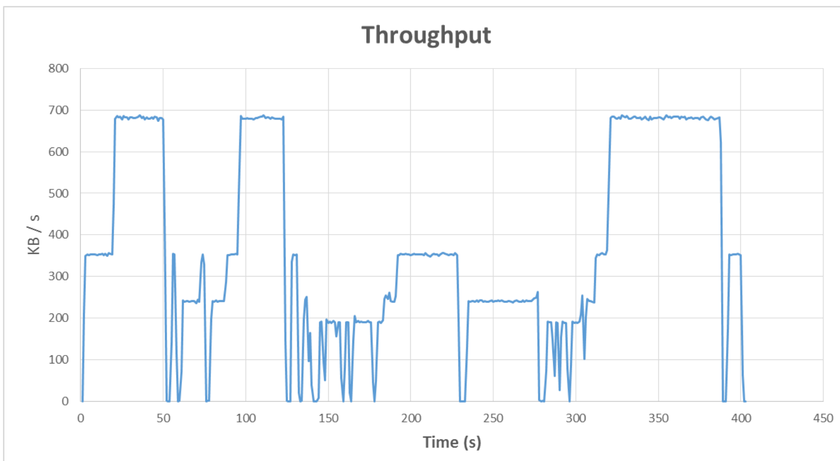


Figure 63 Effect of using proposed mobility and enhanced DSDV routing for online gaming

The effect of sending large payload size of 10KB on our proposed model is shown in Figure 64. Online games usually send shorter bursts for longer periods, thus by increasing the payload to 10KB, segmentation of packets takes place and we obtained the following performance metrics: throughput is 280.9 KB/s, % packet loss is 2.6 and the average delay is 5.4ms, which are considered very promising for an online gaming application.

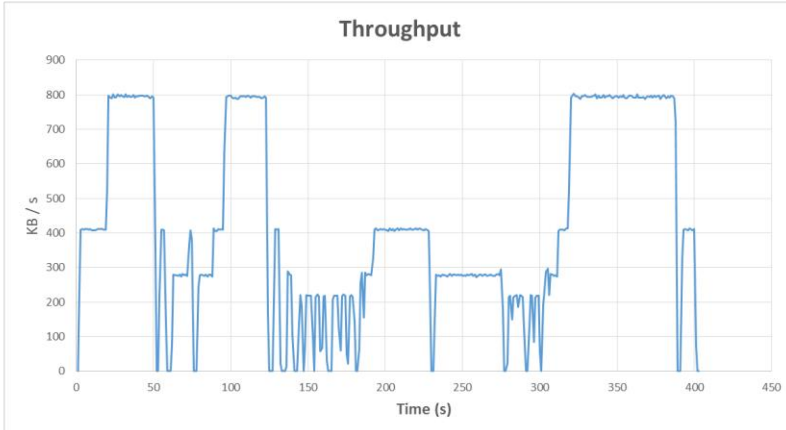


Figure 64 Effect of large packet size on our proposed model for online gaming

Games usually have multiple sessions, the effect of opening multiple sessions on the same vehicle (Node 3) is shown in Figure 65. The performance metrics, in this case, are as follows: the throughput is dropped to 79.5 KB/s, the % packet loss increased poorly to 28.3 and the delay increased to 35.8 ms. This is attributed to the channel switching between game sessions.

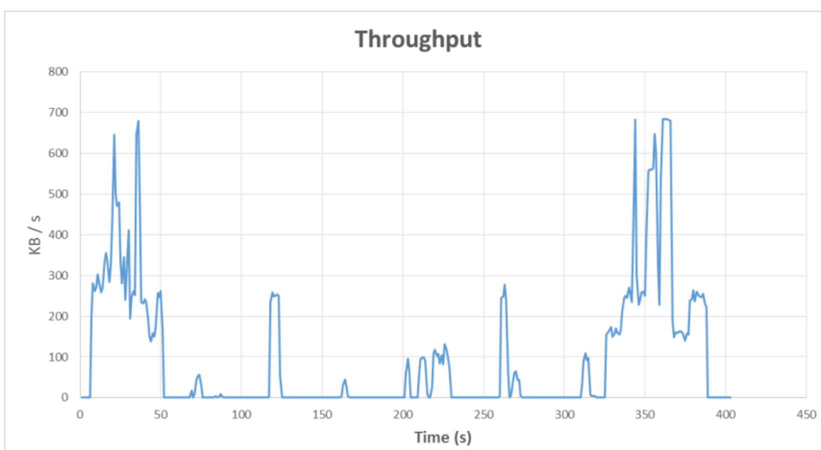


Figure 65 Effect of multiple session on the same node

Finally, the effect of multiple sessions but on different vehicles i.e. node 1 sending to node 3 while node 4 is sending to node 6 is shown in Figure 66. In this case, there is a little enhancement in performance metrics but still beyond the requirements of online gaming. The performance metrics obtained in this case are as follows: Throughput is 180 KB/s, %of packet loss is 21.7 and the average delay is 30 ms. This clearly indicates that the proposed system is not scalable for multiple sessions or for large vehicle density.

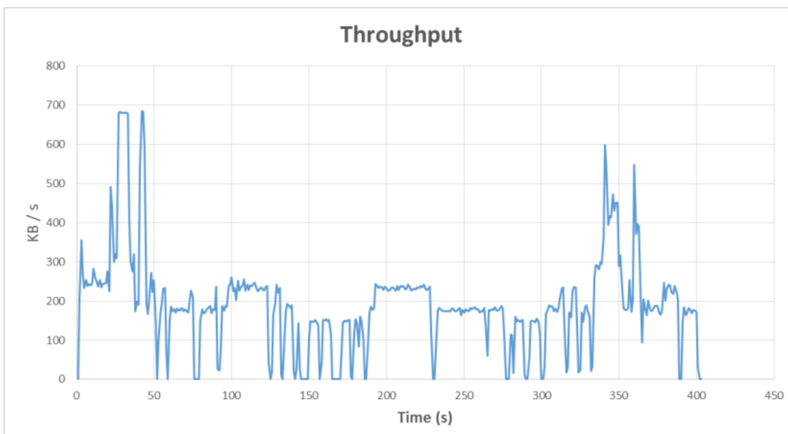


Figure 66 Effect of multiple session on different nodes

As stated earlier, the requirements of online gaming has been captured from real trace files of "First Shooter" games which has a very stringent delay requirement of less than 150ms and %Packet loss of less than 2% and an average traffic load on the network i.e. packet size less than 2KB. The outcome of the simulation results for our enhanced mobility model and DSDV routing protocol (Throughput=345.78 KB/s, % packet loss =1.64 and Average delay=6.8ms), are very promising compared with the online gaming requirements and hence proves the feasibility of online gaming over VANET.

5.5 Mathematical Modeling

The dynamic nature of VANET environment motivates the need for a suitable mathematical model to determine its ability of successful packet delivery (routing) and to analyze the network performance under different parameters. In this work, we present a simplified stochastic mathematical model to explain the effect of node density and vehicle speed on the path duration for the online games and compare the results with simulation.

In this model, we have used Poisson distribution to realize dynamic traffic environment in VANETs. We have used Poisson distribution because we are interested in finding the number of nodes present in a specified forwarding area given the mean density of nodes in the network area. We assumed that the arrival of each node is independent and the nodes in the network area are deployed in a two-dimensional space according to a spatial Poisson process as shown in Figure 67. The main goal of this section is to derive a mathematical expression for path duration between two vehicles by deriving other useful mathematical expressions such as an average number of hops and link duration. In this work, we use traditional traffic flow principle to describe the vehicular environment which will be more accurate for our path duration estimation. Vehicles are assumed to follow Poisson distributed arrivals for obtaining the probability distribution function (pdf).

5.5.1 Modeling Assumptions

In our proposed mathematical model, the following assumptions are made:

- Nodes are equipped with GPS receiver, digital map, and sensors.

- No other fixed infrastructure for communication is present.
- Transmission range for every node is same.
- The average speed of the nodes in the network is constant.
- Nodes are moving away from the source are in the same direction.

5.5.2 Mathematical Notations

The following notations are used to derive equations for path duration:

- R_1: Transmission range of nodes (omnidirectional).
- A: Region covered by transmission range.
- A_s: Selected region of the transmission range.
- ω: Node density.
- x: Number of nodes in the shaded region.
- n: Number of nodes selected out of x nodes.
- P_s: Probability of successfully selecting a node.
- q: Probability of not selecting a node.
- P_n: Probability for selecting at least n nodes in the shaded region.
- E_H: Expected number of hops between source and destination nodes.
- R_2: Distance between next-hop node and destination node.
- Z_1: Distance between source and next-hop node.
- V_R: Relative velocity between the source node and next-hop node.
- α_1 , α_2: Angle between R1 and SD / Angle between R2 and SD.
- θ: Relative angle between the source and next-hop node.

5.5.3 Mathematical Equations

In this part of our thesis, we try to formulate some mathematical equations that help us understand the dynamics of path duration and vehicles speed on our online gaming application. We have used a simplified model of a highway scenario to derive our mathematical equations for path duration between two vehicles by deriving other useful mathematical expressions and compare the results with simulation outcome.

The circle in Figure 67 shows the transmission range of the source node S. The Shaded region of the circle (A_1+A_2) can be used as the next hop border region. The next hope is selected from area A_2, because it is closest to destination node D. Here we have selected Greedy routing approach to select a next-hop node for the given shaded region. The area of interaction of the two circles, one with radius R_1 and the other with radius R_2 can be calculated as

$$A_s = A_1 + A_2 \tag{4}$$

where

$$A_1 = R_1^2 \,.\propto_1 - \frac{R_1^2 \,.\sin(2 \propto_1)}{2} \tag{5}$$

$$A_2 = R_2^2 \,.\propto_2 - \frac{R_2^2 \,.\sin(2 \propto_2)}{2} \tag{6}$$

The line joining the source node S to destination node D is the bisector of angle 90^o (α_1 = 45^o) therefore, area of shaded region, A_s, is given by

$$A_s = R_1^2 \,.\left[\frac{\pi - 2}{4}\right] + R_2^2 \left[\propto_2 - \frac{\sin(2 \propto_2)}{2}\right] \tag{7}$$

The angle α_2 depends on transmission range R_1 and distance between source and destination. As mentioned earlier, we assumed that nodes are two-dimensionally Poisson distributed over the network with node density ω. The number of nodes present in a selected region can be calculated as

$$Number\ of\ nodes = \omega\,.\,\text{Area of region} \tag{8}$$

If we denote X as a random variable of nodes in the region A_s, then the probability that x nodes are located in region A_s can be calculated as

$$P(X = x) = \frac{(\omega A_s)^x}{x!}.\,e^{-\omega A_s}\ , x = 0,1,2,3, \ldots. \tag{9}$$

Then, the probability of selecting n nodes out of x nodes is given by

$$P(Y = n) = \binom{x}{n}\ (P)^n (1 - P)^{x-n} \tag{10}$$

The presence of a node in the shaded area has two possibilities, either the node is selected with probability p_s or not selected with probability q ($1-p_s$). Assuming the probability of both cases is same i.e. $p_s = q = ½$. Then, according to [66] the probability of selecting exactly n nodes in the shaded region is given by:

$$P(n) = \sum_{x=n}^{\infty} \binom{x}{n}\ \ (P_s)^n\,(1 - P_s)^{x-n}\,.\frac{(\omega A_s)^x}{x!}.\,e^{-\omega A_s} \tag{11}$$

$$= \frac{(P_s\ \omega A_s)^n}{n!}.\,e^{-P_s \omega A_s}$$

Substituting the values of p_s =1/2 and A_s in the above equation gives

$$P(n) = \left(\frac{\omega}{2}\ \left\{R_1^2\ \left[\frac{\pi-2}{4}\right] + R_2^2 \left[\propto_2 - \ \frac{\sin(2\propto_2)}{2}\right]\right\}\right)^n \times \tag{12}$$

$$(n!)^{-1}.\ e^{-(\omega/2)\ \{R_1^2\ [(\pi-2)/4] + R_2^2 [\propto_2 -\ \sin(2\propto_2)/2]\}}$$

Similarly, the probability of choosing at least n nodes in the shaded region is will be given by

$$P_n = 1 - \sum_{i=0}^{n-1} \left(\frac{\omega}{2}\ \left\{R_1^2\ \left[\frac{\pi-2}{4}\right] + R_2^2 \left[\propto_2 - \ \frac{\sin(2\propto_2)}{2}\right]\right\}\ \right)^i \times \tag{13}$$

$$(i!)^{-1}.\, e^{-(\omega/2)\ \{R_1^2\ [(\pi-2)/4] + R_2^2 [\propto_2 -\ (\sin(2\propto_2)/2)]\}}$$

We can now get the probability P of having at least one node within the border region as

$$P = 1 - P\ (X = 0) \tag{14}$$

$$= \ e^{-(\omega/2)\ \{R_1^2\ [(\pi-2)/4] + R_2^2 [\propto_2 -\ (\sin(2\propto_2)/2)]\}}$$

5.5.3.1 Average Number of Hops between Source and Destination

The number of hops can be defined as the number of intermediate nodes in the route from source to destination. The number of hops should be as low as possible in order to decrease the chances of link breakage and hence, improve the path duration between nodes [67].

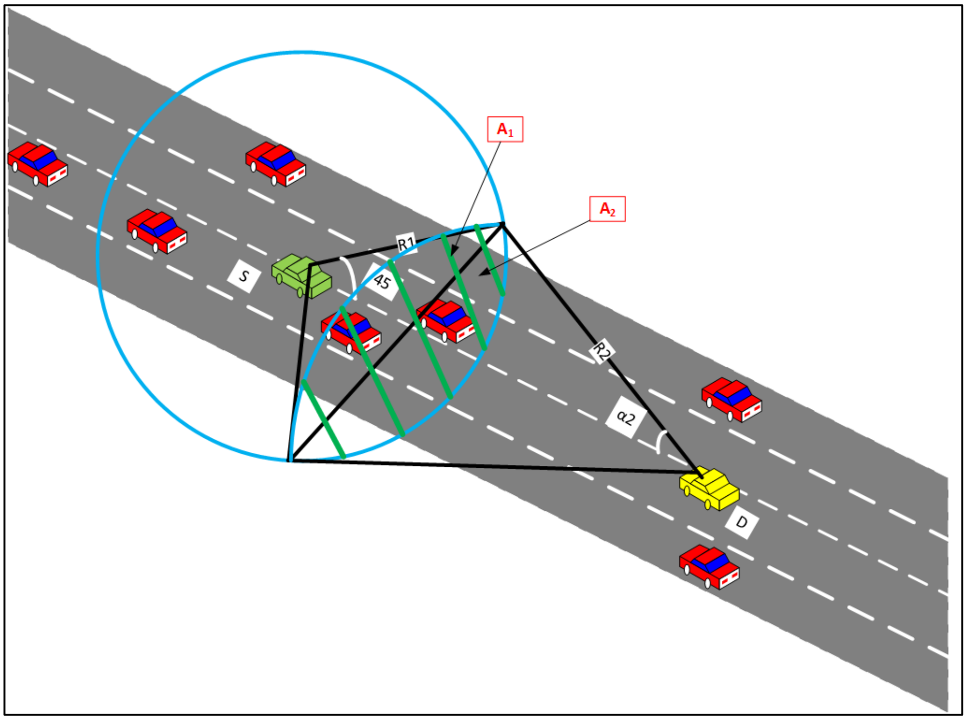


Figure 67 Simplified highway modeling

In order to find the average number of hop counts, we assume that nodes within the transmission range R follow the Poisson distributed model. If destination node is present in the sender's transmission range, then the probability of finding destination node is the same as the probability of finding next-hop node. Here, we assume that Z_1 is the distance between the source and next-hop node. Then the probability density function (pdf) of the link distance, $Z1$, between source and next-hop node is defined as [67].

$$f(\mathrm{Z}_1) = 2\,\pi\,\omega\,\mathrm{Z}_1\,.\,e^{-\pi\omega Z_1^2} \tag{15}$$

The distance between two nodes which provide a link to a route can be defined as the link distance. Link distance can be increased by increasing the distance between the source node and next-hop node towards borderline within the transmission range [68]. The probability of one-hop count can be calculated as

$$P(1) = \int_{0}^{R_1} f(\mathrm{Z1})\, dZ_1 = 1 - e^{-\pi\omega R_1^2} \tag{16}$$

As a result, the k-hop counts probability can be given as [68]

$$P(k) = \left[e^{-(k-1)^2\pi\omega R_1^2} - e^{-k^2\pi\omega R_1^2}\right] \times \left[1 - e^{-(\omega/2).A_s}\right]^{k-1} \tag{17}$$

Now we can calculate the expected number of hops, E_H, between source and destination as given below:

$$E_H = \sum_{H=1}^{k} HP(H) = P(1) + 2\,P(2) + 3P(3) + \cdots \ldots + \mathrm{k}\,P(k), \tag{18}$$

$$E_H = \sum_{H=1}^{k} H\left[e^{-(H-1)^2\pi\omega T^2} - e^{-H^2\pi\omega T^2}\right] \times \left[1 - e^{-(\omega/2)\,\left\{R_1^2\,[(\pi-2)/4] + R_2^2[\propto_2 - (\sin(2\propto_2)/2)]\right\}}\right]^{H-1} \tag{19}$$

5.5.3.2 Velocity of Nodes

The velocity of a node and the direction of movement are essential parameters for the calculation of the path duration in case of VANETs for online gaming. Link duration depends on the relative velocity of the nodes as it can increase the link distance between nodes. To calculate expected link duration, the relative velocity of the source node and next-hop node should be known. Let V_1 and V_2 be the velocity of source and next-hop nodes; then relative velocity V_R of the nodes can be calculated as:

$$V_R = \sqrt{V_1^2 + V_2^2 - 2 . V_1 . V_2 \; cos\,\theta} \tag{20}$$

where θ can vary from 0 to $\pi/2$ as the next hop node can move in the direction of destination only to maintain the communication link (link duration) between nodes. We assume that angle θ is uniformly distributed within (0, $\pi/2$), and pdf of $f_\theta(\theta)$ is $2/\pi$. Also assuming a constant average velocity of nodes, then the pdf of V_R,f $_{\mathrm{VR}}(V_R)$ can be given as

$$f_{V_R} = \frac{1}{\sqrt{1- \; sin^2\,(\theta|2)}} . \frac{2}{\pi} = \sqrt{\frac{4\,V^2 \;\; - V_r}{V}} \; . \; \frac{2}{\pi} \tag{21}$$

5.5.3.3 Link Duration

Link duration is the time for which the direct link between two nodes within the transmission range is active and it is part of the route. We have assumed that the border node will be selected for the next-hop node for each hop between the source and the destination. If the velocity of each node in the network is constant, then the link between the source and the next-hop node will always be maintained. Since we have assumed that Z_1 is the distance between source and next hop node within radius R_1, then the expected value of Z_1 [69] can be computed as

$$E_{Z_1} = \frac{nR_1}{(n+1)} \tag{22}$$

Therefore, link duration T can be expressed as

$$T = \frac{E_{Z_1}}{\mathrm{V_R}} = \frac{nR_1}{\mathrm{V_R}(n+1)} \tag{23}$$

The pdf of T, (T) is given by

$$f_T\ (T) = \int_0^V \mathrm{V_R}\ .\ f_{d_{V_R}}(V_R T, V)dv \tag{24}$$

$$= \int_0^V [E_{Z_1}] \left[\frac{2}{\sqrt{4V^2 - V_R^2}}\ .\ \frac{1}{\pi}\right]\ dv_r$$

5.5.3.4 Path Duration

To improve the performance of online gaming over VANET, path duration plays a key role in maintaining a good gaming experience. The path duration assists in the process of path selection during the transmission of a packet from source to destination. Path duration can be derived from the pdf of the link duration. Let T_1, T_2, T_3…, T_{E_H}denote the link duration of 1, 2, 3..., E_H hops, respectively. E_H is the average number of hops required to reach the destination as estimated in [70]. Finally, the path duration can be expressed as

$$\mathrm{T_{path}} = \mathrm{MIN}\ (\mathrm{T_1}, \mathrm{T_2},\ \mathrm{T_3} \ldots, T_{E_H} \tag{25}$$

Using Bayes' theorem [66], the pdf of $\mathrm{T_{path}}$ is

$$\mathrm{T_{path}} = E_H . E_Z . C_T^{E_H - 1} \tag{26}$$

Here, T represents the link duration and $C_T = 1 - F_T$ is the complementary cumulative density function (CDF) of T. Hence

$$\mathrm{T}_{\text{path}} = E_H . f_T(T) . \left[1 - \int_{T=0}^{\infty} f_T(T)\, dT \right]^{E_H - 1} \tag{27}$$

Finally, the average path duration can be calculated as

$$E_{\mathrm{T}_{\text{path}}} = \int_0^{\theta} \mathrm{T}_{\text{path}} . f\left(\mathrm{T}_{\text{path}}\right) . d\mathrm{T}_{\text{path}} \tag{28}$$

$$E_{\mathrm{T}_{\text{path}}} = \int_0^{\theta} \mathrm{T}_{\text{path}} . E_H . f_T(T) . \left[1 - \int_{T=0}^{\infty} f_T(T)\, dT \right]^{E_H - 1} . d\mathrm{T}_{\text{path}}$$

5.5.3.5 Comparing mathematical model and simulation results

The impact of velocity and density of nodes on path duration have been analyzed using both the mathematical model and the simulation results. For the mathematical model, we have focused on the equations of velocity and the node density and implemented it using MatLab. The mathematical estimation of path duration has been simulated using NCTUns 6.0 VANET simulator as shown in Figure 68. A set of five horizontal and vertical roads crossing each other was used as simulation area. The lane width used was 5m. The velocity was allowed to vary from 0 to 60Km. The packet size of 512 bytes, traffic type as CBR, wireless channel, omnidirectional antenna, 802.11p as a wireless standard, and 300s simulation time. The average of ten different simulation runs was reported for the selected metrics for different source and destination.

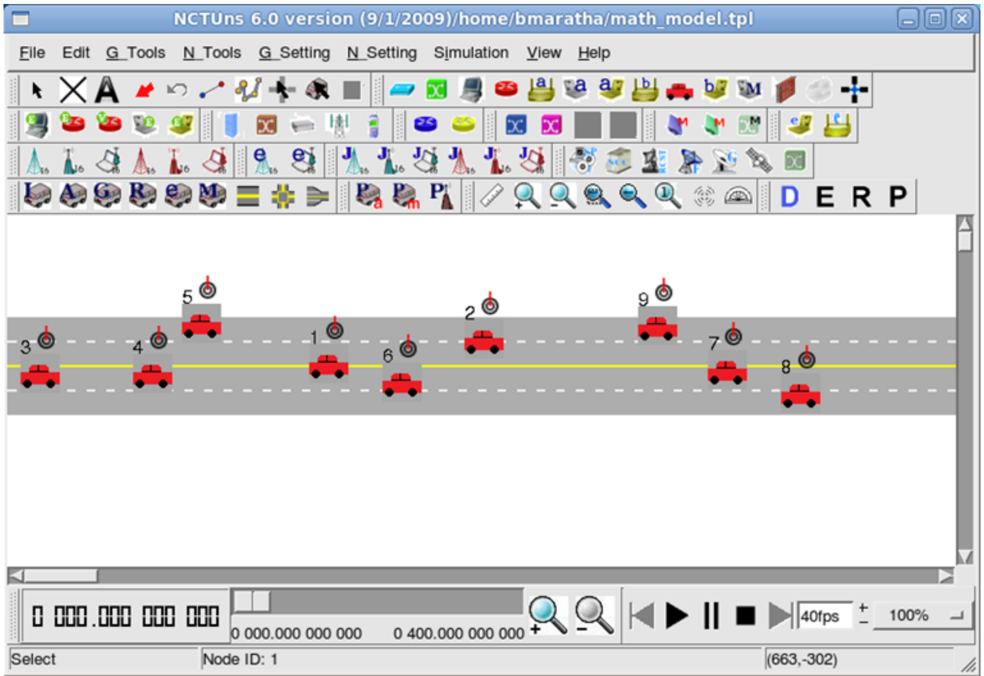


Figure 68 Simplified highway modeling

Node density is an essential parameter for path duration due to the possibility of finding an alternative next-hop node and is increased with the increased number of nodes. Figure 69 shows the effect of node density on average path duration. By increasing the node density in a given area also increases path duration. However, the results also convey that, for a given node density, increasing the number of hops in the path decreases average path duration. The closeness between analytical and simulation results for hops = 15 is smaller as compared to hops = 10 due to the increment in the network dynamics with increasing number of hops.

The impact of high velocity of vehicles on average path duration is depicted in Figure 70. The high velocity of nodes makes vehicles in and out of transmission range of the source node, which causes most of the link or path breakage in the network.

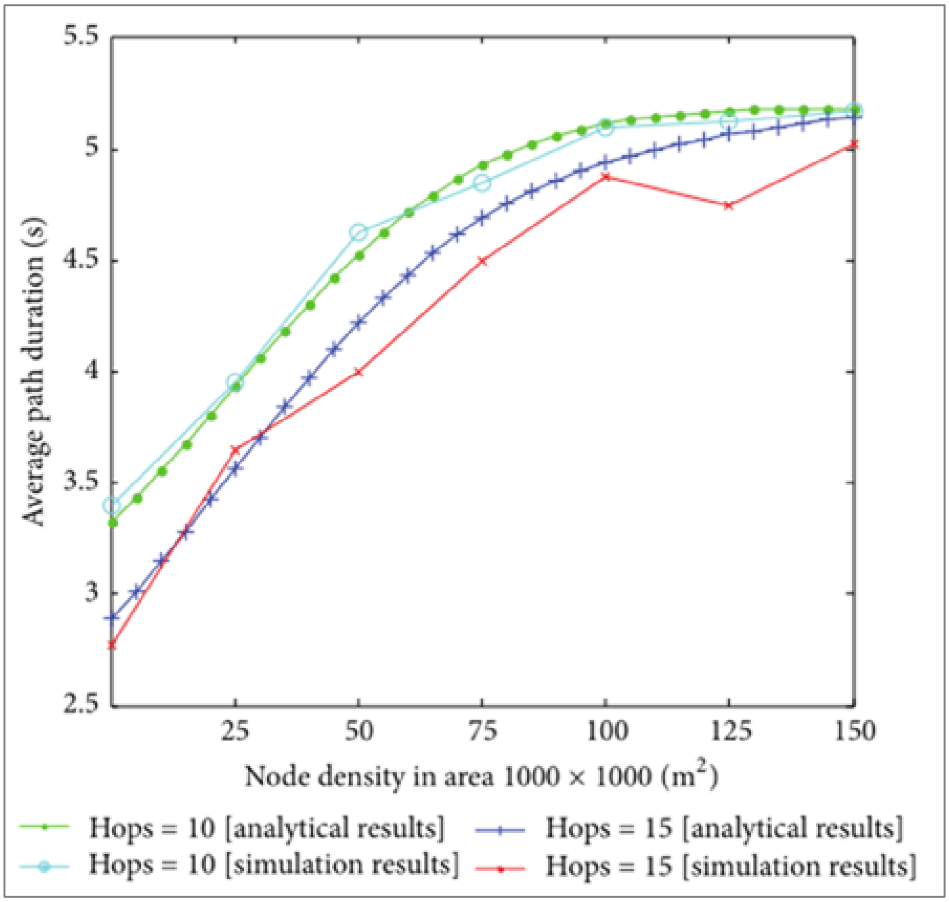


Figure 69 Path duration versus node density

It can be observed that increasing the velocity of nodes decreases the path duration. This can be attributed to the fact that increasing the velocity of nodes in the network increases the probability of link failure which ultimately decreases average path duration. Moreover, it also reveals that increasing the number of hops for a given velocity decreases average path duration due to the increment in the number of links in the path that again increases the probability of link failure. In this case, the simulation results are very close to the analytical results.

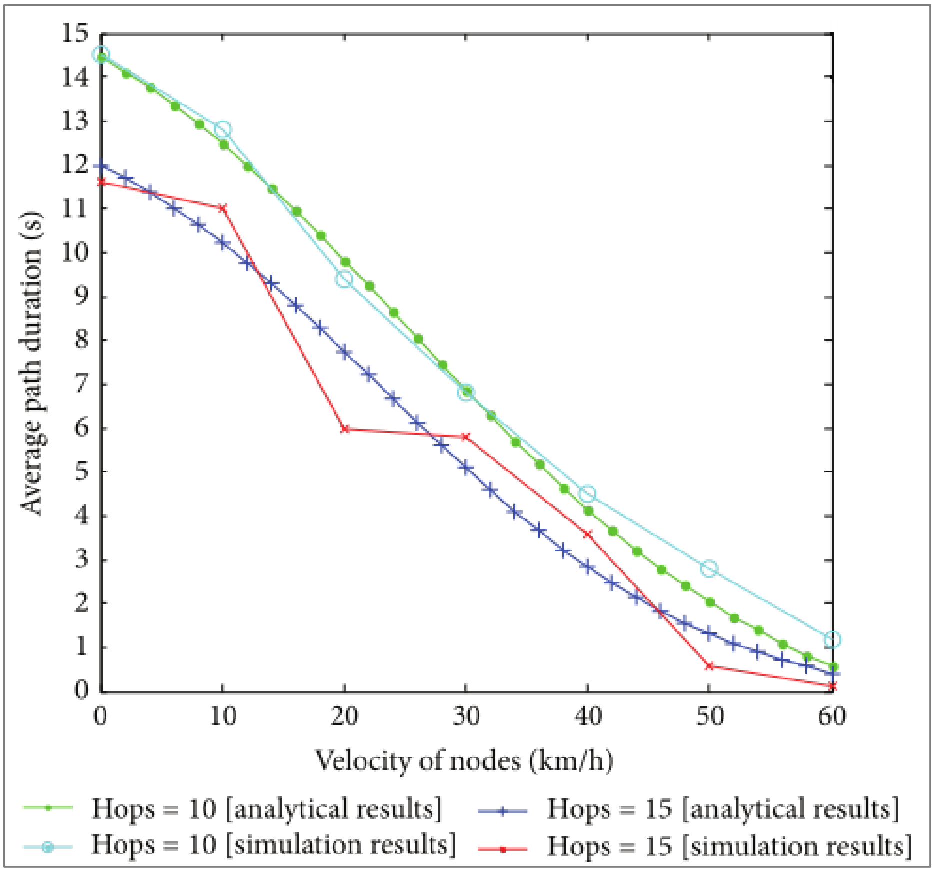


Figure 70 Path duration versus velocity

5.6 Summary

In this chapter, we have presented the main contribution of our thesis namely feasibility of online gaming over VANETs. After getting insight about the requirements of online gaming in terms of traffic flow (Packet size), delay constraints to maintain an enjoyable gaming experience and percentage of allowed packet drops, we were at a stage to evaluate the performance of online gaming over VANET. We have decided to use DSDV routing protocol due to its best performance in lower node density scenarios in terms of throughput and end to end delay while maintaining the packet drop limit. Here we considered a group of six vehicles moving in the same direction towards their destination in a highway scenario. First, the scenario was tested using the default mobility model of NCTUns 6.0 VANET simulator in which vehicles move freely and can go several hops away from their destination with no interaction between them to adjust their speed. The performance was very poor due to the increase in the disconnection period. Secondly, we test our proposed mobility model by incorporating driver behavior to adjust vehicle's speed if it is five hops away from their destination. The performance was drastically improved due to long connection period between source and destination. Finally, we enhance the drawback of DSDV of periodic updates to all vehicles and restricted that to only vehicles moving in the same direction and the performance was further enhanced and being within the requirements of online gaming.

In addition, a simple mathematical model has been presented as an evidence to compare the results of our VANET simulator and the results shows almost the same trend. In VANET, there is no mathematical model yet standardized due to the high dynamic nature of the network and the environment, and only very specific models exists for certain scenarios under study. Thus in this work, we modeled a simple gaming experience of a group of vehicles and derive some useful mathematical equations for average path duration as a function of node density and vehicle speed. These results have been compared with the outcome of VANET simulator tool, namely NCTUns 6.0. Researchers could benefit from the derived equations and use them in other similar scenarios or even be very helpful when trying to standardize a mathematical model for VANET in a bigger project such as ITS.

Finally, the field of VANET has not been standardized yet and many proposed works in routing or even gaming, highly dependent on the scenario in hand and the type of application namely, safety, traffic management, or entertainment. Safety applications has the highest priority in using the channel bandwidth and has some reserved channel allocation. They use a very stringent routing protocol called Wave Short Message Protocol (WSMP) and exchange Wave Short Messages (WSM) between nodes. For traffic management and control applications such as congestion control or weather forecast there are two options to use from, either the IP network or the WSMP. For Comfort and entertainment applications, only the IP stack can be used for routing and message exchange. Thus even if VANET works for safety applications and being tested well, it does not mean it will work for other applications as well. This is because the environment might be different (Highway, City, Rural), routing is different, channel allocation is different and performance metric is different as well. The requirements of online gaming applications over VANETs are very challenging, such as stringent delay requirement for enjoyable gaming experience, reliable path duration and session management in a multi hop communication and focus on performance metric such as average end to end delay, jitter and % of packet loss. Usually online gaming is played over the internet in a client server architecture and this model is no more valid with VANET which prefers a decentralized architecture i.e. P2P. The thesis work has been tied to the online gaming applications via the use of real trace files of the most stringent games namely, “First shooter” and scanning the requirements of internet online gaming. The outcome of our simulation study after deploying the requirements of online gaming over VANET architecture and preparing an environment to closely resemble a group of vehicles in a gaming experience in a highway scenario was very promising in terms of the selected performance metrics.

CHAPTER 6

CONCLUSION AND FUTURE WORK

Due to the rapid advancement in wireless technologies especially the IEEE 802.11p standard, a new form of communication between vehicles known as VANET has become an active research area in the last couple of years. It allows vehicles to communicate among themselves and with roadside units to play a key role in enhancing the traditional transportation system and participate in a future project known as Intelligent Transportation System (ITS). Many applications can be designed to benefit from this kind of communication such as safety, traffic management, and comfort as well as entertainment. Safety and traffic management applications have been addressed a lot in the literature while entertainment applications have been given a little focus due to the lack of matured algorithms and routing protocols to fulfill their requirements. Thus the goal of this thesis was to seek the feasibility of a new type of applications namely, online gaming over VANET and evaluate its performance in terms of throughput, the percentage of packet drops and average end to end delay. To fulfill this goal, first, we literature reviewed the VANET architecture on which online gaming will operate, its challenges and the best wireless technologies available for it. Secondly, we scanned the literature for the requirements of online gaming in terms of acceptable delay, packet loss, and traffic payload. Thirdly, and the most important is to identify issues in both MANET and VANET routing protocols and select the best for online gaming applications. After an intensive literature review on topology based and position-based routing protocols, we decided to use topology based routing protocols and evaluate their performance for use in VANET for online gaming. The reason for selecting topology based routing protocol was that, these protocols are matured enough and being tested well for different environments. In addition, these protocols have been approved by IETF (Internet Engineering Task Force) for deployment by many network simulators. Many researchers proved that topology based routing does not suit VANET dynamics and this is because they do not have a mechanism to capture node locations. With some modification and integrating with GPS, these routing protocols could be greatly enhanced and used in VANET. Finally, different simulation tools and mobility models have been surveyed and compared for use in our study.

Recognizing the challenges and opportunities the VANET environment implies for online gaming, we have proposed a mobility model to increase the connectivity period among vehicles by adding an extra feature called driver behavior to the mobility model. In addition, we have enhanced the DSDV routing protocol by integrating them with a GPS device to exclude opposite direction traffic and reduce the overhead of periodic updates. Based on our performance evaluation of online gaming with proposed mobility and enhanced routing protocol, we found that the results were very promising (Throughput=345.78 KB/s, % Packet loss=1.64 and Average delay=6.8ms) for such applications in terms of selected metrics.

Although a large amount of research work has been devoted in the literature on routing protocols which represent the key to the success of VANET communication, still there are some areas that need more attention. Due to time constraint, we have only focused on traditional ad-hoc (topology based) and position-based routing protocols, but still, there are other routing protocol categories that need more investigation. Some of the future work are listed below:

- Several other routing methods such as broadcast, geocast, and cluster based routing methods can be considered for the evaluation of routing protocols in VANET for online gaming.
- Different position based routing protocols should be evaluated in the real environment of VANET to check their efficiencies in a real situation.
- New algorithms should be proposed to provide reliable QoS for safety and comfort applications in VANET.
- Other performance metrics such as jitter, average routing overhead etc. should be measured for both topologies based and position based routing methods in VANET.

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