Sudan University of Science and Technology

College of Graduate Studies

School of Electronics Engineering

Performance Evaluation of Voice over the Vehicular Ad-Hoc Network using the Optimized Link State Routing Protocol

تقويم الأداء للصوت عبر شبكات المركبات اللامركزية باستخدام برتوكول توجيه حالة امثلة الارتباط

A research submitted in partial fulfillment for the requirements of the M.Sc. degree in Computer and Network Engineering.

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بسم الله الرحمن الرحيم

قال تعالى:

﴿إِنْ أُرِيدُ إِلَّا الْإِصْلَاحَ مَا اسْتَطَعْتُ
وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾

صدق الله العظيم

سورة هود الآية ٨٨

Dedication

To

Endless love

My mother

To

Man who teaches me to be a man

My father

To

My brothers and Sisters

To

My teachers & My colleagues

Acknowledgements

First, I need to thank fully our **God (Allah)** that without his blessing this work will not complete.

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My deepest thanks to all the staff in the School of Electronics Engineering and the College of Graduate Studies at Sudan University of Science and Technology who contributed in many ways to make this project a memorable and an enriching experience.

Finally, I thank my family, who constantly supported and encouraged me throughout the course of my studies.

Abstract

Voice over Internet Protocol (VoIP) provides good services through Vehicular Ad-hoc Networks (VANET) platform. These networks encounter various challenges to support voice calls with acceptable Quality of Service (QoS). The Optimized Link State Routing Protocol (OLSR) is used in order to investigate the performance for VoIP application in VANET network. The research aims to evaluate network performance for moving vehicles after configured it to work properly in suitable environment in order to obtain accurate data and analyze QoS parameters for each different case. The network was tested before and after running OLSR algorithm, the tests focused on QoS parameters such as end-to-end delay, delay variation (jitter) and probability of packet loss between two moving hops through multi-hop Ad-hoc networks in different scenarios using the ITU G.711 VoIP codec. After measured the end-to-end delay, jitter and probability of packet loss for two nodes the algorithm decreased delay with 18.72%, while decreased jitter about 20.42% and decreased packet loss about 56.25%. However, The OLSR shown initial good performance for four hops and when added more hops the delay exceeded 400ms which is not acceptable according to ITU-T recommendations. This was achieved by implementing a test bed to obtain desired results rather than use a simulation.

المستخلص

يقدم الصوت عبر بروتوكول الإنترنت (VOIP) خدمات جيدة من خلال منصات شبكات المركبات اللامركزية، هذه الشبكات تواجه تحديات مختلفة لكي تدعم مكالمات الصوت بجودة مقبولة. تم استخدام بروتكول توجيه حالة الإرتباط الأمثل للتحقق من أداء تطبيقات شبكات الصوت عبر بروتكول الإنترنت لشبكات المركبات اللامركزية. يهدف البحث لتقيم الشبكة بين عدد من المركبات المتحركة بعد ان تمت تهيئتها للعمل جيدا في بيئة مناسبة من اجل الحصول على بيانات دقيقة وتحليل معاملات جودة الخدمة وتحليلها لكل حالة مختلفة. تم إختبار الشبكة قبل وبعد تشغيل خوارزمية بروتكول توجيه حالة الإرتباط الأمثل، ركز الإختبار على بعض معاملات جودة الخدمة كالتأخير بين كل طرف والأخر, وإختلاف التغيير وإحتمالية فقدان الحزمة بين نقطتين متحركتين خلال الشبكات اللامركزية لحالات مختلفة بإستخدام ترميز الصوت G.711 عبر بروتكول الإنترنت المستخدم بواسطة الإتحاد العالمي للإتصالات. بعد قياس التأخير بين كل طرف والأخر وإختلاف التغيير وإحتمالية فقدان الحزمة بين النقطتين تم تقليل التأخير على الأقل بنسبة 18.72%، بينما التباين بحوالي 20.42%، وكما تم تقليل إحتمالية فقدان الحزمة بحوالي 56.25 %. لكن بروتكول توجيه حالة الإرتباط الأمثل أظهر أداء أولي جيد في حالة خمسة نقاط أما في حالة إضافة المزيد من النقاط فإن التأخير يتجاوز 40 ملي ثانية والتي تعتبر غير مقبولة وفقاً لتوصيات الإتحاد العالمي للاتصالات. وقد تحقق ذلك عن طريق تنفيذ وسط إختبار لإستخلاص النتائج المرجوة بخلاف إستخدام المحاكاة.

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Abbreviations

4G	Fourth Generation
16QAM	16 Quadrature Amplitude Modulation
64QAM	64 Quadrature Amplitude Modulation
AODV	Ad-hoc On Demand Distance Vector
AU	Application Unit
BPSK	Binary Phase Shift Keying
DSRC	Dedicated Short Range Communication
E2E	End to End
EDCA	Enhanced Distributed Channel Access
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GSM	Global System Mobile
HTTP	Hypertext Transfer Protocol
I2I	Infrastructure to Infrastructure
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IPv4	Internet Protocol version 4.
ITS	Intelligent Transportation Systems
ITU-T	International Telecommunications Union Telecommunication
LBS	Location Based Services
MAC	Medium Access Control
MANET	Mobile Ad hoc Networks
MATLAB	Matrix Laboratory
MPR	Multipoint Relays
NIC	Network Interface Card
OBU	On Board Unit
OLSR	Optimized Link State Routing Protocol
PCM	Pulse Code Modulation
PDA	Personal Digital Assistant
PDR	Packet Delivery Ratio

QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
RSU	Roadside Unit
RTP	Real Time Transport Protocol
SIP	Session Initiation Protocol
SMTP	Simple Mail Transfer Protocol
TCP	Transmission Control Protocol
UA	User Agent
UDP	User Datagram Protocol
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VANETs	Vehicular Ad hoc Networks
VHF	Very High Frequency
VOIP	Voice Over Internet Protocol
VOVAN	VOIP Over VANET
WAVE	Wireless Access in Vehicular Environments
WLANs	Wireless Local Area Networks
ZRP	Zone Routing Protocol

CHAPTER ONE

INTRODUCTION

Chapter One
Introduction

1.1. Preview

Wireless communications become significantly available and inexpensive with the development of various network technologies, such as Wireless Local Area Networks (WLANs) and 4G cellular system, all of which promise rapid advancements of Intelligent Transportation Systems (ITS) witnessing the global development of smart cities and provide new attractive and cost effective services to users. As a key component of ITS and smart cities, Vehicular Ad hoc Networks (VANETs) are attracting enormous attentions of more and more institutes and companies.

Mobile ad hoc networks (MANETs) are autonomous networks consisting of mobile nodes equipped with wireless communication and networking capabilities communicating without network centralized infrastructure [1].

VANETs are specific class of MANETs providing real-time information that could be useful for keeping people connected in urban environments or highways in a clear advance to safer and comfort driving. However, such networks introduce several constraints like the high mobility of the nodes, frequently changing topology, hard delay [2]. These characteristics distinguish them from other mobile ad hoc networks.

VANET is a type of networks that is created from the concept of establishing a network of cars for a specific need or situation. VANETs have now been established as reliable networks that vehicles use for communication purpose on highways or urban environments. Along with the benefits, there arise a large number of challenges in VANET such as provisioning of QoS, high connectivity and bandwidth and security to vehicle and individual privacy.

Voice over Internet Protocol (VoIP) is one of the most important technologies that allow making voice calls through Internet connection. As it is well known, the quality of service is important for VoIP applications they especially require limited end-to-end delay and low packet loss rate [3]. The ultimate objective of VoIP is to deliver high-quality voice service, which is comparable to what is provided in traditional circuit-switching networks. When considering the problem of transmitting VoIP traffic over wireless networks, numerous challenges are encountered. Due to the deficiency in the wireless media access methods, the delivery of VoIP often leads to unpredictable delay and packet-loss performances.

1.2. Problem Statement

Providing real-time VoIP services on VANET is a difficult task due to restrictions in device resources, adverse properties of the wireless channel, dynamic topology and the lack of central administration. Because of these limitations, there is a challenge to meet the Quality of Service (QoS) of VoIP in terms of packet delivery ratio (PDR) and end-to-end (E2E) delay that has to be within an acceptable range.

1.3. Aim and Objectives

The aim of this project is to analyze voice traffic to manage the route in order to achieve a better performance and better resource utilization of the network, and to guarantee a certain quality for the carried traffic.

The objectives of the project are:

- prepare suitable environment for moving vehicles.
- establish network between moving hops.
- Design OLSR algorithm for VANET network.
- Generate voice traffic in network and measure metrics of network nodes.
- Collect a real data form this network.
- analyze the QoS parameters for each different case.

1.4. Proposed Solutions

In order to provide real-time VoIP services, a test has been implemented using the OLSR. Many metrics be used in order to describe the characteristics of signaling and media streams according to QoS parameters. The various QoS parameters stated as bandwidth, cost, end -to-end delay, delay variation (jitter), throughput, probability of packet loss, battery charge, processing power etc. Research is going on towards performance improvement by emphasizing any of these parameters.

1.5. Methodology

To assess the performance of the proposed scheme a test bed has been implemented which including, Linux OS, OLSR Switch Agent to create the VANET network, Ekiga Software to generate real voice traffic, Wireshark to capture RTP packets and Matlab to analyze the results. to measure of delay and packet loss determines whether the chosen protocol provides acceptable Performance on the network. End-to-end delay and packet loss results are observed and compared to recommended values for acceptable VoIP quality.

1.6. Thesis Outline

Chapter one provides short Introduction; discuss Problem statement, proposed solution, and Objectives. While, Chapter two reviews Voice over the Vehicular for Ad-Hoc Network. then Chapter three explains overall system and methodology to test this system. Chapter four includes Results and Discussions. Finally, Chapter five contains Conclusion and Recommendations for Future Work.

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CHAPTER TWO

BACKGROUND AND LITERATURE REVIEW

Chapter Two
Background and Literature Review

2.1. Introduction

This chapter gives a general background and overview about the concept of VANET, Voice over IP, Session Initiation Protocol, OLSR algorithm; providing the information that must be taken into account in order to develop and understand this research.

2.2. Wireless Networks

Wireless communication can be via different media such as ultrasound, infrared or electromagnetic radio waves. Radio waves are the most suitable for Location-Based Services (LBS) as the other media have more problems e.g. with walls and other obstacles [4]. Common wireless networks today can be classified by two means. One classifier is the network range which is also induced by the network's purpose and the physical limitations of radio waves. The other classifier is the networks topology, whether the network consists of a large infrastructure of mostly immobile network nodes and the mobile client's access only the nodes or the clients form an "Ad-Hoc" network by being the nodes themselves [5]. Figure 2-1 shows wireless networks classifications.

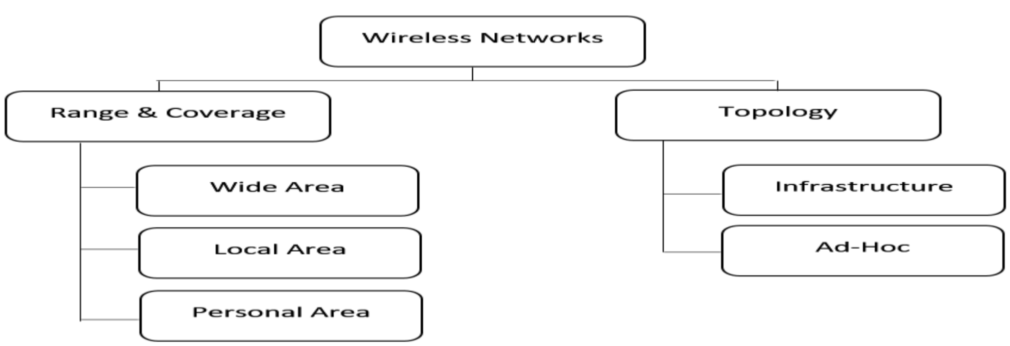


Figure 2-1: Types of Wireless Networks.

2.3. Wireless Network Topologies

Radio waves do have a limited range no matter which technologies and thus what ranges can be reached with a wireless radio transmission, for establishing communication between multiple components as a network three strategies are available: cellular infrastructure networks, Ad-Hoc networks and hybrid networks.

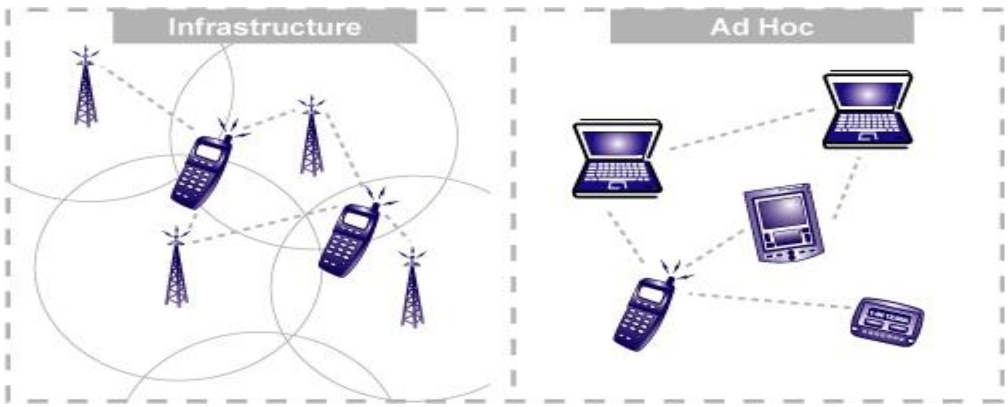


Figure 2-2: Infrastructure and Ad-Hoc Wireless Networks.

2.3.1. Cellular Infrastructure Networks

Cellular Infrastructure Networks are probably the most common way of overcoming the limited range problem. The mobile terminals, e.g. cell phone or Personal Digital Assistant (PDA), communicate with base station. The base stations themselves are again connected to a network which can also be connected to other networks like the internet. Cell phone technologies like Global System Mobile (GSM) work exactly this way. Usually is the base station network covering a whole country. In dense populated areas there are usually more base stations then on the countryside where fewer buildings or other obstacles are interfering with the propagation of the radio waves [5].

2.3.2. Ad-Hoc Networks

Ad-Hoc Networks are linking devices like computers or PDAs connected directly without a base station or access point. Common examples are Bluetooth devices communicating with each other or mobile computers which use just their wireless network capabilities to exchange data directly. To overcome the limited range problem, devices can not only do their own communication but act also as relay-station and forward other messages [5].

2.3.3. Hybrid Networks

Hybrid Networks are combining the two above technologies. Thus a cellular network can be extended into regions where no base station is reachable. The base stations can also then provide access to other networks like the internet.

2.4. Ad hoc Networks Classification

A wireless ad hoc network is a collection of autonomous nodes or terminals that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner. Since the nodes communicate over wireless links, they have to contend with the effects of radio communication, such as noise, fading, and interference. In addition, the links typically have less bandwidth than in a wired network. Each node in a wireless ad hoc network functions as both a host and a router, and the control of the network is distributed among the nodes [6].

The network topology is in general dynamic, because the connectivity among the nodes may vary with time due to node departures, new node arrivals, and the possibility of having mobile nodes. Hence, there is a need for efficient routing protocols to allow the nodes to communicate over multi-hop paths consisting of possibly several links in a way that does not use any more of the network resources than necessary.

2.4.1. Mobile Ad-Hoc Networks (MANETs)

In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users. Significant examples include establishing survivable, efficient, dynamic communication for emergency/rescue operations, disaster relief efforts, and military networks. Such network scenarios cannot rely on centralized and organized connectivity, and can be conceived as applications of Mobile Ad-Hoc Networks. A MANET is an autonomous collection of mobile users that communicate over relatively bandwidth constrained wireless links. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network is decentralized, where all network activity including discovering the topology and delivering messages must be executed by the nodes themselves, i.e. routing functionality will be incorporated into mobile nodes [5].

2.4.2. Vehicular Ad-Hoc Networks (VANETs)

VANET is one of the sub branches of MANET technology. In Mobile Ad hoc Network (MANET) each mobile is considered as node whereas in VANET each vehicle is considered as a node VANET is a technology that uses moving cars as nodes in a network to create a mobile network. VANET turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and, in turn, create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a mobile Internet is created. Fixed equipment can belong to the government or private network operators or service providers [7].

Vehicular Ad-Hoc Network (VANET) is considered as a backbone for all applications and attracted many researchers from both industry and academia all over the world [8],[9]. VANET has the potential to improve vehicle safety on the roads, efficiency of traffic and comfort to commuters [10]. In VANETs, the information exchange occurs among vehicles not only in an ad-hoc based Vehicle-to-Vehicle (V2V) communication but also in a Vehicle-to-Infrastructure (V2I) and Infrastructure-to-Infrastructure (I2I) communication as shown in Figure 2-3

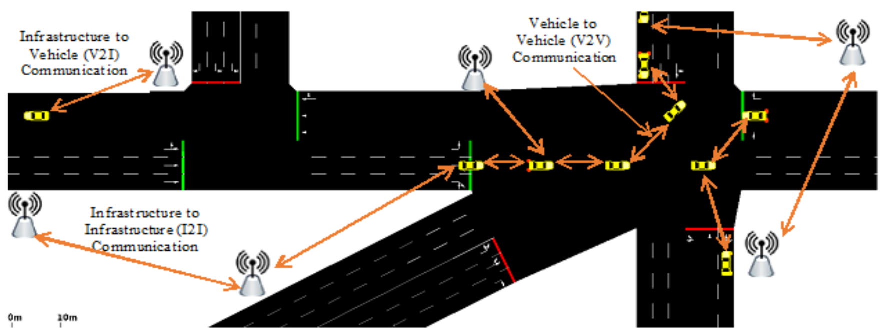


Figure 2-3: Vehicular Ad-Hoc Networks.

VANETs can be utilized for a large range of safety, no safety and comfort applications. These applications include a kind of value added services such as enhanced navigation, automated toll payment, traffic management, vehicle safety and location-based service.

2.5. VANET Architecture

The basic main components of VANET are the AU, OBU and RSU [11]. The RSU's are communication units located on the roadsides where as OBU's are communication units mounted on vehicles. The RSU may act as host application that provides services and the OBU is a peer device that uses the services provided by the RSU through AU. The application may reside in the RSU or in the OBU; the device that hosts the application is called the service provider and the device using the application is described as the user. Each vehicle is equipped with an OBU and a set of sensors to collect the information and then send it as a message to other vehicles or RSUs through the wireless medium. The RSU can also connect to the Internet or to another server which allows OBUs of multiple vehicles to connect to the Internet.

2.5.1. On Board Unit (OBU)

An OBU is a device usually mounted on a vehicle, which is used for exchanging information with RSUs or with other OBUs of different vehicles. It consists of resources which includes a memory used to store and retrieve information, a user interface, a specialized interface to connect to other OBUs and a network device for short range wireless communication based on IEEE 802.11p radio technology. These devices are connected through wireless link based on the IEEE 802.11p radio frequency channel. The main functions of the OBU are wireless radio access, ad hoc and geographical routing, network congestion control, reliable message transfer, data security and IP mobility [12].

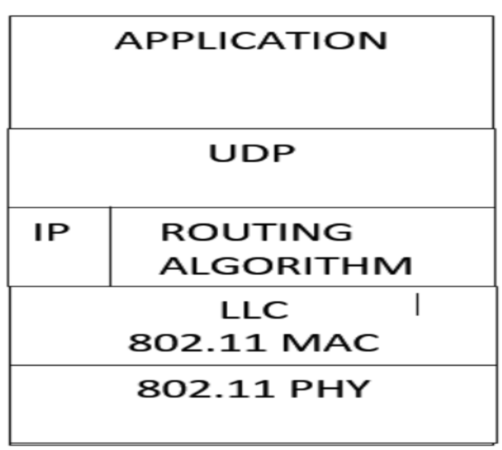


Figure 2-4 OBU Node on a Vehicle.

2.5.2. Roadside Unit (RSU)

In MANET, the nodes will move randomly whereas, in VANET the nodes move in well-defined path. The routing used in VANET are proactive routing, reactive routing, hybrid routing. The vehicle with VANET application contains positioning system, communication facility, and human-machine interface in the vehicle. A vehicle with all these facilities will reduce the number of accidents and the data sharing will be more confidentiality, integrity, and availability. All this are done by using the fixed infrastructure called Roadside Unit (RSU). The Roadside unit is responsible to register the vehicle who wants to participate in VANET to form a group. It connects to internet and produces the needed information for the user, when the vehicle is connected to particular nearby RSU.

2.5.3. Application Unit (AU)

Application Unit (AU) executes the program making OBUs communicational capabilities. The AU is the device equipped within the vehicle that uses the applications provided by the provider using the communication capabilities of the OBU. The AU can be a dedicated device for safety applications or a normal device such as a personal digital assistant (PDA) to run the Internet, the AU can be connected to the OBU through a wired or wireless connection. The distinction between the AU and the OBU is logical. The AU communicates with the network solely via the OBU which takes responsibility for all mobility and networking functions [13], [14].

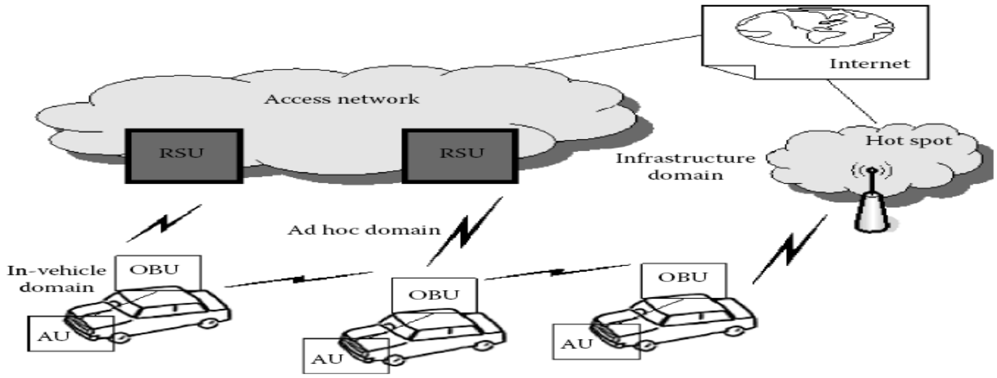


Figure 2-5: VANET Components [7]

2.6. Communication Types in VANET

In VANET, Vehicle to Vehicle (V2V) communication, Vehicle to Infrastructure (V2I) communication, Infrastructure to Infrastructure (I2I) communication also called Hybrid communications are the main research goals of ITS

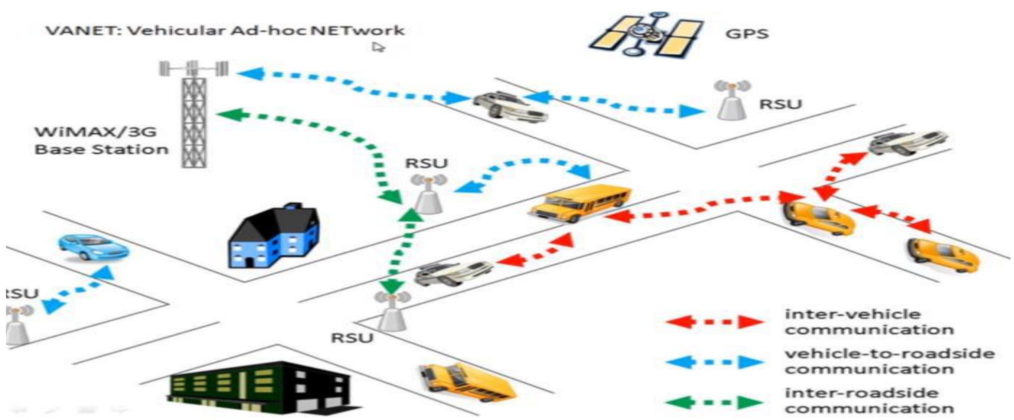


Figure 2-6: Types of VANET Communications [13].

2.6.1. Vehicle to Vehicle Communication

Allows the direct vehicular communication without relying on a fixed infrastructure support and can be mainly employed for safety, security, and dissemination applications, V2V communication has Advantages as:

- Allows short and medium range communication.
- It does not need any roadside infrastructure.
- Less cost.
- It supports short message delivery.
- It minimizes latency in communication link.
- It is fast and reliable and provides real time safety.

And has Disadvantages as:

- Frequent topology partitioning due to high mobility.
- Problems in long range communication.

2.6.2. Vehicle to Infrastructure Communication

In vehicle to infrastructure allows a vehicle to communicate with the roadside infrastructure mainly for information and data gathering applications. It is also called as Ad Hoc domain on VANET [15]. Figure 2-7 shows how one vehicle communicates with another vehicle directly if there is a direct wireless connection available between them, forming a single hop vehicle to vehicle communication (V2V). When there is no direct connection between them a dedicated routing protocol is used to forward data from one vehicle to another until it reaches the destination point, forming multi-hop vehicle to vehicle communication. Vehicle communicates with RSU in order to increase the range of communication by sending, receiving and forwarding data from one node to RSU to process special application forming vehicle to infrastructure.

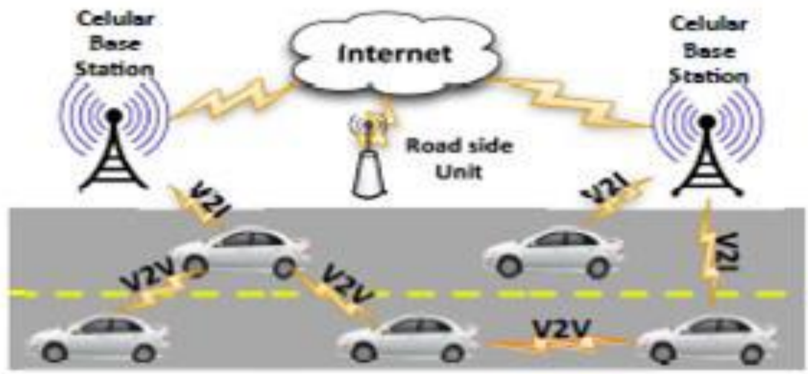


Figure 2-7: Hybrid Communication.

2.6.3. Infrastructure to Infrastructure (I2I/RSU to RSU) Communication

RSU connects to the internet and produces needed information for user, when the vehicle is connected to nearby RSU [16]. The vehicle with VANET application contains the positioning system which identifies the nearby RSU. Once the vehicle identifies the nearby RSU, it sends the hello packet to get the conformation. All information will be provided to user, when they are registered in RSU (for sending warning information between two vehicles there is no need of registration.

2.7. VANET Challenge

A VANET has some particular features despite being a special case of a MANET and presenting some similar characteristics, such as low bandwidth, short transmission range and omnidirectional broadcast:

• **Highly dynamic topology**: a vehicular network is highly dynamic due to two reasons: speed of the vehicles and characteristics of radio propagation. Vehicles have high relative velocities in the order of 50 km/h in urban environments to more than 100 km/h in highways. They may also move at different directions. Thus, vehicles can quickly join or leave the network in a very short period of time, leading to frequent and fast topology changes.

• **Frequently disconnected**: the highly dynamic topology results in frequent changes in its connectivity, thus the link between two vehicles can quickly disappear while they are transmitting information;

• **Geographical communication**: vehicles to be reached typically depend on their geographical location. This differs from other networks where the target vehicle or a group of target vehicles are defined by an ID or a group ID.

• **Constrained mobility and prediction**: VANETs present highly dynamic topology, but vehicles usually follow a certain mobility pattern constrained by roads, streets and highways, traffic lights, speed limit, traffic conditions, and drivers' driving behaviors. Thus, given the mobility pattern, the future position of the vehicle is more feasible to be predicted.

• **Propagation model:** typically, VANETs operate in three environments: highway, rural, and city. In a highway, the propagation model is usually assumed to be free-space, but the signal can suffer interference by the reflection with the wall panels around the roads. In a city, its surroundings make the communication complex due to the variable vehicle density and the presence of buildings, trees, and other objects, acting as obstacles to the signal propagation. Such obstacles cause shadowing, multi-path, and fading effects. Usually, the propagation model is assumed to not be free-space due to those characteristics of the communication environment. In rural environments, due to the complex topographic forms (fields, hills, climbs, dense forests, etc.), it is important to consider the signal reflection and the attenuation of the signal propagation.

2.8. Protocol Stack for VANETs

The protocol stack for vehicular networks has to deal with communication among nearby vehicles, and between vehicles and fixed roadside equipment considering their distinct characteristics. Since there is no coordination or prior configuration to set up of a VANET, there are several challenges in the protocol design. In the following sections, we discuss protocols for VANETs according to each layer of the network architecture.

2.8.1. Physical Layer

Protocols for the physical layer have to consider multipath fading and Doppler frequency shifts caused by fast movements of nodes among roadway environment. Experimental vehicle-to-vehicle communications have used radio and infrared waves [17]. Very high frequency, micro, and millimeter waves are examples of radio waves used for V2V communications. Both infrared and millimeter waves are suitable only for line-of-sight communications, whereas VHF and microwaves provide broadcast communications. In particular, VHF supports long-range links at low speeds and, because of that, the trend is to use microwaves.

Defined specifically to VANETs, the DSRC (Dedicated Short-Range Communication) system is a short to medium range communication technology that operates in the 5.9 GHz band for the use of public safety and private applications [18]. Therefore, in the United States, the Federal Communications Commission (FCC) allocated 75MHz in the 5.850–5.925 GHz band for DSRC, in contrast to the European Telecommunications Standards Institute (ETSI), which allocated 70MHz in the 5.855–5.925 GHz band. The DSRC system supports a vehicle speed up to 200 km/h, nominal transmission range of 300m (up to 1000 m), and the default data rate of 6 Mbps (up to 27 Mbps).

DSRC is known as IEEE 802.11p WAVE (Wireless Access in Vehicular Environments), designed based on earlier standards for Wireless LANs [19].

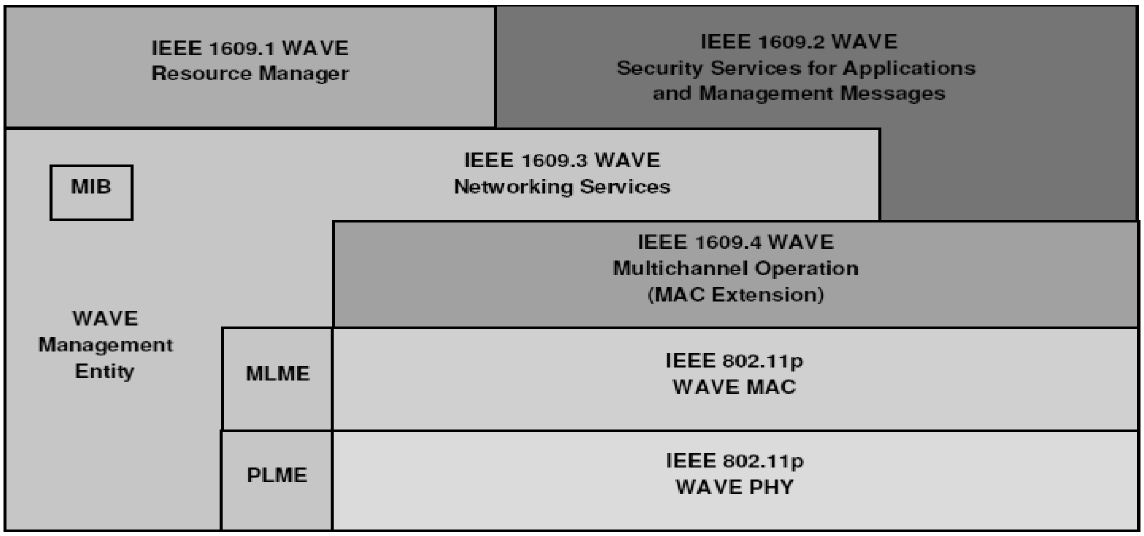


Figure 2-8: The IEEE 1609 (WAVE) Reference Architecture and Relationship to the IEEE 802.11p MAC and Physical Layers.

Table 2-1: Comparison of PHY Parameters in IEEE 802.11a and IEEE 802.11p.

Parameters	**IEEE 802.11a**	**IEEE 802.11p**	**Changes**
Channel bandwidth	20 MHz	10 MHz	Half
Bit rate (Mbps)	6,9,12,18,24,36 ,48,54	3,4.5,6,9,12,1 8,24,27	Half
Modulation Mode	BPSK, QPSK,16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM	No change
Number of subcarriers	52	52	No change
Symbol duration	4µs	8µs	Double
Guard Interval Time	0.8µs	1.6µs	Double

2.8.2. MAC Layer

The MAC layer has to provide a reliable, fair and efficient channel access. MAC protocols should consider the different kinds of applications for which the transmission will occur. For instance, messages related to safety applications must be sent quickly and with very low failure rates. This calls for an efficient medium sharing, which is even more difficult in VANETs due to high node mobility and fast topology changes. MAC protocols for VANETs [20] have to deal with the hidden station problem, which frequently shows up in scenarios where vehicles form long rows causing a decrease on the data transfer. For the adaptation of IEEE 802.11a to IEEE 802.11p, no changes in the MAC layer have been done. The MAC protocol used in 802.11p is the same as in 802.11a, the Enhanced Distributed Channel Access (EDCA), which is an enhanced version of the basic access mechanism in IEEE 802.11 using QoS [21], [22].

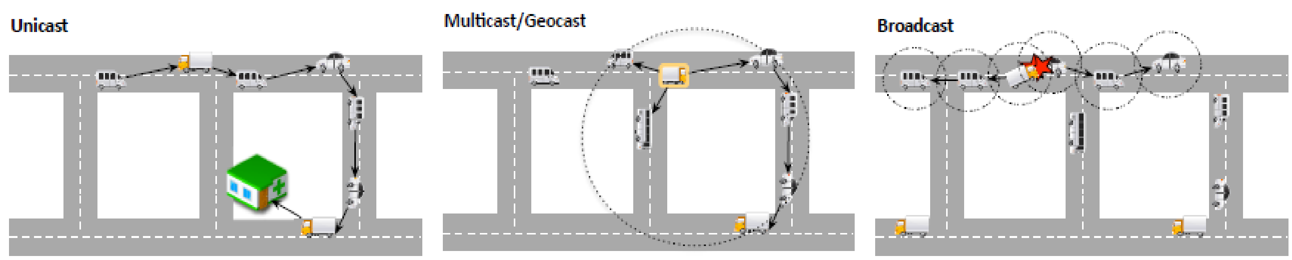
2.8.3. Network Layer

In the network layer, the routing protocol has to implement strategies that provide a reliable communication and do not disrupt the communication. Vehicular networks support different communication paradigms. These can be categorized as follows:

• **Unicast communication**: the main goal is to perform data communication from a source node to a target node in the network via multi-hop wireless communication. The target node may be at either a precise known location or an approximate location within a specified range. Despite the unicast communication to be a useful mode in VANETs, multicast is more suitable for applications that require dissemination of messages to different nodes in the network [23].

• **Multicast/Geocast communication**: the main goal is to perform data communication from a source node to a group of target nodes. Geocast is a specialized form of multicast addressing, in which a message is sent to a group of target nodes in a particular geographic position, usually relative to the source of the message.

• **Broadcast communication**: the main feature is to have a source node sending information to all neighbors' nodes at once. The neighbors' nodes that receive the broadcast message forward it through a new broadcast in order to deliver a message to the target nodes. Broadcast is also used at the discovery phase of some routing protocols in unicast communication paradigm in order to find an efficient route from the source vehicle to the target vehicle [23].



(a) Unicast (b) Multicast/Geocast (c) Broadcast

Figure 2-9: Different Communication Scenarios in VANETs.

Topology-based protocols use information about communication paths for packet transmission. In this case, every node maintains a routing table, which is the case of routing protocols for MANETs. Topology-based protocols can be further divided into proactive (table-driven) and reactive (on-demand).

2.8.4. Transport and Applications Layers

As mentioned above, vehicular networks are characterized by intermittent connectivity and rapid topology changes. In contrast with other ad hoc networks, VANETs present more predictable mobility patterns. In these scenarios, vehicles connecting to an access point at higher speed have few seconds to download information in an environment with high losses that decrease the performance of both TCP and UDP protocols [24].

2.9. Ad-hoc Mobile Routing Protocols

Routing protocols between any pair of nodes within an ad-hoc network can be difficult because the nodes can move randomly and can also join or leave the network. This means that an optimal route at a certain time may not work seconds later. Discussed below are three categories that existing ad-hoc network routing protocols fall into: Table Driven Protocols, On Demand Protocols and Hybrid Protocols [25].

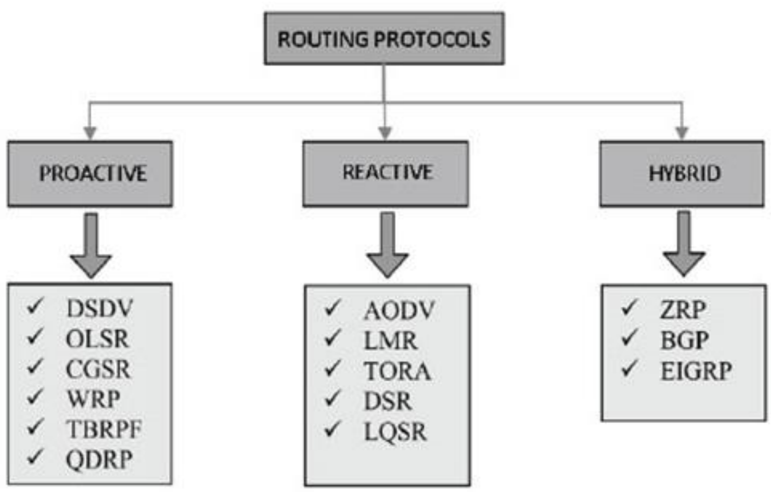


Figure 2-10: Classifications of Wireless Networks.

2.10. The Optimized Link State Routing Protocol

The Optimized Link State Routing Protocol (OLSR) is developed for mobile ad-hoc networks. It operates as a table driven, proactive protocol, i.e. exchanges topology information with other nodes of the network regularly. Each node selects a set of its neighbor nodes as "multipoint relays" (MPR). In OLSR, only nodes, selected as such MPRs, are responsible for forwarding control traffic as shown in figure 2-11, intended for diffusion into the entire network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required [26].

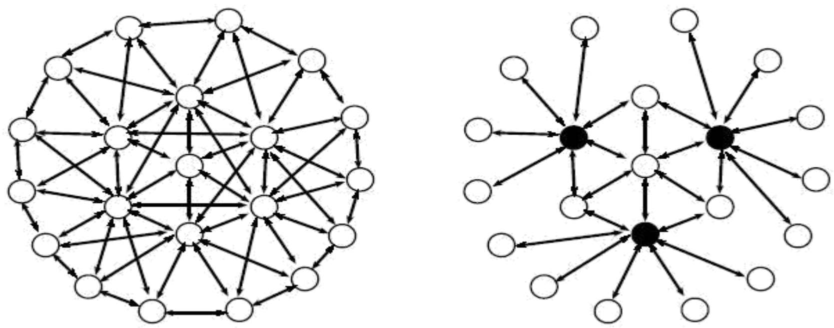


Figure 2-11: Multipoint Relays.

Nodes, selected as MPRs, also have a special responsibility when declaring link state information in the network. Indeed, the only requirement for OLSR to provide shortest path routes to all destinations is that MPR nodes declare link-state information for their MPR selectors. Additional available link-state information may be utilized, e.g. for redundancy.

Nodes which have been selected as multipoint relays by some neighbor node(s) announce this information periodically in their control messages. Thereby a node announces to the network, that it has reachability to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. Furthermore, the protocol uses the MPRs to facilitate efficient flooding of control messages in the network. A node selects MPRs from among its one hop neighbors with "symmetrical", i.e. bidirectional, linkages. Therefore, selecting the route through MPRs automatically avoids the problems associated with data packet transfer over unidirectional links (such as the problem of not getting link-layer acknowledgments for data packets at each hop, for link layers employing this technique for unicast traffic). OLSR is developed to work independently from other protocols. Likewise, it makes no assumptions about the underlying link-layer. It inherits the concept of forwarding and relaying from HIPERLAN (MAC layer protocol) which is standardized by ETSI. The protocol is developed in the IPANEMA project (part of the Euclid program) and in the PRIMA project (part of the RNRT program) [26].

2.10.1. Protocol Applicability

OLSR is a proactive routing protocol for mobile ad-hoc networks (MANETs). It is well suited to large and dense mobile networks, as the optimization achieved using the MPRs works well in this context. The larger and denser network, the more optimization can be achieved as compared to the classic link state algorithm. OLSR uses hop-by-hop routing, i.e. each node uses its local information to route packets.

OLSR is well suited for networks, where the traffic is random and sporadic between a larger set of nodes rather than being almost exclusively between a small specific set of nodes.

As a proactive protocol, OLSR is also suitable for scenarios where the communicating pairs change over time: no additional control traffic is generated in this situation since routes are maintained for all known destinations at all times.

2.11. VOIP Over VANET (VOVAN)

Voice over Internet Protocol (VoIP), It is also called Internet protocol Telephony, Internet telephony or Digital Phone. VoIP is a technology for communicating using “Internet protocol” instead of traditional analogue systems. Some VoIP services need only a regular phone connection, while others allow you to make telephone calls using an Internet connection instead. Some VoIP services may allow you only to call other people using the same service, but others may allow you to call any telephone number including local, long distance, wireless and international numbers.

2.11.1. VoIP Transcoding

To transport voice over a data network, the speech source alternates between talking and silence period which is typically considered to be exponentially distributed. The speech will enter to the digitalization process that is composed of sampling, quantization and encoding. The encoded speech is then packetized into packets of equal size preparing them for transmission over IP network. In the receiver side, encoded speech will be comprised by the payload for certain duration depends on the codec deployed, then reverse process is performed (packetized and decoded).

The first step for voice communication is the application of a voice CODEC (Coder/Decoder) which is a device and/or software program that is used typically to digitally encode an analog voice waveform. Various encoding techniques have been developed and standardized by the International Telecommunications Union (ITU-T). Table 2-2 shows some of the commonly used ITU-T standard CODECs, and lists their attributes. Generally, Coding process involves converting the incoming analog voice pattern into a digital stream and converting that digital stream back to an analog voice pattern at the ultimate destination. The objective of a codec is to obtain the lowest rate bit stream possible after conversion without degrading the quality of the signal such that the received audio signal can be generated without noticeable differences in quality. CODECs generate constant bit-rate audio frames consisting of 40 bytes IP/UDP/RTP headers followed by a relatively payload. Voice traffic has a very stringent delay and packet loss constraint. However, CODECs add additional delay to the total network delay that will influence the speech quality.

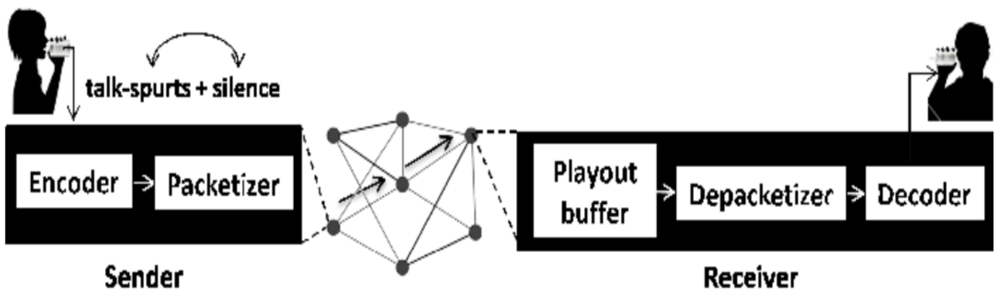


Figure 2-12: VoIP System Over MANETs [27].

Table 2-2: Voice CODECs Description.

Codec	**Bit rate (kbps)**	**Sample size (bytes)**	**Packets per second**	**Payload size (bytes)**
G.711	64	80	50	160
G.723.1	5.3	20	33.3	20
G.726	32	20	50	80
G.729A	8	10	50	20

2.11.2. Advantages of VoIP Service

For provider saving bandwidth (Packet switching). Open standard and multivendor interoperability (Can use any vender product without compromising functionality). Integrated voice and data (need only single network) for user cheaper call. Increase functionality (multiple numbers, incoming call automatically routed to IP-phone wherever it is plug-in).

2.12. Internet Protocol Architecture

Internet Protocol (IP) is responsible for the delivery of packets (or datagrams) between host computers. IP is a connectionless protocol, that is, it does not establish a virtual connection through a network prior to commencing transmission; this is the job for higher level protocols.

IP makes no guarantees concerning reliability, flow control, error detection or error correction. The result is that datagrams could arrive at the destination computer out of sequence, with errors or not even arrive at all. Nevertheless, IP succeeds in making the network transparent to the upper layers involved in voice transmission through an IP based network.

Any Voice over IP transmission must use IP, which is not well suited to voice transmission. Real time applications such as voice and video require guaranteed connection with consistent delay characteristics. Higher layer protocols address these issues to a certain extent.

The diagram below shows the header that precedes the data payload to be transmitted. In its most basic form, the header comprises 20 octets. There are optional fields which can be appended to the basic header, but these offer additional capabilities which are not necessary for VoIP transmission as described in this document.

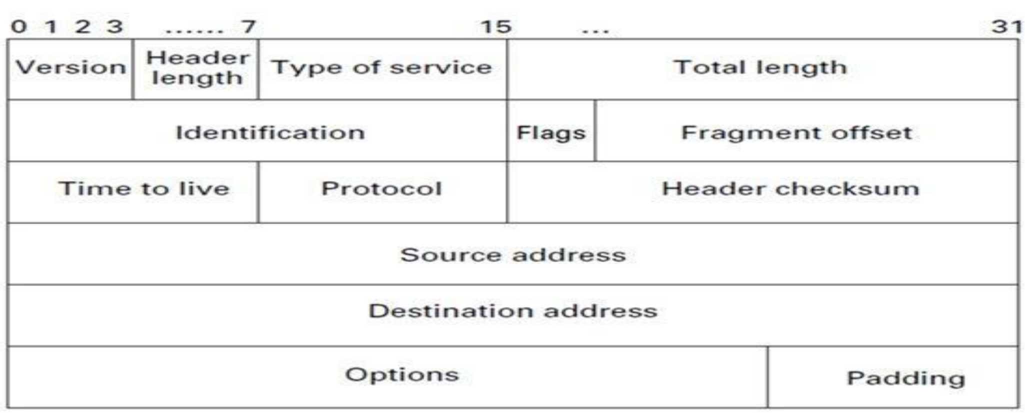


Figure 2-13: IPV4 Header.

2.13. Session Initiation Protocol

The Session Initiation Protocol (SIP) is a signaling protocol for initiating, managing and terminating voice and video sessions across packet networks. SIP sessions involve one or more participants and can use unicast or multicast communication. Borrowing from ubiquitous Internet protocols, such as Hypertext Transfer Protocol (HTTP) and Simple Mail Transfer Protocol (SMTP), SIP is text-encoded and highly extensible. SIP may be extended to accommodate features and services such as call control services, mobility, interoperability with existing telephony systems, and more [28]. SIP is being developed by the SIP Working Group, within the Internet Engineering Task Force (IETF). The protocol is published as IETF RFC 2543 and currently has the status of a proposed standard.

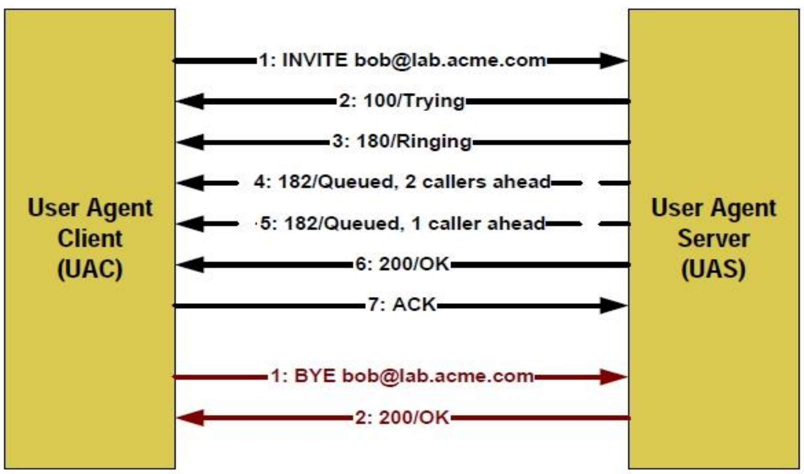


Figure 2-14: SIP Session Establishment and Call Termination.

2.13.1. SIP Entities

A SIP network is composed of four types of logical SIP entities. Each entity has specific functions and participates in SIP communication as a client (initiates requests), as a server (responds to requests), or as both. One physical device can have the functionality of more than one logical SIP entity. For example, a network server working as a Proxy server can also function as a Registrar at the same time. Following are the four types of logical SIP entities:

- **User Agent:** In SIP, a User Agent (UA) is the endpoint entity. User Agents initiate and terminate sessions by exchanging requests and responses.
- **Proxy Server:** A Proxy Server is an intermediary entity that acts as both a server and a client for the purpose of making requests on behalf of other clients. Requests are serviced either internally or by passing them on, possibly after translation, to other servers. A Proxy interprets, and, if necessary, rewrites a request message before forwarding it.
- **Redirect Server:** A Redirect Server is a server that accepts a SIP request, maps the SIP address of the called party into zero (if there is no known address) or more new addresses and returns them to the client. Unlike Proxy servers, Redirect Servers do not pass the request on to other servers.

2.14. Performance Metrics

Performance metrics are used to establish the performance of systems. The performance metrics are delay, packet loss, jitter, throughput, and number of route calculations.

Evaluating performance in a VANET for VoIP traffic requires end-to-end delay and packet loss be minimized since VoIP applications are sensitive to any type of latency and packet loss. These metrics are compared to the recommended values for each to determine whether OLSR can support VoIP traffic in a VANET [29].

2.14.1. End-to-End Delay

Delay is measured from the instant a packet leaves the sender's Network Interface Card (NIC) to the instant it is received at the destination's NIC. According to the International Telecommunications Union (ITU) Recommendation delay in VoIP applications should never exceed 400ms otherwise the quality of the VoIP stream is significantly degraded. However, the average delay for a VoIP stream should be less than 150ms for acceptable perceived quality [30]. This end-to-end delay includes any time needed to calculate a new route and other routing delays such as router (i.e., another ad hoc node) processing and queuing delays.

2.14.2. Packet Loss

VoIP applications are sensitive to packet loss. Even though VoIP applications tolerate packet loss up to 10%, a packet loss of 1% still affects the quality of the VoIP stream [31]. Packet loss is measured as the present of packets dropped at the receiver prior to data stream playback.

2.14.3. Jitter

When referring to VoIP applications, jitter occurs when packets are received with variances in delay. Packets can arrive out-of-order due to these delay variances or because of routing (i.e., a packet travels a different route than a prior packet). Variances in delay are due to packet position in queues along the path from source to destination. One packet could experience minimal queuing delays while the packet sent after it experiences long queuing delays along the same path, this affects the quality of streaming audio like VoIP. Jitter buffers at the receiver temporarily store packets to mask the variances in delay. Jitter, in this study, is measured at the receiver and does not assume any jitter buffers.

2.14.4. Throughput

Throughput is the total number of bits that are sent through the channel per second. The channel is the ad hoc network, thus, throughput is the maximum number of bits that can be sent per second through the ad hoc network.

2.15. Related Works

In May 2012 Said El Brak ; Mohammed. Bouhorma ; Anouar Abdelhakim. Boudhir and Mohamed El Brak published paper “Voice over V ANETs (Vo V AN): QoS Performance Analysis of Different Voice CODECs in UrbanV ANET Scenarios” In this paper, approach is based on VoIP over VANETs (VoVAN) by simulation. For this task, a performance evaluation of various voice CODECs and its impact on quality of service metrics will be analyzed, focusing on inter vehicular voice communication. To achieve good results, the mobility information obtained from vehicular traffic generator which is based on the real road maps of an urban environment. Results of the simulations are presented in terms of both network level (such as E2E delay) [32].

In April 2013 Said El Brak, Mohammed Bouhorma, Mohamed El Brak and Anouar Bohdhir published paper “Speech Quality Evaluation Based Codec For Voip Over 802.11P” This paper is organized as follows overviews VANETs and provides technical aspects such as architecture, routing and MAC protocols, presents VoIP Service over vehicular networks it shows the methodology for the simulation. Results and performance analysis, and comparisons [33].

In December 2013 Kalpana Gurung and Hari Mohan Singh publish paper “Performance Analysis of Different Voice CODECs in Integrated VANET-UMTS Wireless Network by using H.323”, in this paper study is based on inter-vehicle communication over VANET, various voice CODECs behaviour was tested and analyzed the impact of varying traffic condition on the performance of QoS of VoIP, Results of simulations are presented in the terms of average jitter, average end-to-end delay, average throughput, average delay [34].

In August 2014 Ekta Agrawal and Kanojia Sindhuben Babulal publish paper “Evaluation of Voice Codecs of VoIP Applications for MANET” In this paper in this paper estimated the performance of various VOIP codecs with WiMAX in different scenarios (sparse and dense) over MANET. Voice codecs are evaluated with some QoS metrics such as average jitter, average throughput, average delay and signal received with error. The performance & quality of VOIP applications using H.323 signaling protocol in Qualnet simulator [35].

In 2015 Tanuja K,Sushma T M,Bharathi M and Arun K H published paper “A Survey on VANET Technologies” This paper provides a broad survey on difference between MANET and VANET, VANET architectures components, VANET communication domains, wireless access technologies, VANET characteristics, challenges and VANET applications. This paper aims to provide the key concepts of VANET to the researchers [36].

In August 2015 Khalid Hamid Bilal published paper “Performance Evaluation of Ad-hoc On Demand Distance Vector (AODV), OLSR

Routing Protocol in VOIP Over Ad Hoc “This paper investigates the performances of routing protocols (AODV, OLSR) in MANETs carrying VoIP traffic. Via a simulation study we analyze and evaluate some QoS indicators like bandwidth, end- to-end delay and packet loss. Using Network Simulator (ns2), several voice codecs are studied to determine their effect on metrics QoS [37].

In April 2015 Shivani Attri published paper “Performance Analysis of OLSR and DSR Routing Protocols for Static Wireless Sensor Networks (WSN)” In this paper, an attempt has been made to evaluate the performance of OLSR and DSR routing protocol using Random Waypoint model, and also investigate how well these selected protocols performs on WSNs, in static environments, using OPNET 16.0 Simulation tool. The performance analysis of these protocols will focus on the impact of the network size and the number of nodes. The performance metrics used in this work are throughput, average end-to-end delay and network load [38].

In 2016 Vinita Jindal1 and Punam Bedi published paper “Vehicular Ad-Hoc Networks: Introduction, Standards, Routing Protocols and Challenges” This paper provides a broad survey on the development of communication standards, routing protocols and major challenges for Vehicular Ad hoc NETworks (VANETs) [39].

In March 2017 Subodh Kumar, G.S. Agrawal and Sudhir Kumar Sharma published paper “Impact of Mobility on MANETs Routing Protocols Using Group Mobility Model” In this study the group mobility model has been used to deploy the mobility effect in the scenario to investigate the impact of group mobility on performance of routing protocols under group mobility model using QualNet simulator. In the paper it is illustrate that how the performance results of an ad hoc network protocol drastically change with the increasing node density. The various scenarios investigated with varying density of nodes in groups. Performance analysis is carried out on the basis of performance metrics under group mobility model. The outcome of this work shows that mobility has a detrimental impact on the performance of routing protocols. The results, it is shown that the DSR protocol clearly outperform all other routing protocols with increasing node density under group mobility model [40].

In June 2018 Muhammad Rizwan Ghori ; Kamal Z. Zamli ; Nik Quosthoni; Muhammad Hisyam ;Mohamed Montaser published paper "Vehicular ad-hoc network (VANET): Review" This paper introduces the vehicular ad hoc networks from the research perspective, covers basic architecture, critical research issues, and general research methods of VANETs, and provides a comprehensive reference on vehicular ad hoc networks [41].

Table 2-3: Summary of Related Works.

No. of Ref.	Authors	Year	Methodology used	Achieved Results
32	Said El Brak ;Mohammed. Bouhorma; Anouar Abdelhakim. Boudhir ; Mohamed El Brak	2012	Ns-2 Simulator	• Generally, QoS decreased with the scenario size and VoVAN connections. • G.723.l presents the best optimal performance in terms of delay.

33	Said El Brak1, Mohammed Bouhorma2, Mohamed El Brak3 and Anouar Bohdhir	2013	Ns-2 Simulator	In term of packet losses, all CODECs exceed the acceptable threshold
34	Kalpana Gurung and Hari Mohan Singh	2013	QualNet 6.1 Simulator	G.711 presents the best performance in sparse condition of both city and highway scenario
35	Ekta Agrawal and Kanojia Sindhuben Babulal	2014	Qualnet 6.1 Simulator	G.711 performs best in case of average throughput, average delay and energy consumption.
36	Tanuja K,Sushma T M,Bharathi M and Arun K H	2015	Survey	Provides broad survey on difference between MANET and VANET, VANET architectures components, VANET communication domains, wireless access technologies, VANET characteristics, challenges and VANET applications.
37	Khalid Hamid Bilal	2015	Ns-2 Simulator	OLSR always presents an adequate behavior in E2E delay especially with GSM codec, OLSR shown the good performance compared to AODV.

38	Shivani Attri	2015	OPNET Simulator	Throughput average of OLSR in all scenarios is much better than DSR and average end to end delay of DSR is much higher than OLSR and in terms of network load DSR shows less average network load as compared to OLSR routing protocol.
39	Vinita Jindal1, Punam Bedi	2016	Survey	Provide a comprehensive list of challenges exist in VANETs with the current state of the research and future perspectives in order to enable the deployment of VANET technologies, infrastructures, and services cost effectively, securely, and reliably
40	Subodh Kumar, G.S. Agrawal and Sudhir Kumar Sharma	2017	QualNet 6.1 Simulator	• Reactive routing protocols AODV, DSR and DYMO are best suited in large dense scenarios for group mobility. • Proactive routing protocols Bellman ford, Fisheye, LANMAR, RIP, and STAR are not show good performance as with the increasing node density • The hybrid routing protocol ZRP connote the nastiest performance in case of all performance metrics

41	Muhammad Rizwan Ghori ; Kamal Z. Zamli ; Nik Quosthoni; Muhammad Hisyam ;Mohamed Montaser	2018	Survey	AODV performance is better with high mobility nodes and the most suited protocol for the VANET.

All the above mentioned studies used a simulation technique to test voice over VANET (VOVAN), whereas this thesis will use a test bed to test Qos of VOVAN and overcome the problems that mentioned in chapter one.

CHAPTER THREE

METHODOLOGY

Chapter Three
Methodology

3.1. Introduction

This chapter describes the algorithm designed to accomplish a dynamic load balancing system, and presents the components and software tools used in this research to set the testbed.

3.2. Measurement Methodology

VANETS performance evaluation is being studied by several researchers. However, measurement of an actual VOVAN is expensive and infeasible. Therefore, below real test seems to be the most feasible solution. For this purpose, Linux OS, OLSR Switch Agent, Wireshark and Matlab were used with Ekiga to generate real voice traffic.

3.3. Algorithm Description

OLSR is a proactive routing protocol for mobile ad hoc networks. The protocol inherits the stability of a link state algorithm and has the advantage of having routes immediately available when needed due to its proactive nature. OLSR is an optimization over the classical link state protocol, tailored for mobile ad hoc networks.

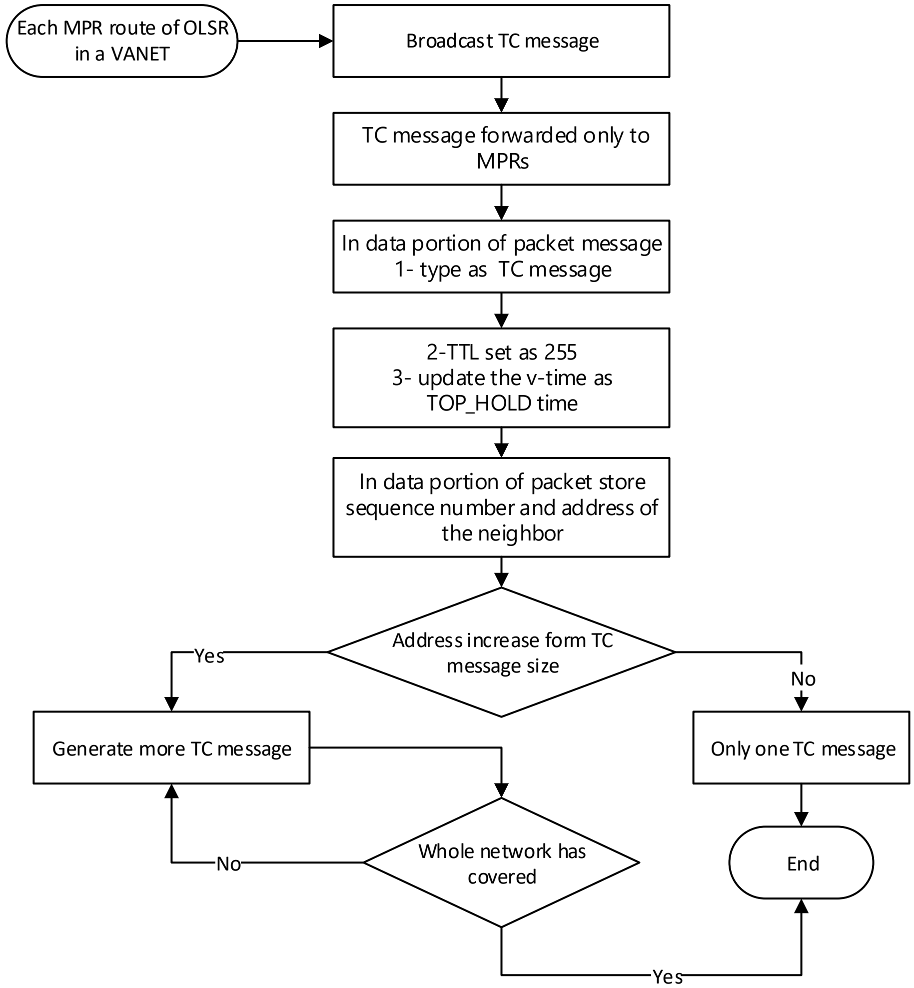


Figure 3-1: Flow Chart of TC Messages in OLSR [41].

The protocol is an optimization of the classical link state algorithm Tailored to the requirements of a mobile wireless LAN. The key concept used in the protocol is that of multipoint relays (MPRs). MPRs are selected nodes which forward broadcast messages during the flooding process. This technique substantially reduces the message overhead as compared to a classical flooding mechanism, where every node retransmits each message when it receives the first copy of the message. In OLSR, link state information is generated only by nodes elected as MPRs. Thus, a second optimization is achieved by minimizing the number of control messages flooded in the network. As a third optimization, an MPR node may choose to report only links between itself and its MPR selectors. Hence, as contrary to the classic link state algorithm, partial link state information is distributed in the network. This information is then used by for route calculation. OLSR provides optimal routes (in terms of number of hops). The protocol is particularly suitable for large and dense networks as the technique of MPRs works well in this context [43].

- **Step one**

  Every node must sponsor in HELLO messages its complete neighborhood specifying the kind of neighbor (SYM/ASYM). From now on we will simply call neighbors only the SYM neighbors

- **Step two**

  Each node must select a subset of N2i , as small as possible. In the HELLO messages, the state of each neighbor contains another bit that is MPR/NOT_MPR so each MPR knows its selector set. Only the MPR nodes participate in flooding messages rebroadcasting the packets from their selectors.

- **Step three**

  Only MPR nodes will generate TC messages. Each TC message includes the selector set of the MPR that generated it.

3.4. Implementation Overview

In this research a test-bed has been implemented under Linux, using OLSR to create the VANET network, the open-source EKIGA as real voice generate, Wireshark to analysis the network metrics for all scenarios, following diagram illustrate the design steps.

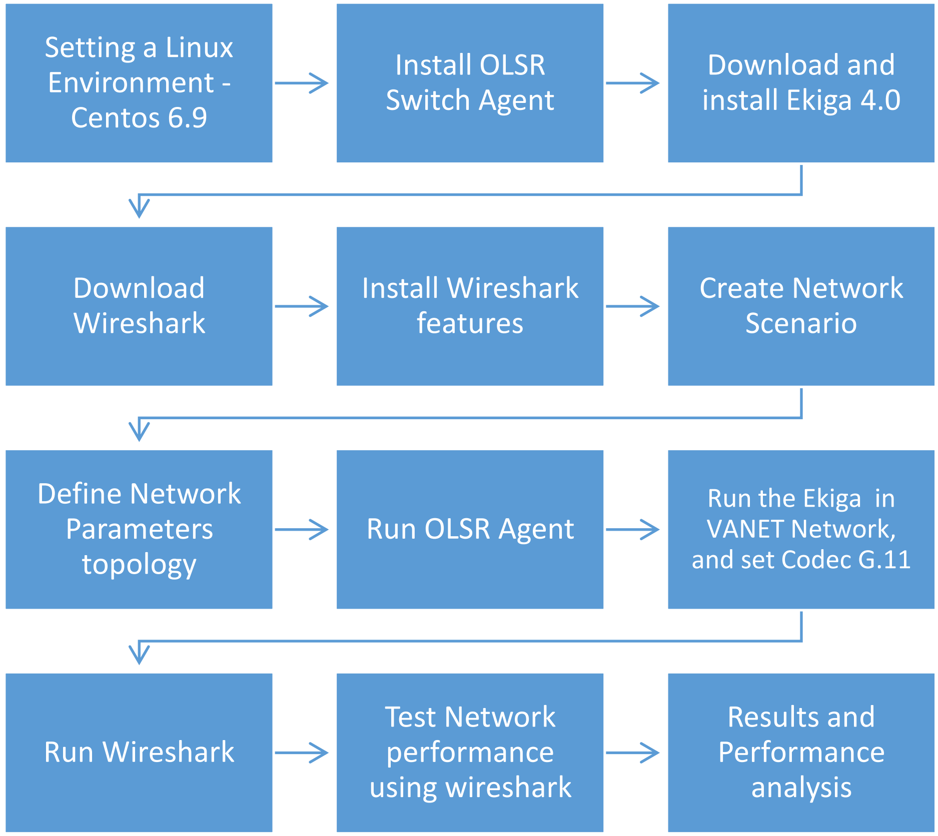


Figure 3-2: VANET Network Design Steps.

3.5. Components and Software Tools

3.5.1. OLSR Agent

OLSR is an implementation of the Optimized Link State Routing (OLSR, RFC3626) protocol this implementations optimized for mobile ad hoc networks on embedded devices like commercial of the shelf routers, smartphones or normal computers. Sometimes these networks are called "mesh networks".

OLSR Agent main advantages:

1. OLSR Agent is an open source project.
2. Custom topologies can be created.
3. OLSR runs real programs.

3.5.2. Voice Generator (EKIGA)

Ekiga is a VoIP and video conferencing application for GNOME and Microsoft Windows. It is distributed as free software under the terms of the GNU General Public License. Ekiga supports the SIP and many high-quality audio and video codecs. Ekiga has main advantages:

1. Call forwarding on busy, no answer, always.
2. Call transfer (SIP and H.323)
3. Call hold (SIP and H.323)

3.5.3. Audio Codecs

G.711 is an ITU-T standard for audio compounding. It is primarily used in telephony. Its formal name is Pulse code modulation (PCM) of voice frequencies. It can also be used for fax communication over IP networks.

G.711 is a narrowband audio codec that provides toll-quality audio at 64 Kbit/s. G.711 passes audio signals in the range of 300–3400 Hz and sampling them at the rate of 8,000 samples per second.

G.711 defines two main compression algorithms, the µ-law algorithm (used in North America & Japan) and A-law algorithm (used in Europe and the rest of the world). Both are logarithmic, but A-law was specifically designed to be simpler for a computer to process, and provides more quantization levels at lower signal levels [44].

3.5.4. Wireshark

Wireshark is a free and open source packet analyzer. It is used for network troubleshooting, analysis, software and communications protocol development, and education. Wireshark is the world's foremost and widely-used network protocol analyzer, Wireshark has main advantages:

1. Deep inspection of hundreds of protocols, with more being added all the time.

2. Live capture and offline analysis.
3. Multi-platform: Runs on Windows, Linux, MacOS, Solaris, FreeBSD, NetBSD, and many others.
4. Captured network data can be browsed via a GUI, or via the TTY-mode TShark utility.
5. Rich VoIP analysis.

3.6. Test Bed Parameters

Table 3-1: Test Bed Parameters.

Parameter	Value or Protocol
Propagation model	Outdoor area
PHY/MAC layer	802.11
Network layer	Tuned OLSR
Transport layer	RTP/UDP
Application Layer	SIP
Voice CODECs	G.711
VoIP Duration average	54 s
nodes speed	15 km/h

3.7. Scenario Description

To test this case node1 (10.0.0.1) and node2 (10.0.0.2) has been selected to establish the performance of the system Using soft phone software (Ekiga). As shown is the figures below:

Figure 3-3: Location of the Network.

3.7.1. First Scenario: Performance Measurement Through One Hop

The call established from station (10.0.0.1) and node2 (10.0.0.2) directly

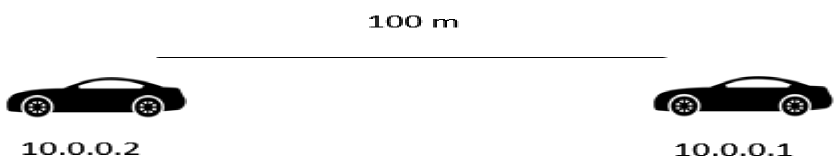


Figure 3-4: First Scenario Calling Through One Hop.

Figure 3-5 shown the first scenario before perform OLSR algorithm the delay was 24.88ms, jitter was 1.73ms and packet loss was 0.00%

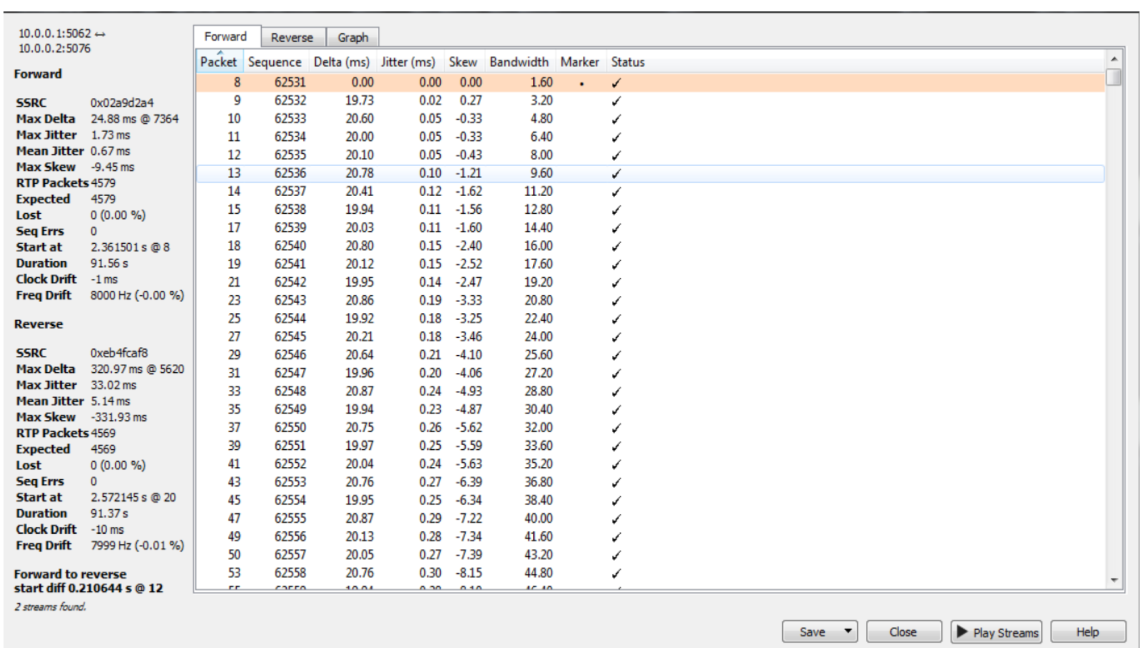
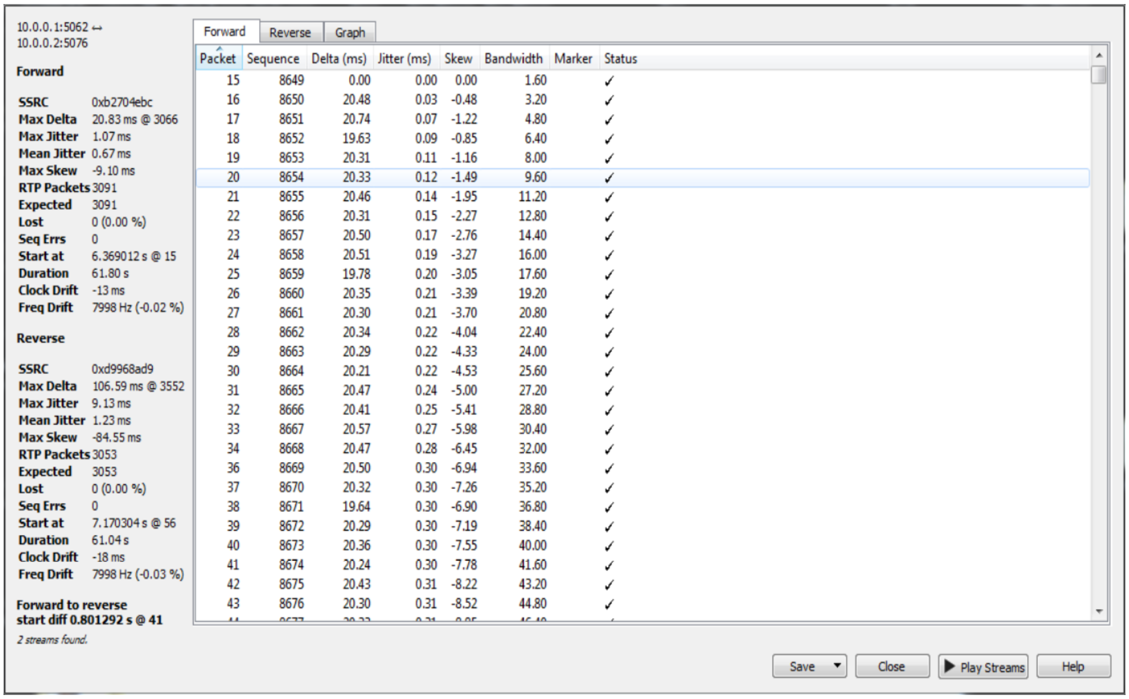


Figure 3-5: RTP Stream Analysis for One Hop Before OLSR Algorithm.

Figure 3-6 shown the first scenario after perform OLSR algorithm the delay was 20.83ms, jitter was 1.07ms and packet loss was 0.00%.



Packet	Sequence	Delta (ms)	Jitter (ms)	Skew	Bandwidth	Marker	Status
15	8649	0.00	0.00	0.00	1.60		✓
16	8650	20.48	0.03	-0.48	3.20		✓
17	8651	20.74	0.07	-1.22	4.80		✓
18	8652	19.63	0.09	-0.85	6.40		✓
19	8653	20.31	0.11	-1.16	8.00		✓
20	8654	20.33	0.12	-1.49	9.60		✓
21	8655	20.46	0.14	-1.95	11.20		✓
22	8656	20.31	0.15	-2.27	12.80		✓
23	8657	20.50	0.17	-2.76	14.40		✓
24	8658	20.51	0.19	-3.27	16.00		✓
25	8659	19.78	0.20	-3.05	17.60		✓
26	8660	20.35	0.21	-3.39	19.20		✓
27	8661	20.30	0.21	-3.70	20.80		✓
28	8662	20.34	0.22	-4.04	22.40		✓
29	8663	20.29	0.22	-4.33	24.00		✓
30	8664	20.21	0.22	-4.53	25.60		✓
31	8665	20.47	0.24	-5.00	27.20		✓
32	8666	20.41	0.25	-5.41	28.80		✓
33	8667	20.57	0.27	-5.98	30.40		✓
34	8668	20.47	0.28	-6.45	32.00		✓
36	8669	20.50	0.30	-6.94	33.60		✓
37	8670	20.32	0.30	-7.26	35.20		✓
38	8671	19.64	0.30	-6.90	36.80		✓
39	8672	20.29	0.30	-7.19	38.40		✓
40	8673	20.36	0.30	-7.55	40.00		✓
41	8674	20.24	0.30	-7.78	41.60		✓
42	8675	20.43	0.31	-8.22	43.20		✓
43	8676	20.30	0.31	-8.52	44.80		✓

Figure 3-6: RTP Stream Analysis for One Hop after OLSR Algorithm Metric Equal One.

3.7.2. Second Scenario: Performance Measurement Through Two Hops

The call established from station (10.0.0.1) and node2 (10.0.0.2) through node3 (10.0.0.3)

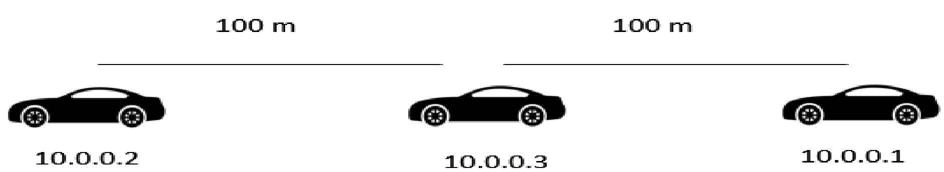


Figure 3-7: Second Scenario Calling Through Two Hops.

Figure 3-8 shown the second scenario before perform OLSR algorithm the delay was 79.42ms, jitter was 12.53ms and packet loss was 0.00%.

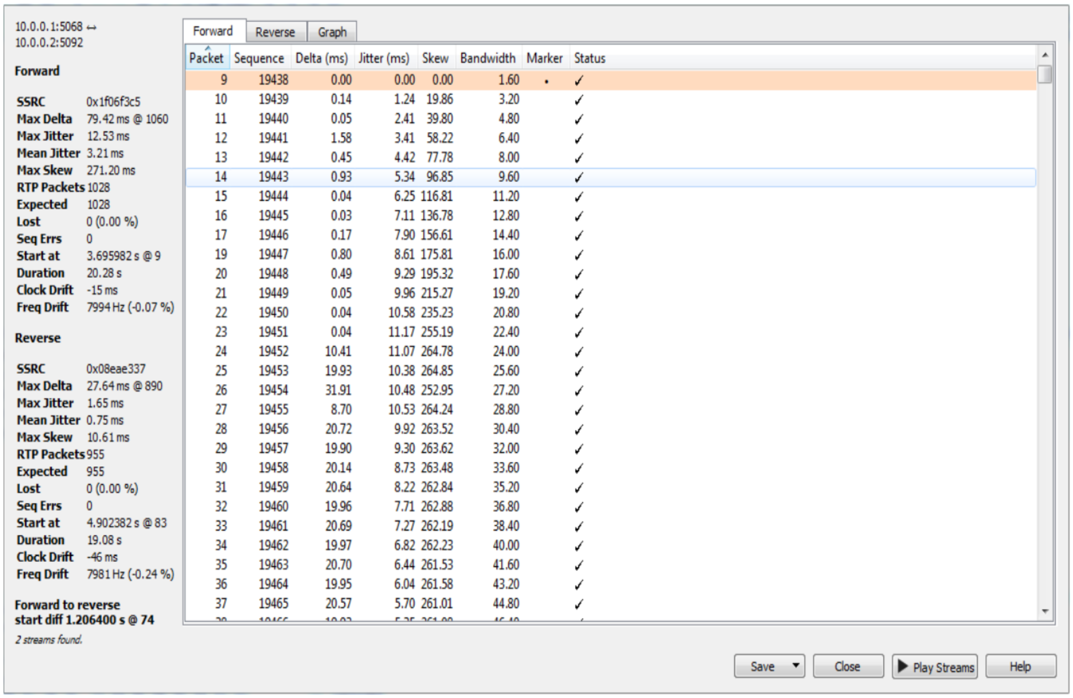


Figure 3-8: RTP Stream Analysis for Two Hops Before OLSR Algorithm.

Figure 3-9 shown the second scenario after perform OLSR algorithm the delay was 46.85ms, jitter was 9.55ms and packet loss was 0.00%.

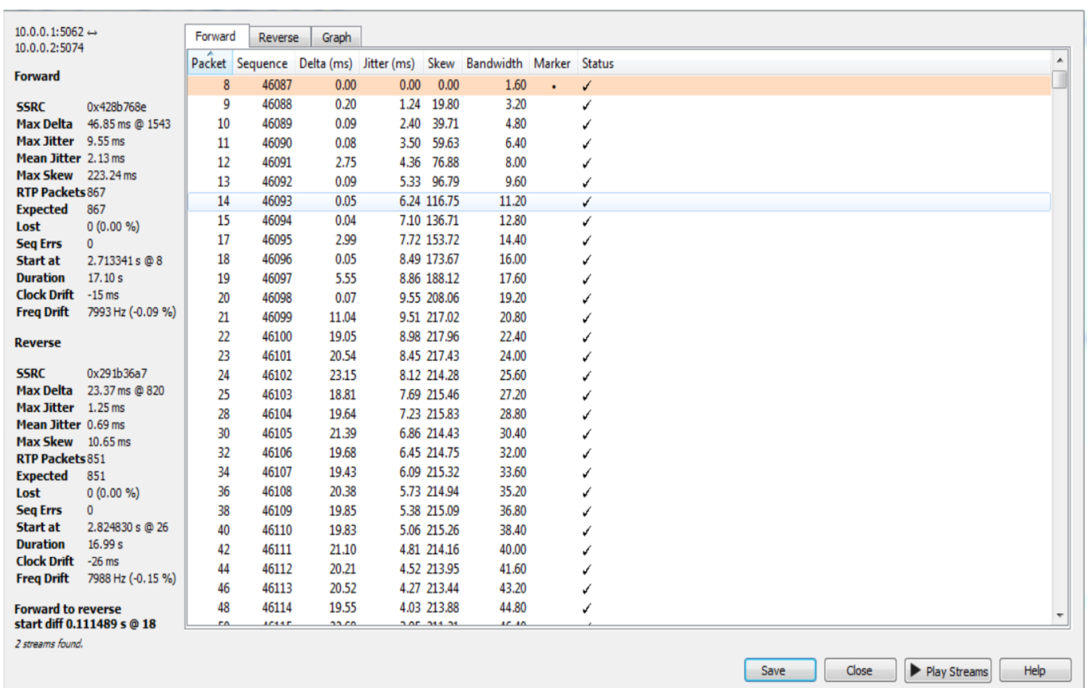


Figure 3-9: RTP Stream Analysis for Two Hops After OLSR Algorithm Metric Equal Two.

3.7.3. Third Scenario: Performance Measurement Through Three Hops

The call established from station (10.0.0.1) and node2 (10.0.0.2) through node3 (10.0.0.3) and node4 (10.0.0.4).

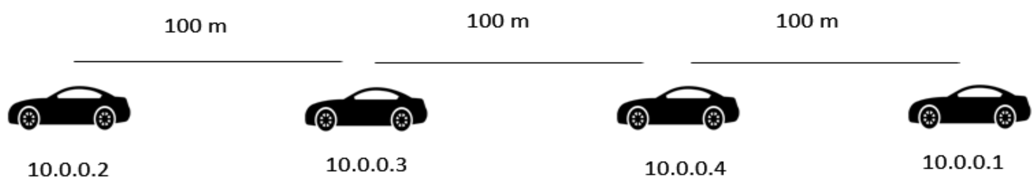


Figure 3-10: Third Scenario Calling Through Three Hops.

Figure 3-11 shown the third scenario before perform OLSR algorithm the delay was 111.15ms, jitter was 16.00ms and packet loss was 0.06%.

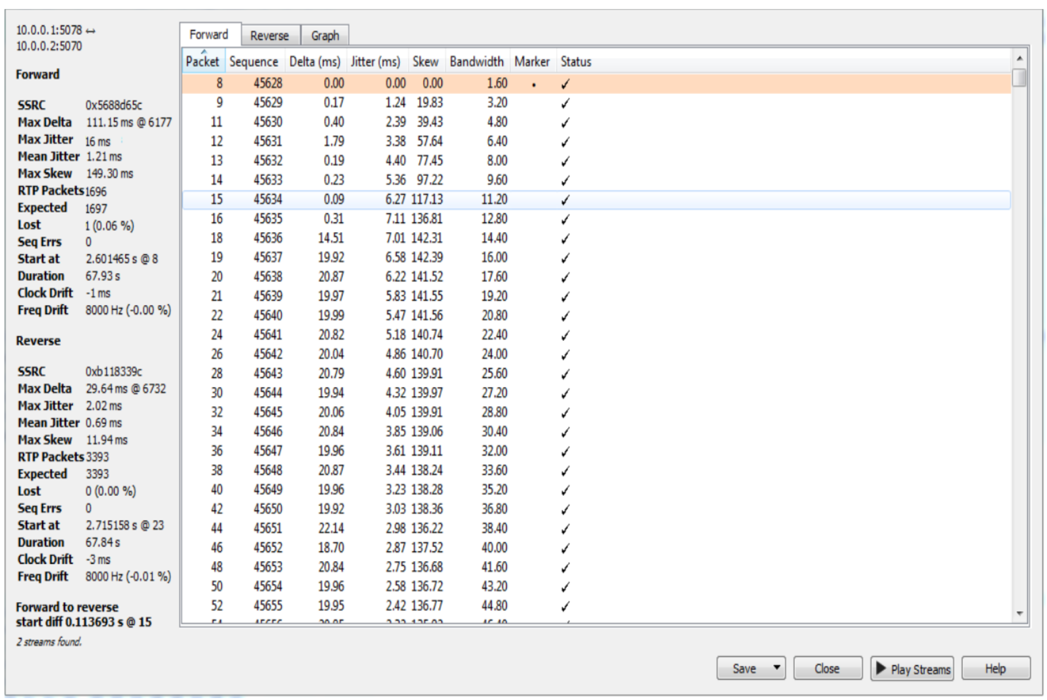


Figure 3-11: RTP Stream Analysis for Three Hops Before OLSR Algorithm.

In figure 3-12 the third scenario after perform OLSR algorithm the delay was 100.79ms, jitter was 13.00ms and packet loss was 0.02%.

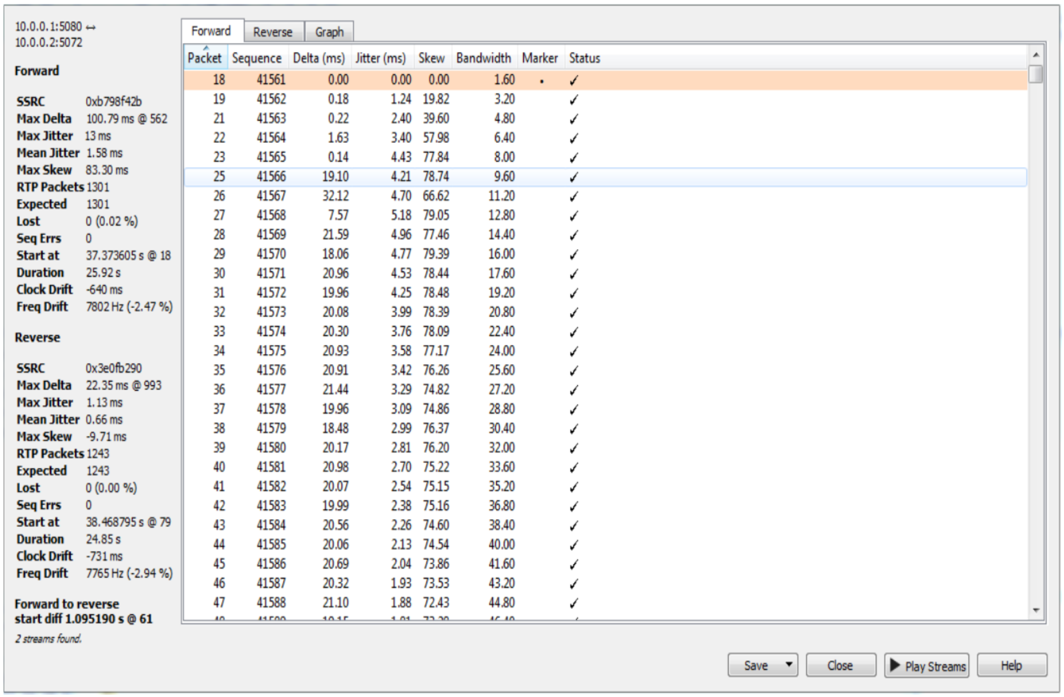


Figure 3-12: RTP Stream Analysis for Three Hops After OLSR Algorithm Metric Equal Three.

3.7.4. Fourth Scenario: Performance Measurement Through Four Hops

The call established from station (10.0.0.1) and node2 (10.0.0.2) through node3 (10.0.0.3), node4 (10.0.0.4) and node5 (10.0.0.5)

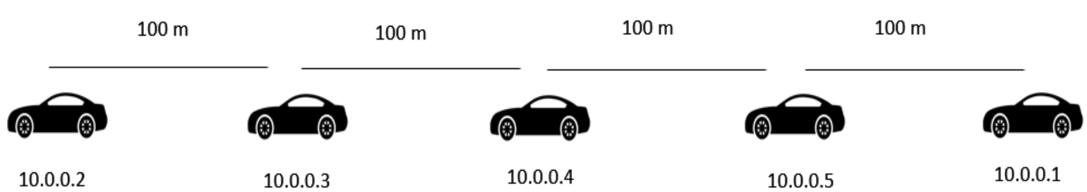


Figure 3-13: Fourth Scenario Calling Through Four Hops.

Figure 3-14 shown the fourth scenario before perform OLSR algorithm the delay was 271.20ms, jitter was 21.16ms and packet loss was 0.59%.

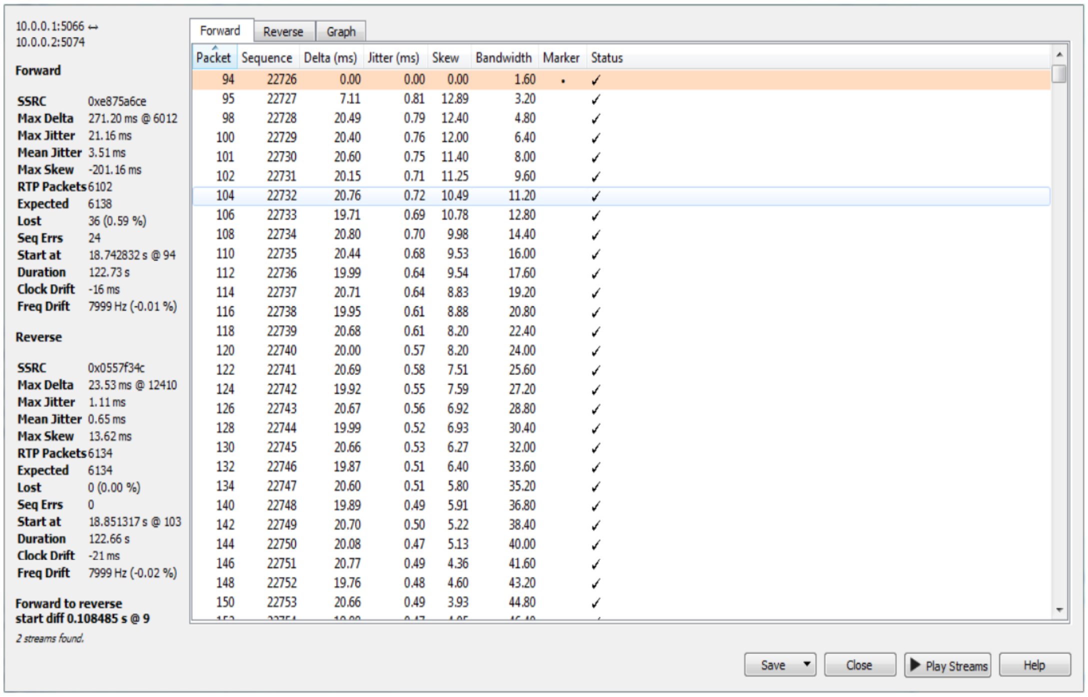


Figure 3-14: RTP Stream Analysis for Four Hops Before OLSR Algorithm.

Figure 3-15 shown the fourth scenario after perform OLSR algorithm the delay was 241.45ms, jitter was 19.08ms and packet loss was 0.24%.

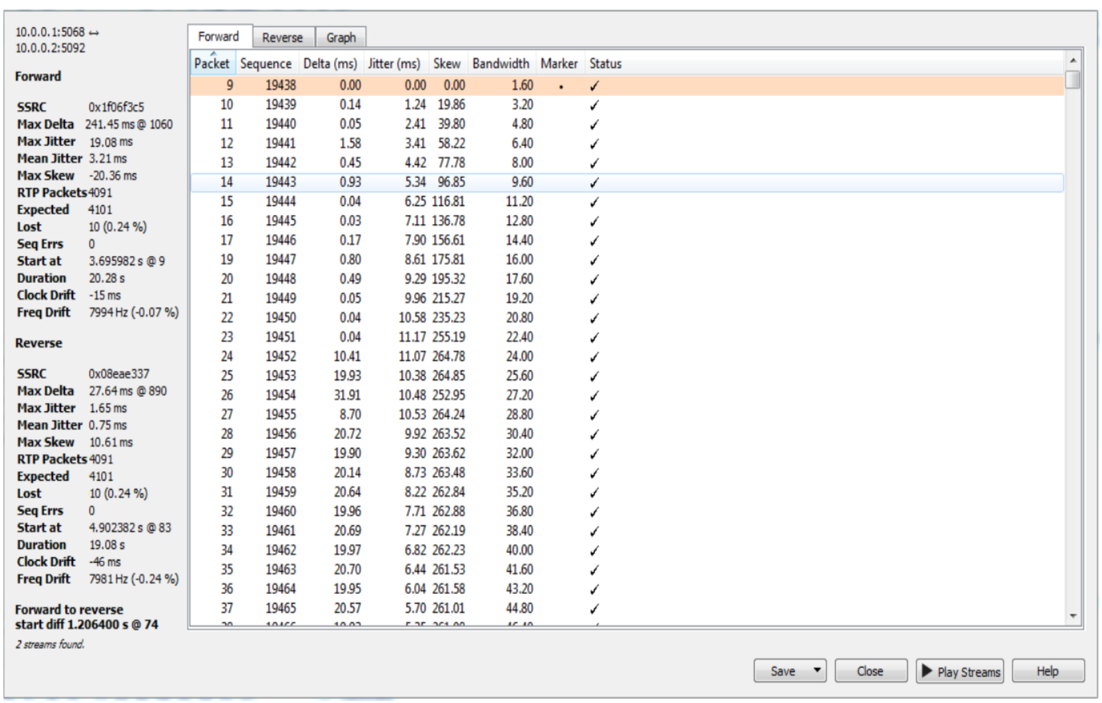


Figure 3-15: RTP Stream Analysis for Four Hops After OLSR Algorithm Metric Equal Four.

CHAPTER FOUR

RESULTS AND PERFORMANCE EVALUATION

Chapter Four
Results and Performance Evaluation

4.1. Introduction

This chapter describes the proposed scenarios, then shows and explains the results obtained with all of proposed scenarios.

4.2. Analysis of Voice Over VANET

VoIP traffic has two significant features that are different from the no-voice flows. The first difference is the payload size. As is well known, a network packet consists of two parts: header and payload. The packet header records how the data are to be transmitted while the payload has the real information that has to deliver. In each network, the header size is almost fixed for each packet, so it is common to use a big payload size to increase network reuse. But for voice flows, the payload size is always small (even smaller than the header size) as the information to be delivered depends upon the speed of human speech.

This leads to the low channel reuse of the networks. The second difference comes from the fact that the hearing process can in general tolerate a certain amount of loss ratio (less than 4%).VoIP traffic should meet the delay requirement (usually less than 400ms by the (ITU)) [30], although it does not require 100% reliable connection.

4.3. Results Analysis

Table 4-1: Testing Results of all Scenarios.

Scenario No.	OLSR Algorithm	QoS of VOVAN		
		Delay (ms)	Jitter (ms)	Packet Loss %
1	Before	24.88	1.73	0%
	After	20.83	1.07	0%
2	Before	79.42	12.53	0%
	After	46.85	9.55	0%
3	Before	111.15	16	0.06%
	After	100.79	13	0.02%
4	Before	271.2	21.16	0.59%
	After	241.45	19.08	0.24%

4.3.1. Delay

Above table shows the delay that occurred before apply OLSR algorithm and after applied it between vehicles for each scenario, for first scenario the delay before perform OLSR was 24.88ms and after perform it was 20.83ms, for second scenario the delay before perform OLSR was 79.42ms and after perform it was 46.85ms, for third scenario the delay before perform OLSR was 111.15ms and after perform it was 100.79ms, for forth scenario the delay before perform OLSR was 271.2ms and after perform it was 241.45ms.

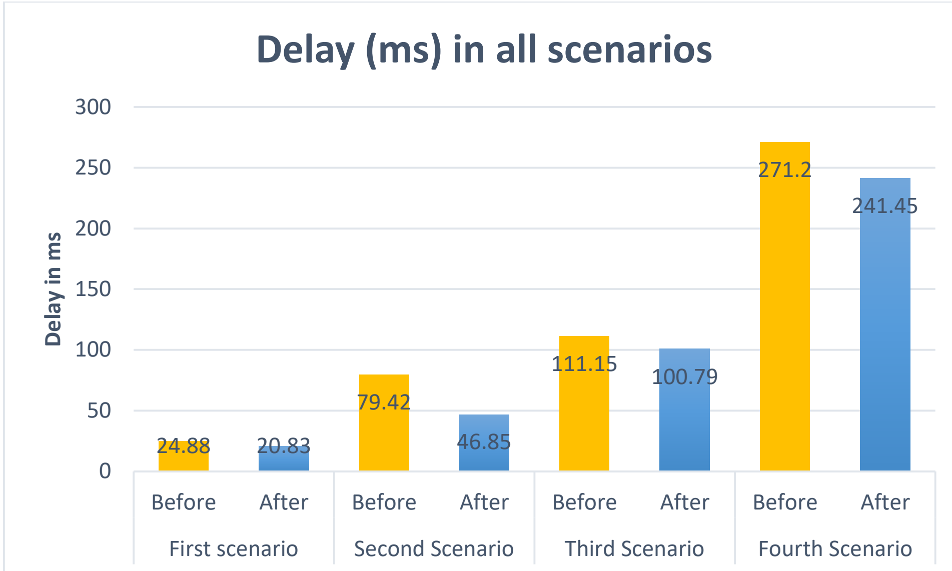


Figure 4-1: Delay in all Scenarios.

4.3.2. Jitter

From table 4-1 shows the jitter that occurred before apply OLSR algorithm and after applied it between vehicles for each scenario, for first scenario the jitter before perform OLSR was 1.73ms and after perform it was 1.07ms, for second scenario the jitter before perform OLSR was 12.53ms and after perform it was 9.55ms, for third scenario the jitter before perform OLSR was 16.00ms and after perform it was 13.00ms, for forth scenario the jitter before perform OLSR was 21.16ms and after perform it was 19.08ms.

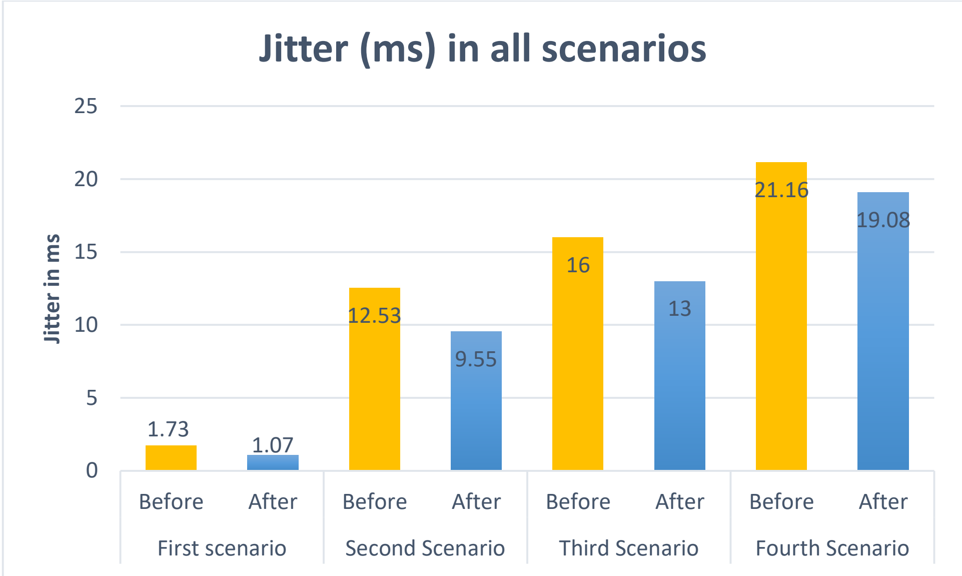


Figure 4-2: Jitter in all Scenarios.

4.3.3. Packet loss

From table 4-1 shows the packet loos that occurred before apply OLSR algorithm and after applied it between vehicles for each scenario, for first and second scenarios the packet loos before and after perform OLSR was zero, for third scenario the packet loos before perform OLSR was 0.06% and after perform it was .0.02%, for forth scenario the packet loos before perform OLSR was 0.59% and after perform it was 0.24%.

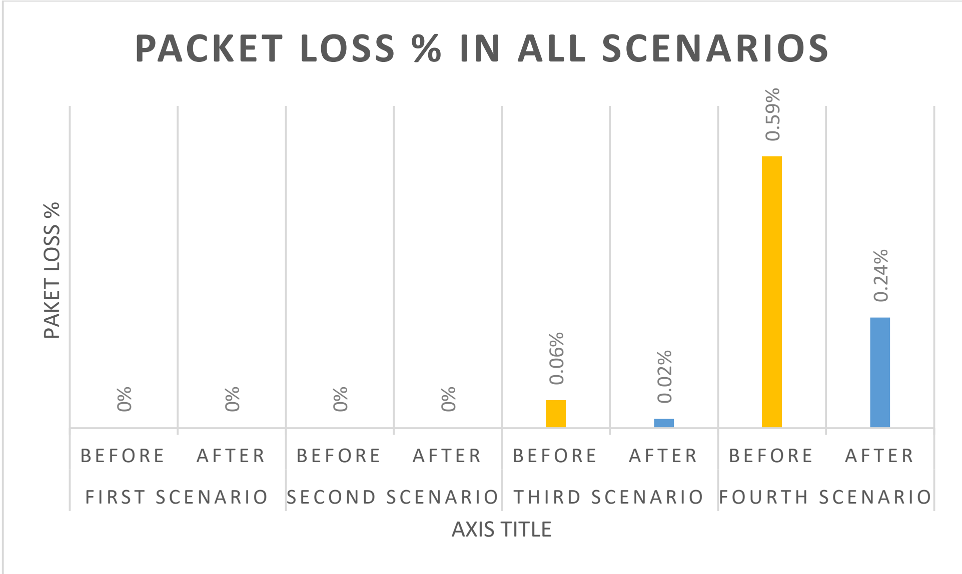


Figure 4-3: Packet loss in all Scenarios.

4.4. Performance Analysis

To summarize the table 4-2, an average performance has been calculated as shown in the following table.

Table 4-2: Average results of all scenarios.

OLSR Algorithm	QoS of VOVAN		
	Delay (ms)	**Jitter (ms)**	**Packet Loss %**
Before	121.6625	12.855	0.16%
After	102.48	10.675	0.07%

The network showed a much better performance in the first scenario after running OLSR Switch. The average network Delay before OLSR was 121.67ms, and it became 102.48ms with decreased at least 18.72%. The average Jitter has decreased by 20.42% after OLSR algorithm with an average of 10.67ms, the Packet Loss has decreased 56.25% after OLSR algorithm with an average of 0.07 as shown in figure 4-4.

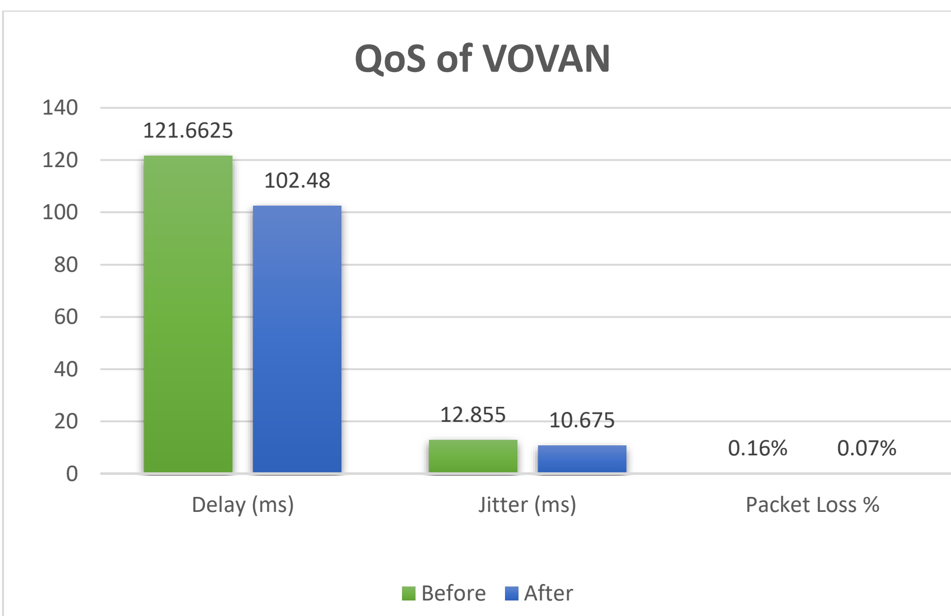


Figure 4-4: Comparison of QoS Parameters.

Using the result above, a code has been implemented using Matlab to find the second order derivation for the delay and jitter to provide a good projection for multi-hop delay and jitter. The second order derivations for the delay and jitter as below:

Figure 4-5 shown the second order derivation for the delay

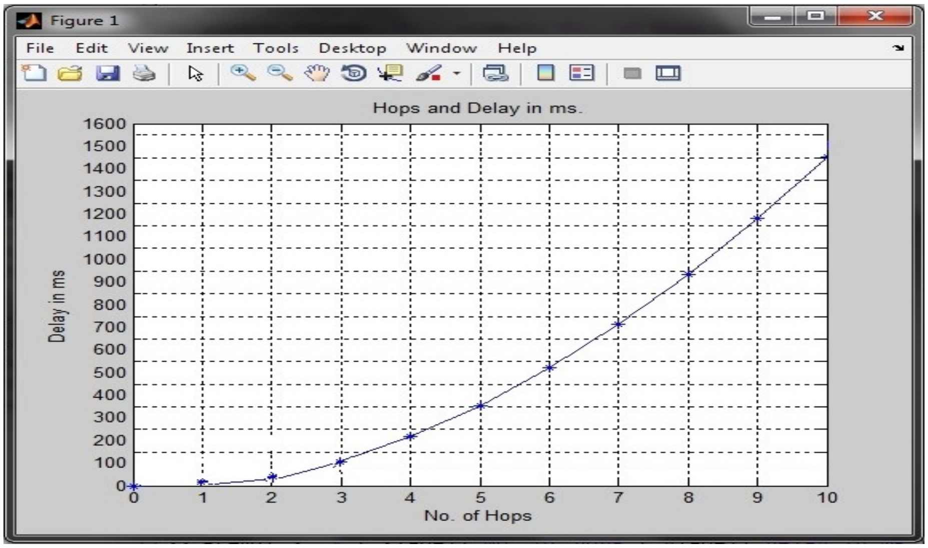


Figure 4-5: The Second Order Derivation for The Delay.

Figure 4-6 shown the second order derivation for the Jitter.

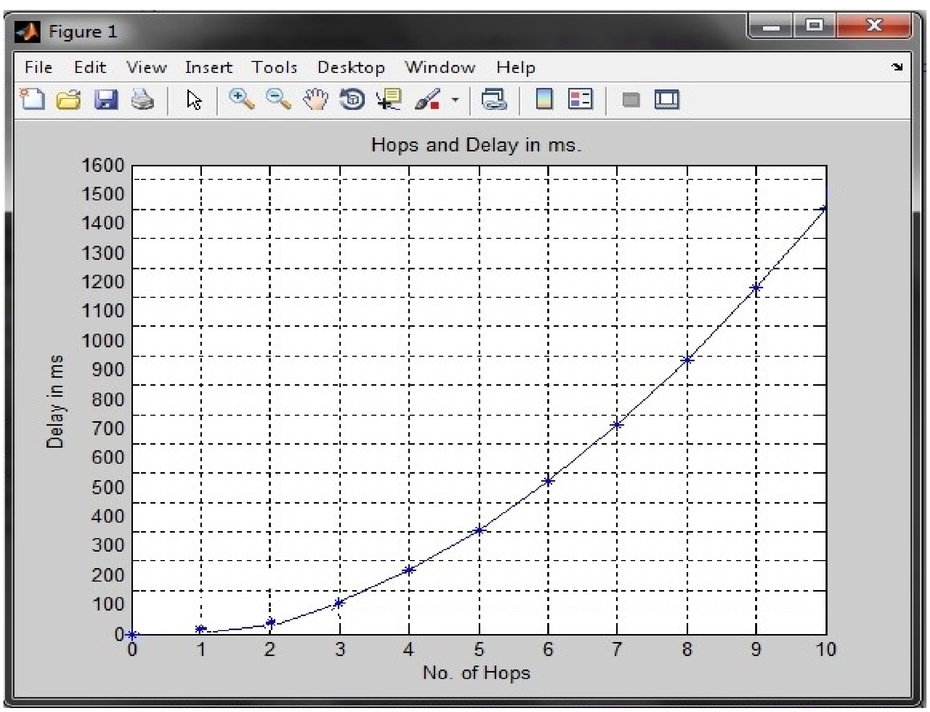


Figure 4-6: The Second Order Derivation for The Jitter.

Delay QoS in Real time communication system is very significant so ITU standardized the maximum delay for real-time (voice) application in communication system 400ms [30], as shown before that delay QoS is affected by number of hops. In figure 4-4 when no of hops equal 6 the delay exceeded 400ms. The result is five hops which can be implemented by 6 terminals.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

Chapter Five
Conclusion and Recommendations for Future Work

5.1. Conclusion

VANET is an emerging field in networking area. Real-time voice transmission over such network is very much demanding and necessary, especially in VANET emergency scenarios. This work analyzed the performance evaluation of VoIP services in VANET in context of G.711 CODEC using The Optimized Link State Routing Protocol (OLSR).

This work aims at providing meaningful results to guide the design of efficient strategies and protocols to support VoIP communications over VANETs in order to investigate how voice over Internet Protocol (VoIP) application is influenced by wireless multi-hop network characteristics in order to optimize it for providing scalable communication.

Considering the QoS requirements of a VoIP application the performance of OLSR has been investigated for VoIP application in VANET in different scenarios, using one hop, two hops, three hops and four hops.

OLSR presents an adequate behavior in packet loss, jitter and end-to end delay especially with G.711 codec. Based on this, OLSR had shown the best initial performance within four hops then QoS decreased with the scenario size and VoVAN connections

5.2. Recommendations for Future Work

After finishing these research there are some other issues can be considering for future research these include:

- Work with other voice codecs G.723.1, G.726.A.

- Using different Ad-hoc routing protocols like The Ad hoc On Demand Distance Vector (AODV) protocol as Reactive routing protocol or Zone Routing Protocol (ZRP) as Hybrid routing protocol.
- Investigate the performances of different topologies of different sizes.
- Extend the algorithm to complex networks, or hybrid networks.
- Implement VOVAN using IPv6.

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