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Performance Evaluation of OLSR Routing Protocol for VOIP Applications under IPv6 Environment

تقييم الأداء لبرتوكول التوجيه او.ال.اس.ار لتطبيقات الصوت عبر الأنترنت
في بيئة البرتوكول السادس للأنترنت

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Abstract

In areas in which there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use, wireless mobile users may still be able to communicate through the formation of an ad hoc network. This research investigates the overall performance of the Optimized Link State Routing (OLSR) protocol on Voice over Internet Protocol (VoIP) applications in Mobile Ad hoc Networks (MANETs) under IPv6 environment. Using VoIP over MANETs takes advantage of the mobility and versatility of a MANET environment and the flexibility and interoperability of a digital voice format affords. Research shows that VoIP-like traffic can be routed through an ad hoc network using the Ad hoc On-demand Distance Vector routing protocol. This research determines the suitability of OLSR as a routing protocol for MANETs running VoIP applications in IPv6 networks.

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List of Abbreviations

MANET	Mobile Ad hoc Network
VoIP	Voice over Internet Protocol
OLSR	Optimized Link State Routing
IP	Internet Protocol
MPRs	Multipoint Relays
TC	Topology Control
PSTN	Public Switched Telephone Network
DES	Discrete Event Simulation
MTU	Maximum Transmission Unit
AODV	Ad hoc On-demand Distance Vector
DSDV	Destination-Sequenced Distance Vector
DSR	Dynamic Source Routing
TORA	Temporally Ordered Routing Algorithm
GRP	Gathering-based routing protocol

1. Introduction

1.1 Overview

Technology changes considerably throughout the last ten centuries, in the tenth or twelve century, people have remarkable advance in field of science and medical innovation. The twenty first century became the century of Computer Science, Artificial Intelligence, Robotics and Space Science. One of the core computer system concepts is computer networking. This is the age computer network and internet. The internet most commonly a collection various networks collaborating and connecting to create a world wide area network also called the Information Super Highway. Computer Network consists of two fundamental network concepts, wired network and wireless network.

Wired Network is a type of network where wire cables are used to design and implement in certain network. A wired network consists of node, server and link component. On the other hand wireless network is consists of node, server and frequency link component. Two type of wireless network can be categorized, Infrastructure Network and Infrastructure less network, also called Mobile Ad-hoc network or MANET.

The growths of laptops and 802.11/Wi-Fi wireless networking have made MANETs a popular research topic since the mid-1990s. Many academic papers evaluate protocols and their abilities, assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other. Different protocols are then evaluated based on measures such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput, ability to scale, etc.

A Mobile Ad-hoc Network (MANET) is a multi hop wireless network formed by a group of mobile nodes that have wireless capabilities. MANET is a collection of wireless nodes that dynamically create a wireless network among them without any infrastructure (1).Ad-hoc is a communication mode that allows computers to directly communication with each other without a router. In Latin, ad-hoc means “for this” meaning “for this special purpose”. In ad hoc networks, nodes do not start out familiar with the topology of their networks; instead, they have to discover it. The basic idea is that a new node may announce its presence and should listen for announcements broadcast by its neighbors. Each node learns about nodes nearby and how to reach them and may announce that it, too, can reach them (2).

With the development of the network and Internet services, Voice over IP (VoIP) has been playing a primary role in cutting the telephone calls costs. It can be viewed that since the demand of VoIP over wireless network is developing, utilization of VoIP over Mobile Ad-hoc Network (MANET) is required to develop as well (1).

Since no static infrastructure or centralized management exist, these networks are self-configured and end-to-end interaction may need routing information through various intermediary nodes. Nodes can associate to each other arbitrarily and making random configuration. Every node in MANET behaves both as a host and as a router to propagate messages for other nodes that are not inside the same radio coverage. The up to date standardized protocols are categorized into three classes: Reactive routing protocols, Proactive routing protocols, Hybrid routing protocols.

Many studies have been done on the performance evaluation of routing protocols of MANET, but most of these studies are based on IPv4.

On the other hand, IPv6 gains popularity because it has some additional features over IPv4 as it supports multicasting, multi-homing, efficient routing. IPv6 is more secure as compared to IPv4 and has large address space to support. On account of these features of IPv6, many organizations are moving to use IPv6, and therefore, it is worthwhile to evaluate the performance of routing protocols under IPv6 environment (2).

1.2 Problem statement

In Mobile Ad-hoc Network (MANETs), VOIP is one of the heavy applications that have led to some challenges in the performance of the network. A Mobile Ad hoc Network (MANET) poses a challenging environment for Voice over Internet Protocol (VoIP) due to multi-hop routing and dynamic route calculation. Also determines suitability of OLSR as a routing protocol for MANETs running a VoIP application.

1.3 Aim and Objective:

This thesis is aim to get in depth understanding about the performance of OLSR routing protocol in Mobile Ad-hoc Network under IPv6 environment and to design, simulate such network. MANET has a number of routing protocols and there a number of protocols are on their way or under development. Also determine whether routing protocols affect VoIP quality in MANETs.

Also the prime objective of this research to carry out a simulation based performance evaluation of Optimized Link State Routing (OLSR) MANET routing protocol under IPv6 environment for VOIP traffic.

1.4 Research Scope

In areas in which there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use, wireless mobile users may still be able to communicate through the formation of an ad hoc network. In such a network, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad hoc routing protocol that allows it to discover "multi-hop" paths through the network to any other node.

These research goals will be met by sending representative VoIP traffic across a MANET network under ipv6 environment. Objective measurement of delay and packet loss determines whether OLSR under IPv6 provides better and acceptable performance on the MANET.

1.5 Methodology:

The MANET is simulated in OPNET modeler, which is capable of running Discrete Event Simulations (DES). VoIP traffic is send through the network. End-to-end delay and packet loss results are observed under IPv6 environment and compared to recommended values for acceptable VoIP quality.

A number of routing parameters of MANET are supported by OPNET Modeler and so it is easy to design network in OPNET Modeler and to evaluate the performance of these routing protocol. These parameters are known as performance metrics. Specific application and transport layer protocols demand their own set of performance metrics to evaluate the network efficiency.

The simulations focused on the performance of OLSR routing protocol in the ipv6 environment. There are six simulation scenarios consisting of 5, 10, 15 and 20 nodes. The nodes were randomly placed within certain gap from each other in 5000x5000 square meters campus Environment.

1.6 Project Outline

This project is organized as follows:

Chapter 1: Introduction

In this chapter a brief description about MANET networking, research aim and objectives and motivation were discussed. This chapter also contain full project outline

Chapter 2: Overview and Literature Research

This chapter provides background information and reviews of the related work in MANET routing protocols and VoIP applications.

Chapter 3: Research Methodology

This chapter present the simulation and the performance metric been used to evaluate the performance of the optimized link routing protocol in mobile ad hoc network under IPv6 environment.

Chapter 4: Simulation Results

This chapter presents the simulation layout and come with results and analyzes of the data collected from scenarios under IPv6 environment.

Chapter 5: Conclusion & Recommendations

This chapter provides conclusions and areas for future work.

2 Literature Review

2.1 Background:

A Mobile Ad hoc Network (MANET) poses a challenging environment for Voice over Internet Protocol (VoIP) due to multi-hop routing and dynamic route calculation. Routing in a MANET uses routing protocols such as Ad hoc On-demand Distance Vector (AODV) and Optimized Link State Routing (OLSR).

2.2 Mobile Ad Hoc Network (MANT):

A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly.

The MANET working group, created within the Internet Engineering Task Force (IETF), exists due to the necessity for open standards regarding MANETs (3). The MANET working group standardizes Internet Protocol (IP) routing protocols and provide functionality with an emphasis on wireless routing - accounting for both static and dynamic topologies. The standards developed by the MANET working group are intended to handle networks employing various hardware with wired and wireless hosts. This includes infrastructures with fixed and mobile router implementations.

MANETs are a kind of Wireless ad hoc network that usually has a routable networking environment on top of a Link Layer ad hoc network. MANETs consist of a peer-to-peer, self-forming, self-healing network.

The growths of laptops and 802.11/Wi-Fi wireless networking have made MANETs a popular research topic since the mid-1990s. Many academic papers evaluate protocols and their abilities, assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other. Different protocols are then evaluated based on measures such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput, ability to scale, etc.

2.2.2 The major characteristics of an ad hoc network are:

- **Mobility**: Mobility can be individual node or group mobility involving random or pre-planned routes. Mobility affects routing and network performance since the network must re-learn node locations after movement.
- **Multi-hopping**: Data can traverse several nodes prior to reaching its destination and must account for obstacle negotiation, spectrum re-use and energy conservation.
- **Self-Organizing**: Ad hoc networks autonomously determine configuration parameters and topology.
- **Energy Conservation**: Nodes rely on limited battery power and usually cannot generate power.
- **Scalability**: As the number of nodes in an ad hoc network increase, the complexity of routing and configuration management also increases.

Since no static infrastructure or centralized management exist, these networks are self-configured and end-to-end interaction may need routing information through various intermediary nodes. Nodes can associate to each other arbitrarily and making random configuration. Every node in MANET behaves both as a host and as a router to propagate messages for other nodes that are not inside the same radio coverage.

2.3 MANET Routing Protocols:

Routing protocols in MANET are categorized in to three classes: reactive, proactive and hybrid routing protocols.

2.3.1 Reactive Routing Protocols:

Reactive routing protocol is a type of routing protocol in which route is established when it is needed by source node to send data packets to the destination node. In reactive routing protocol flooding technique is used for route discovery. Once routes are discovered the routes are stored and maintained in route cache. The main advantage of this type of routing protocols is to save precious bandwidth of ad hoc network, i.e. Ad hoc On Demand Distance Vector (AODV).

2.3.2 Proactive Routing Protocols:

Proactive is a type of routing protocol in which each node maintains routing information of every other node in a network. In proactive routing protocol routing information is kept in routing tables and updated when topology is changed. The main advantage of this type of routing protocols is that nodes get the route information immediately and establish a session, i.e. Optimized Link State Routing (OLSR).

2.3.3 Hybrid Routing Protocols:

This kind of routing protocol deduced from the two previous ones, having the benefit of both protocols (reactive/proactive routing protocol), utilizing some quality of and improving it with the involvement of the other one, i.e. Gathering-based routing protocol (GRP).

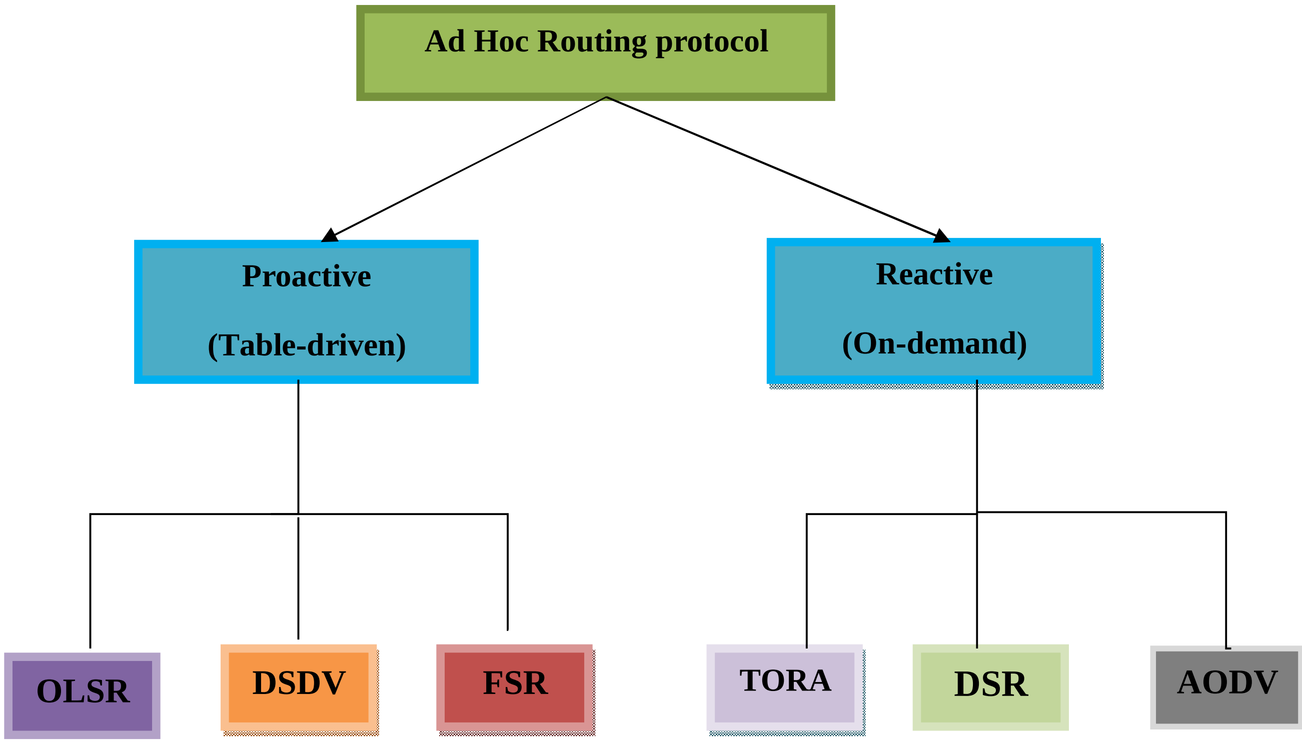

Figure 2-1: Classification of Routing Protocol

2.4 Optimized Link State Routing Protocol (OLSR):

OLSR, first presented by Philippe Jacquet, Paul Muhlethaler, Thomas Clausen, Anis Laouiti, Amir Qayyum and Laurent Viennot in 1998, concentrates on routing in ad hoc networks.

OLSR is a proactive protocol. Its main functionality is to construct a routing table for each node in the MANET. The OLSR protocol is a variation of the pure LSR protocol and is designed specifically for MANETs (3). The OLSR protocol achieves optimization over LSR through the use of MPR (Multi Point Relay) nodes. The MPR nodes are selected and designated by neighboring nodes (4). OLSR is type of table-driven proactive link state routing protocol developed for mobile ad hoc network. OLSR exchange information with other nodes in the network (5). In OLSR the concept multi point relay (MRP) is used to reduce control traffic overhead. In OLSR nodes elect MRP among themselves. MRP is transmitting the control messages on the behalf of other nodes in the network. Each node in a network has a list of MPR nodes. The OLSR is suited for large and dense network. MPR helps in providing the shortest path to destination. Different types of control messages are used in OLSR. Hello message are used to find link status information and host's neighbor.

OLSR is designed to work in a completely distributed manner and does not depend on any central entity. The protocol does NOT REQUIRE reliable transmission of control messages: each node sends control messages periodically, and can therefore sustain a reasonable loss of some such messages. Such losses occur frequently in radio networks due to collisions or other transmission problems (RFC3626).

OLSR does not require reliable transmission of control traffic since control messages are sent periodically. It is, therefore, able to sustain control message losses without severely impacting performance. Since each control message contains a sequence number that is incremented only when a new periodic message is sent, OLSR tolerates out-of-order delivery.

2.4.1 Multipoint Relays:

MPRs are a subset of all the one-hop neighbors of a node chosen in such a way that all two-hop neighbors are covered by this set.These nodes are the only nodes that forward broadcast messages during the flooding 7 process. This reduces overhead since in a classical flooding mechanism, every node retransmits each message it receives the first time. The goal of

MPRs is to minimize control message traffic sent throughout the network, thereby reducing overhead and conserving battery life. An OLSR route in an ad hoc network is a sequence of hops through the MPRs from source to destination.

Figure 2.3 compares MPR flooding to full flooding as used by classic flooding mechanisms. In full flooding, all nodes receive control messages and retransmit (or flood) the message to all its neighbors. Thus, a node may receive the same message from multiple neighbors. In MPR flooding, only the MPR nodes retransmit the message to their neighbors. All other nodes process the message but do not retransmit.All nodes still receive the message through MPR flooding, but with less overhead as compared to full flooding.

Each node in the network selects a set of nodes among its neighbors to retransmit its packets. This set contains the MPRs for that node. Thus, a smaller MPR set results in an optimal OLSR. Nodes chosen as MPRs maintain an MPR selector set. This set lists all the nodes that have chosen it

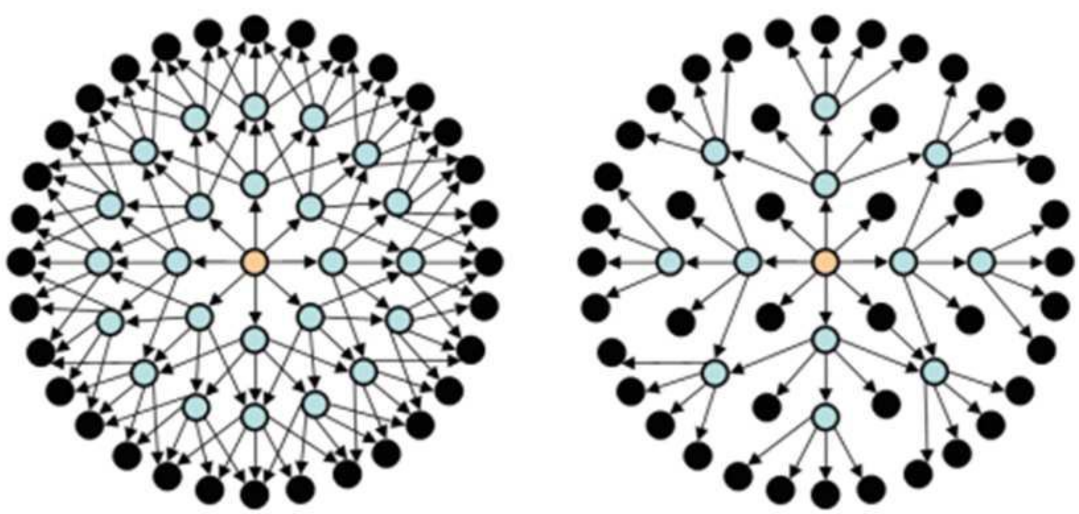

Figure 2-2: Comparison of Full Flooding (left) and MPR Flooding (right)

2.4.2 HELLO Messages:

Nodes learn about their neighbors through HELLO messages. HELLO messages are broadcast by each node in the network and perform the following tasks:

- *Link Sensing*: contains the links associated with the node using the local link set. The local link set lists all nodes that have a link with the node of interest as well as their link status. A link's status can be bi-directional, unidirectional, or MPR.
- *Neighbor Detection:* declares all the neighbors of the node using the neighbor set. The neighbor set lists all the neighbors of the node of interest, up to two hops away.
- *MPR Selection:* Signaling declares the MPRs of a node using the MPR set. The MPR set lists all the nodes that the node of interest has chosen as its MPRs.

HELLO messages are generated and broadcast periodically based on changes to the local link set, neighbor set and MPR set.

2.4.3 Topology Control Messages:

Each node periodically broadcasts Topology Control (TC) messages to declare its MPR selector set and populate its topology table. These messages are forwarded like usual broadcast messages throughout the entire network (through MPRs) and are sent at normal intervals unless there has been a change to the MPR selector set. A change to the MPR selector set results in a TC message sent sooner than the interval. A node with an empty MPR selector set (i.e., nobody has selected it as an MPR) does not generate TC messages.

The topology table, maintained at each node, records information about the topology of the network as obtained from TC messages. This topology information is used to calculate routes for the routing table. Each topology table entry has an associated holding time; once expired, the entry is marked invalid and is removed. The topology table maintains topology information by recording:

- Destination Addresses: These are the MPR selectors obtained from the TC message. These nodes selected the node of interest as an MPR and are the nodes that the node of interest must forward messages to.
- Destination's MPR: These are the last-hop node to the destination. These nodes are the originators of the TC messages and provide the route to the MPR selectors.
- MPR Selector Sequence Number: This sequence number is maintained to specify the most recent MPR selector set. It is only incremented when the MPR selector set has been modified.
- Holding Time: This specifies how long an entry will be maintained in the topology table.

2.4.4 Route Table Calculation:

A routing table is kept at each node and contains routes to all other destinations in the network. This table is built by tracking connected pairs (i.e., pairs whose link status is bi-directional) in the topology table. In order to obtain optimal paths, only connected pairs are selected on the minimal path. There is no entry for destinations whose routes are broken or are not fully known. Route table entries contain the destination address, next-hop address, and estimated distance to destination (in number of hops).

2.5 Voice over Internet Protocol:

VoIP is a relatively new technology that sends digital voice data over packet switched networks. Conventional voice telephony is transported in full duplex mode on Public Switched Telephone Network (PSTN) circuits optimized for voice (6) . In VoIP, analog voice data is converted to a digital format and compressed using a coder/decoder (codec). This stream of binary data is then sent to the Transmission Control Protocol (TCP)/IP stack where it is broken into a series of packets for transmission across the network (7). Once at the receiver, the IP packets are stripped of their headers and the payload is sent as a constant bit stream to a compatible codec (8).

2.6 INTERNET PROTOCOL VERSION 6

IP version 6 (IPv6) is a new version of the Internet Protocol, designed as the successor to IP version 4 (IPv4). The changes from IPv4 to IPv6 fall primarily into the following categories:

- Expanded Addressing Capabilities

  IPv6 increases the IP address size from 32 bits to 128 bits, to support more levels of addressing hierarchy, a much greater number of addressable nodes, and simpler auto-configuration of addresses. The scalability of multicast routing is improved by adding a "scope" field to multicast addresses. And a new type of address called an "anycast address" is defined, used to send a packet to any one of a group of nodes.

- Header Format Simplification

  Some IPv4 header fields have been dropped or made optional, to reduce the common-case processing cost of packet handling and to limit the bandwidth cost of the IPv6 header.

- Improved Support for Extensions and Options

  Changes in the way IP header options are encoded allows for more efficient forwarding, less stringent limits on the length of options, and greater flexibility for introducing new options in the future.

- Flow Labeling Capability

  A new capability is added to enable the labeling of packets belonging to particular traffic "flows" for which the sender requests special handling, such as non-default quality of service or "real-time" service.

- Authentication and Privacy Capabilities

  Extensions to support authentication, data integrity, and (optional) data confidentiality are specified for IPv6 (9).

Internet protocol is a primary communication protocol which is used to send data packets from source to destination node in network. Data is transmitted in the form of data gram. Fragmentation is a technique which is used to send large datagram in network in it large datagram is divided into small data packets that can easily be transmitted in the network, because every network link has limited size for messages transmission in a network which known as maximum transmission unit (MTU).

With the rapid development in wireless communications in recent years, the necessity for sufficient Internet protocol (IP) addresses to meet the demand of mobile devices, as well as flexible communications without infrastructure, are especially considerable. The next-generation IP, Internet Protocol version 6 (IPv6) provides sufficient IP addresses to enable all kinds of devices to connect to the Internet and promotes mobile wireless commerce (m-commerce). The IPv6-enabled network architecture will become the future standard.

Additionally, most current mobile devices are equipped with IEEE 802.11 wireless local area network (WLAN) interface cards. IEEE 802.11 WLAN supports two operating modes: infrastructure mode and ad hoc mode. The infrastructure mode requires all mobile devices to directly communicate to the access point (single-hop communication). In the ad hoc mode, mobile devices dynamically form a mobile ad hoc network (MANET) with multi-hop routing. Clearly, the ad hoc mode allows for a more flexible network, but its aim is not to connect to the Internet. In this paper, we address the issue of connecting MANETs to global IPv6 networks while supporting IPv6 mobility with various routing protocols.

2.7 RELATED WORK:

In (10), the author tested three routing protocols of mobile ad hoc networks OLSR, AODV, GRP under IPv4 and IPv6 environment. On the basis of observation, we say that OLSR performs better in terms of throughput and network load. Thus we conclude that OLSR performs better as compared to AODV and GRP under IPv6 environment. The results shows that GRP not perform well IPv6 environment and not suitable for the IPv6 environment. Results also show that AODV performance well in data dropped Under IPv6 environment. However, it is not necessary that OLSR always perform better the results may vary by varying networks.

In (1), the authors talked about the three routing protocols (AODV, OLSR and TORA) depend on OPNET simulator. Various proactive and reactive ad-hoc routing protocols was examined with various mobile nodes transmitting GSM voice traffic data. At last, it is found that the total performance of OLSR is better selection for small and large networks. The performance of TORA performs well with small and large sized network in comparison of AODV. Simulation result also described TORA reactive routing protocol is best suitable for MANET protocol in high population of nodes, while AODV has very poor QoS in high population of node networks with GSM voice traffic data.

In (11), the authors tested four routing protocols of mobile ad hoc network DSDV, I-DSDV, OLSR and ZRP under IPv6 environment. On the basis of observation, it has been observed that OLSR performs better in terms of end to end delay and packet delivery fraction, whereas ZRP shows good result in terms of routing overhead. Thus they conclude that OLSR and ZRP perform better as compared to DSDV and I-DSDV. However, it is not necessary that OLSR and ZRP always perform better the result may vary by varying network.

In (12), Mobility and the Node Density are key factors that upset the behavior of TORA-enabled Mobile Ad hoc Network. TORA has three stages of operations (route creation, route maintenance and deletion); the time taken for route reply is not specified in the route creation stage. The conceptual model presented finds basis on the fact that on-demand routing protocols establish paths only when necessary. The route establishment operation invokes a route-determinations procedure. However, such procedures only terminate when a route is been detected or no route is available. Therefore, specifying the time taken for the reply to occur might optimize the performance of TORA with respect to mobility and node density. The time it takes to establish communications is as quite important, and the suggested model adapts a four [4] seconds benchmark. Standards emphasize on seven [7] seconds limits, which could be measured. However, most ad hoc routing protocols have been noted to have matched this requirement.

Jitter is seen to be severely impacted by the mobility of the nodes. Moreover, the results also indicate that an increase in speed of the nodes on the network influences an attendant increase in bit rate error. Node density also causes strict impact on network end-to-end delay. A higher number of nodes are seen to aggravate the delay such that packets cannot be transported effectively. However, as the nodes number reduces, the delay tends toward reduction, allowing for efficient communication among nodes. Although general voice quality is not very encouraging, fewer number of the nodes within the network make better results an average of 3.2 MOS value is obtained which is considered fair. This means that communication in an ad hoc network using TORA is more productive and effective with fewer nodes. It could also be said that given the utilization of TORA routing protocol in MANET, quality of voice communication is disproportionate to node density. Increase in the number of nodes greatly depreciates voice quality. Overall throughput is also influenced by the mobility and density of nodes.

3. Research Methodology

3.1 Introduction

This chapter discusses the methodology for this research. Section 3.2 discussed the general methodology and the simulator used in this research (OPNET 14.5) .System components described in section 3.3, and section 3.4 discusses the performance metrics of the simulation. Independent variables are described in section 3.5. Section 3.6 explains the evaluation technique, and Section 3.7 describes the experimental scenario.

3.2 General Methodology

Discrete Event Simulation software OPNET (Optimized Network Engineering Tool) Modeler version 14.5 is used in this study. OPNET is a commercial network simulator that is used widely to design heterogeneous networks like ad hoc networks. OPNET is a graphical user interface based network and so it is easy to use. OPNET incorporates a number of features to support an increase stability and mobility in the mobile ad-hoc network. The modeler uses object-oriented modeling approach. The nodes and protocols are modeled as classes with inheritance and specialization. The development language is C. It provides a variety of toolbox to design, simulate and analyze a network topology.

It is easy to design a network in an OPNET Modeler and to evaluate the performance of these routing protocols. These parameters are known as performance metrics. Specific application and transport layer protocols demand their own set of performance metrics to evaluate the network efficiency.

3.2.1 Optimized Network Engineering Tool (OPNET)

OPNET is one of the most widely used commercial simulators based on Microsoft Windows platform and incorporates more MANET routing parameter as compared to other commercial simulator available. It not only supports MANET routing but also provides a parallel kernel to support the increase in stability and mobility in the network

In this study, the simulations focused on the performance of Optimized Link State Routing (OLSR) in the IPv6 environment is evaluated on the basis of three parameters delay and network load, network throughput, MOS (Mean Opinion Score) and jitter.

The simulated system consists of four major components - ad hoc nodes, an ad hoc network, OLSR routing protocol, and VOIP traffic application. Methodology configuration showed in appendix A.

3.3 System components

3.3.1 Ad Hoc Nodes:

Each node in the ad hoc network functions as both a client and a server. As clients, the nodes complete two tasks - send requests to the network and receive information from the network. As servers, the nodes process information received from the network and determines whether packets require forwarding. If so, the node services the packet accordingly. Thus, each node provides the services of both a router and an end unit.

3.3.2 Ad Hoc Network:

The ad hoc network is measured by observing VoIP traffic as it travels through the network. This network provides the medium that transports

VoIP traffic from one ad hoc node to another. This network is simulated in OPNET using the wireless network suite.

3.3.3 Routing Protocol – OLSR:

When there are no direct links between the sender and receiver, packets must pass through other nodes in the network to reach their destination. This multi-hop routing is implemented using routing protocols. OLSR determines routes from each node to every other node in the network.

3.4 Performance Metrics:

Performance metrics are used to establish the performance of systems. The performance metrics are delay, packet loss, jitter, throughput, and MOS (Mean Opinion Score).

Evaluating performance in a MANET 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 MANET under IPv6 environment.

3.4.1 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. However, the average delay for a VoIP stream should be less than 150 ms for acceptable perceived quality (13). 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.

3.4.2 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.

3.4.3 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.

3.4.4 Mean Opinion Score (MOS)

In voice interaction, quality generally prescribes whether the experience is a good or bad one. Besides the qualitative explanation we hear i.e. 'quite good' or 'very bad', there is a mathematical way of showing voice quality. It is known as Mean Opinion Score (MOS). MOS offers a mathematical indication of the detected quality of the media obtained after being transmitted. MOS is showed in one number, from 1 to 4, 4 being the best and 1 the worst.

3.4.5 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 (13). Packet loss is measured as the percent of packets dropped at the receiver prior to data stream playback.

3.5 Independent Variables

Independent Variables are the parameters that are varied during analysis to observe their effect on the performance metrics. They are node density and mobility.

3.5.1 Node Density

Since the simulation area is fixed for all scenarios, the number of nodes in each scenario (5, 10, 15, and 20) fit in the 5,000 m by 5,000 m area.

3.5.2 Mobility

When nodes are static, nodes in the network have no trajectory, thus they remain in their initial position throughout the simulation period. When the nodes are mobile, every node in the network has a randomly-generated trajectory. These random trajectories are chosen by OPNET using the random waypoint mobility profile. Appendix A covers mobility settings for scenario creation in OPNET. Nodes using random waypoint mobility are not assigned trajectories that result in the node traveling outside the simulation area. Therefore, all nodes remain in the simulation area throughout the simulation period.

3.6 Evaluation Technique

Ad hoc wireless network scenarios are created with random node placement in a 5,000 m by 5,000 m area campus network using the wireless workstation node model adjusted to meet the goals of the experiment. Table 3.1 lists the node attributes adjusted for this study. The nodes are randomly placed in the simulation area by OPNET’s random node placement feature.

The simulation time is 10 minutes and the simulation kernel used is the optimized 32-bit sequential kernel.

Table 3-1 OPNET wireless workstation Node Model Attributes

Parameter	Setting
Routing Protocol	OLSR
Area	5000x5000 square meters
Data rate	11 Mbps
Node	4,10,20
Application Traffic	VOIP
Simulation Time	10 minutes

VoIP traffic is introduced into the network with constant packet size of 1,024 bits and an exponential inter-arrival time starting at 0.0 sec with the stop time being the end of simulation. OLSR parameters used in OPNET are shown in Table 3.2.

Table 3-2 OLSR Parameters in OPNET

Parameter	Setting
Willingness	default
HELLO interval	2 sec
TC interval	5 sec
Neighbor hold time	6 sec
Topology hold time	15 sec
Duplicate message hold time	30 sec
Internet Protocol	IPv6,IPv4

3.7 Scenarios

The figures in this section are screen shots for some of the scenarios simulated in OPNET. The nodes are placed randomly throughout the simulation area by OPNET. For the mobile scenarios, this is the state of the scenario at the beginning of the simulation. Each mobile scenario has various end states since the random waypoint mobility profile selects random trajectories and speeds at the time of simulation.

Figure 3-1 Static Nodes in OPNET

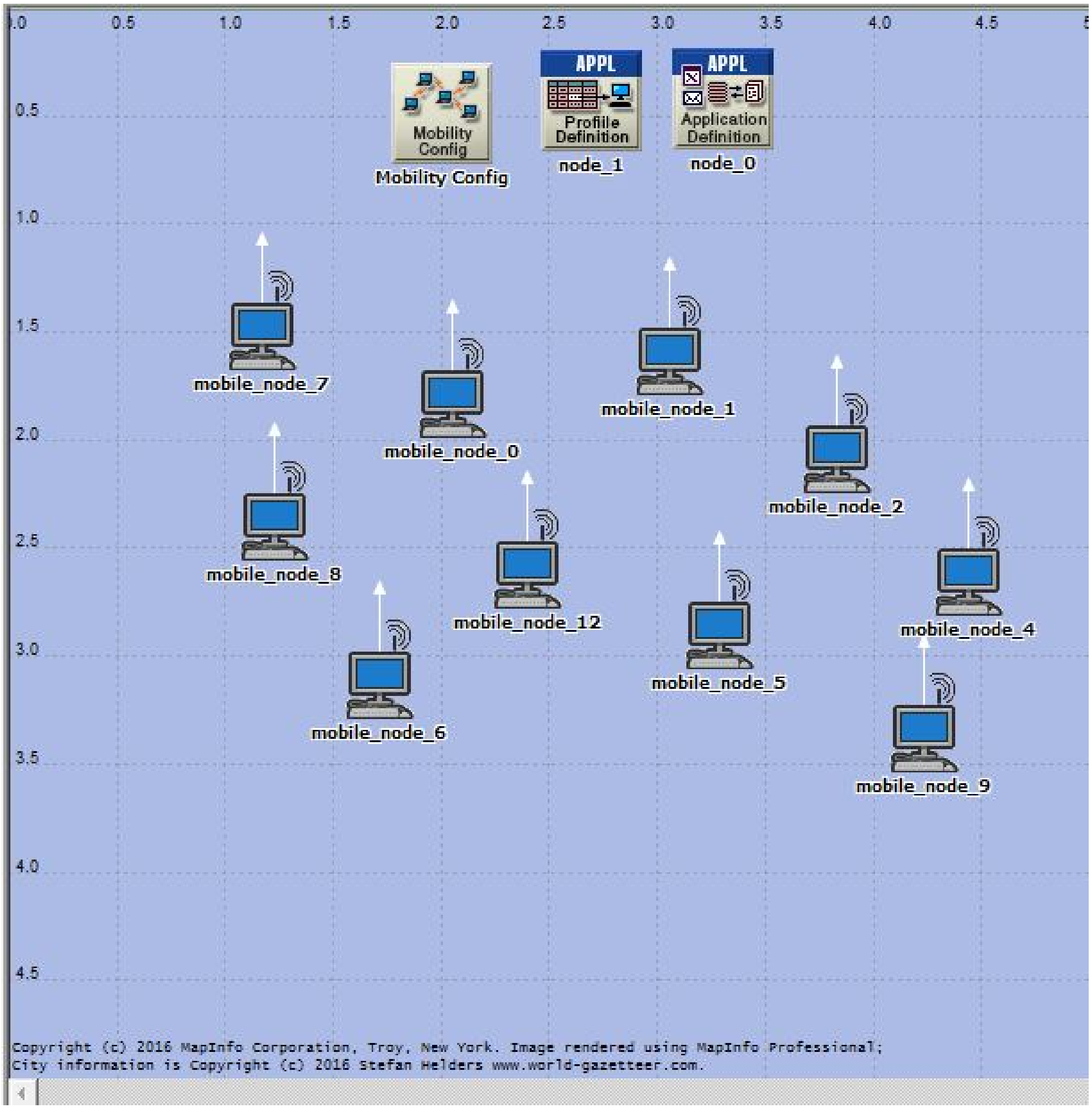

Figure 3-2 10 Mobile Nodes in OPNET

Below table 3-3 shows the summary of all scenarios had been done in OPNE the number of nodes and the mobility status.

Table 3-3 All Scenarios Summary

No of Scenarios	No of Nodes	Mobility
1	5	Static
2	10	Static
3	10	Mobile
4	15	Static
5	20	Static
6	20	Mobile

4 Results and Discussions

4.1 Introduction

Given the OPNET setup described earlier, and having conducted the simulation therein, factors looked into during the test included; mobility and node density for which test metrics of end-to-end delay, jitter, throughput, Mean Opinion Score (MOS) and packet loss were carried out. The aim remained the test for the performance behavior of OLSR in mobile ad hoc network transmitting voice traffic. Below are the results obtained and their analysis.

4.2 Impact of Number of Nodes

Figure 4.1 compares End-To-End delay in relation to the number of nodes. Node density exerts severe impacts to network end-to-end delay, as the nodes number reduces the delay also tends to reduce. The x axis represents the simulation time period (10 minutes) and the y axis represents End-To-End delay in seconds.

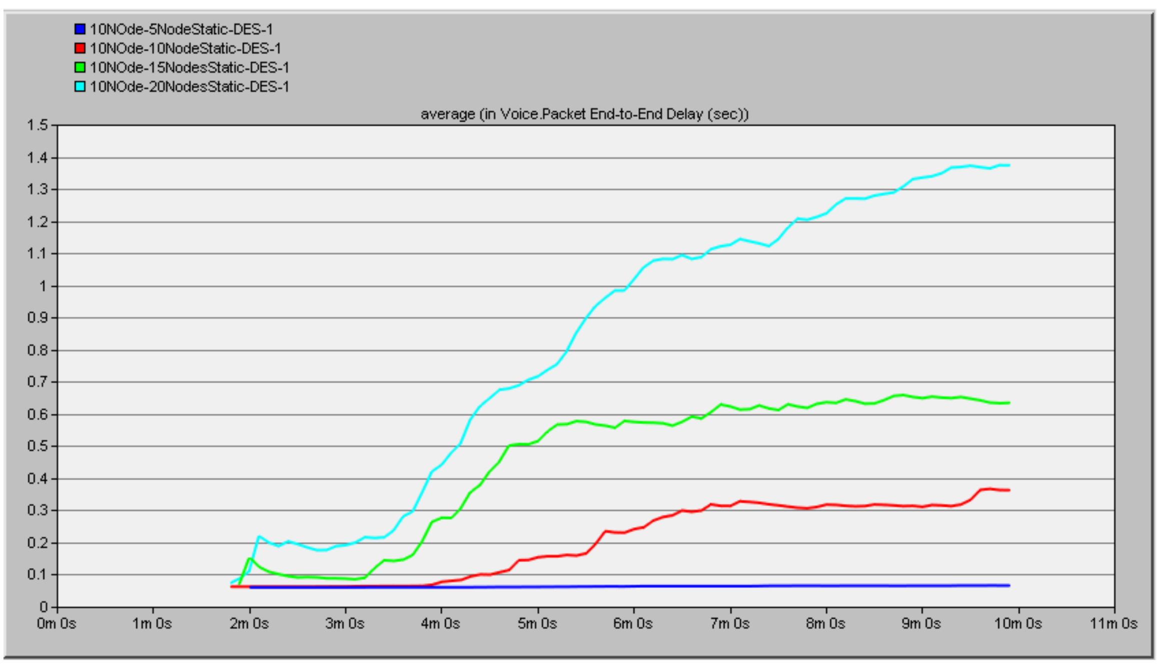

Figure 4-1 End-To-End delay for 5, 10, 15 & 20

Figure 4.2 compares jitter in relation to the number of nodes. Overall jitter increased as the number of nodes increase from 5, 10, 15 and 20 nodes. The x axis represents the simulation time period (10 minutes) and the y axis represents voice jitter in seconds.

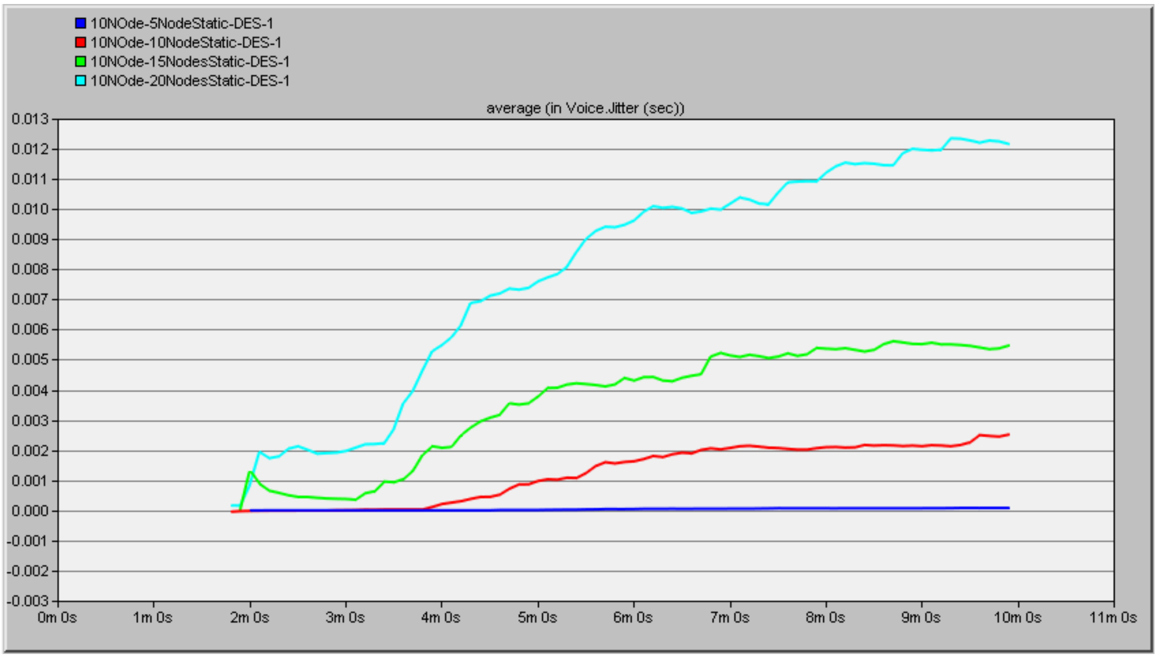

Figure 4-2jitter in IPv6 5, 10, 15, 20 Nodes

Figure 4.3 compares Throughput in relation to the number of nodes. It is clear that throughput of OLSR increases quickly with simulation time and number of nodes. The x axis represents the simulation time period (10 minutes) and the y axis represents simulation throughput in bits/sec.

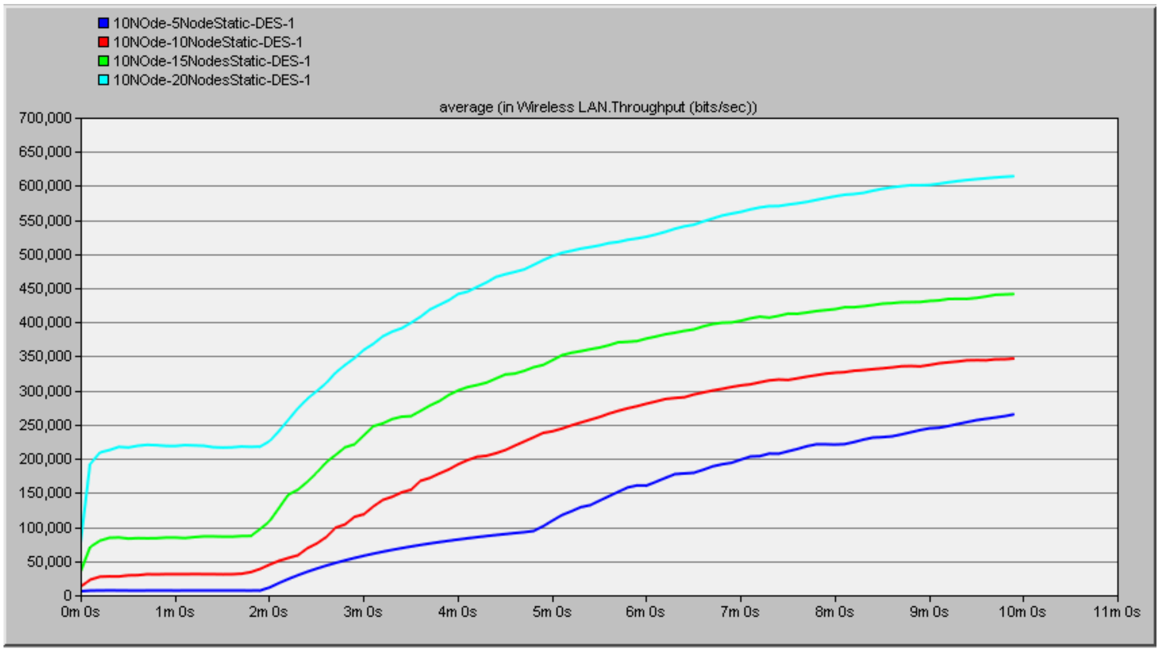

Figure 4-3 Throughput difference between 5, 10, 15&20 Nodes

Figure 4.4 compares Mean Opinion Score (MOS) in relation to the number of nodes. Increase in the number of nodes greatly deteriorates voice quality. This means that communication in an ad hoc network using OLSR is more productive and effective with fewer nodes. The x axis represents the simulation time period (10 minutes) and the y axis represents MOS which showed in one number, from 1 to 4, 4 being the best and 1 the worst.

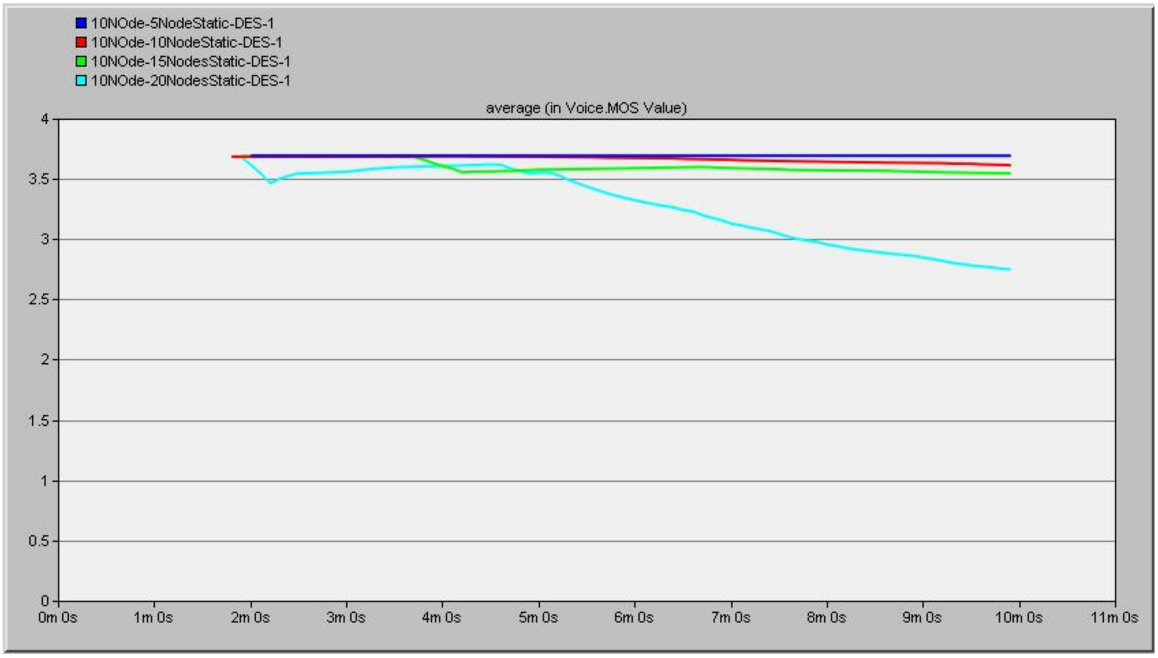

Figure 4-4 MOS for IPv6 5, 10, 15 &20 Nodes

Figure 4.5 compares Packet loss in relation to the number of nodes. It has been observed that packet loss is increased with nodes increment. The x axis represents the simulation time period (10 minutes) and the y axis represents Traffic dropped and represent by packets/sec.

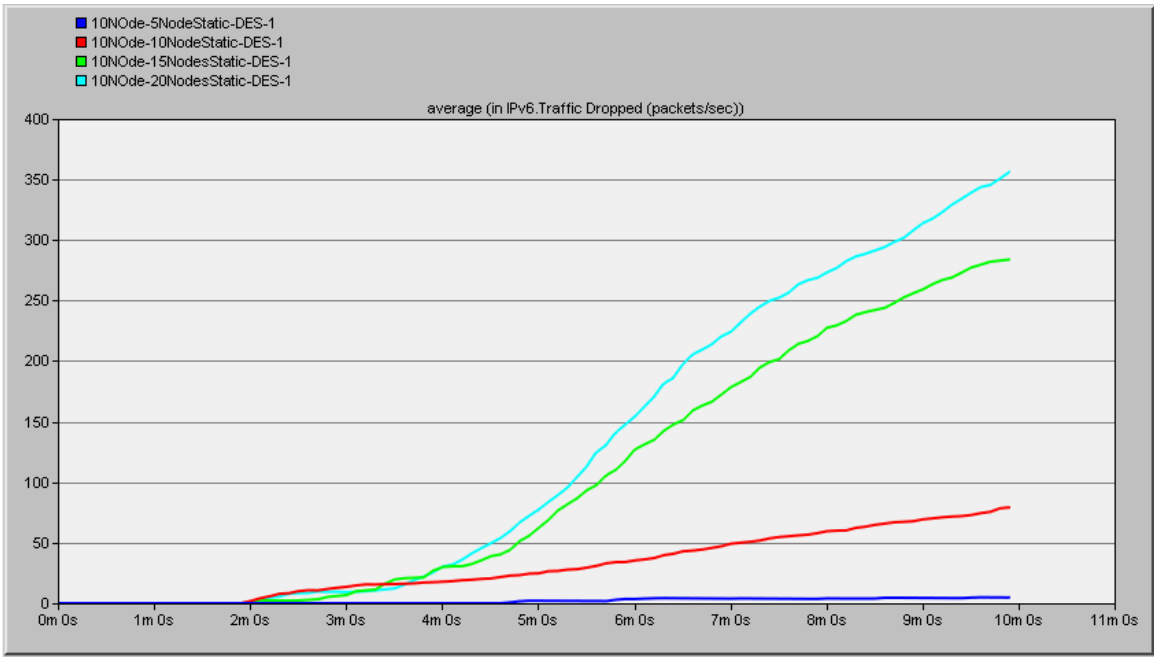

Figure 4-5 IPv6 traffic dropped for 5, 10, 15 & 20 Nodes

4.3 Impact of Node Mobility

Mobility is seen to have significant impact on the behavior of the ad hoc network.

Figure 4.6 compares the effect of mobility on End-To-End delay. Delay began to drop slightly as the nodes mobile. The x axis represents the simulation time period (10 minutes) and the y axis represents End-To-End delay in seconds.

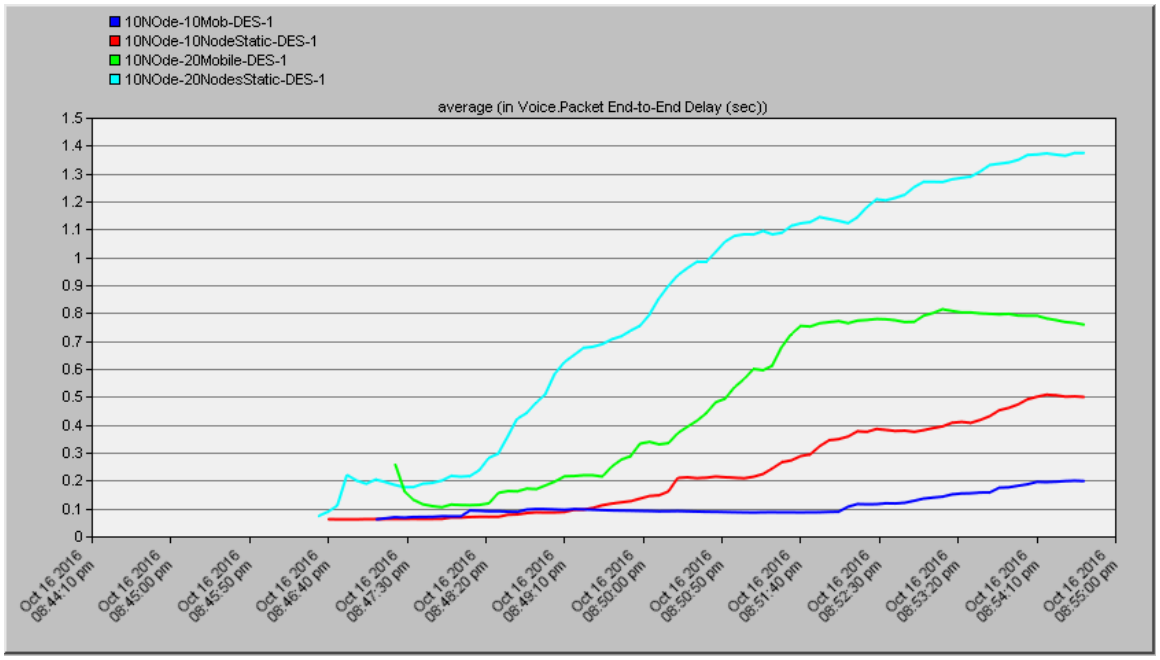

Figure 4-6 End-To-End delay Mobile Nodes

Figure 4.6 compares the effect of mobility on jitter. Indicate irregular jitter curves. Given that the nodes were randomly placed, mobility slightly decreases the jitter. The x axis represents the simulation time period (10 minutes) and the y axis represents voice jitter in seconds.

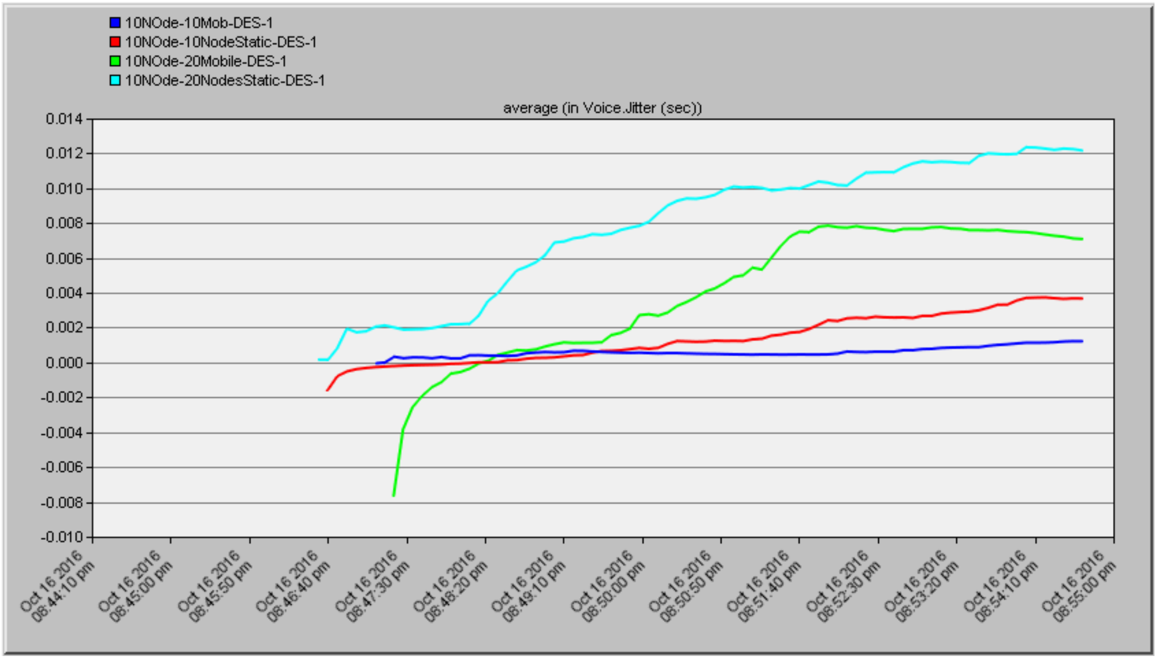

Figure 4-7 jitter in 10 & 20 Mobile Nodes

Figure 4.7 compares the effect of mobility on throughput. Observed that mobility decrease overall throughput. The x axis represents the simulation time period (10 minutes) and the y axis represents simulation throughput in bits/sec.

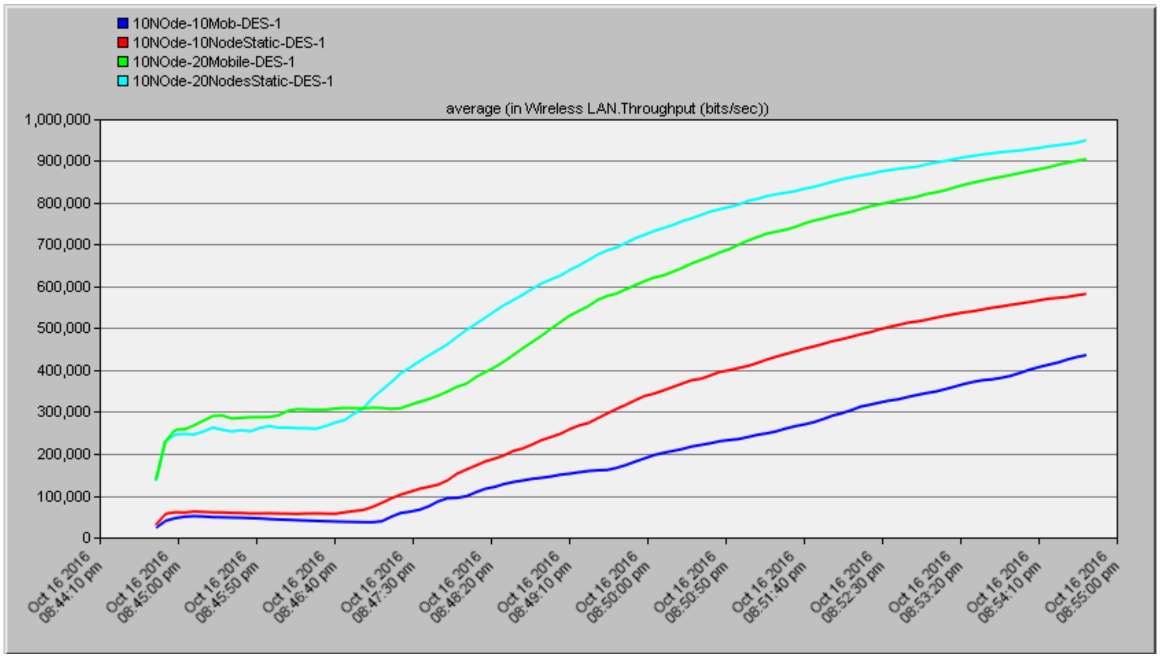

Figure 4-8 Throughput in Mobility for 10 &20 Nodes

Figure 4.8 compares the effect of mobility on Mean Opinion Score (MOS). Bad voice quality was observed when stations were static compared to mobile stations. The x axis represents the simulation time period (10 minutes) and the y axis represents MOS which showed in one number, from 1 to 4, 4 being the best and 1 the worst.

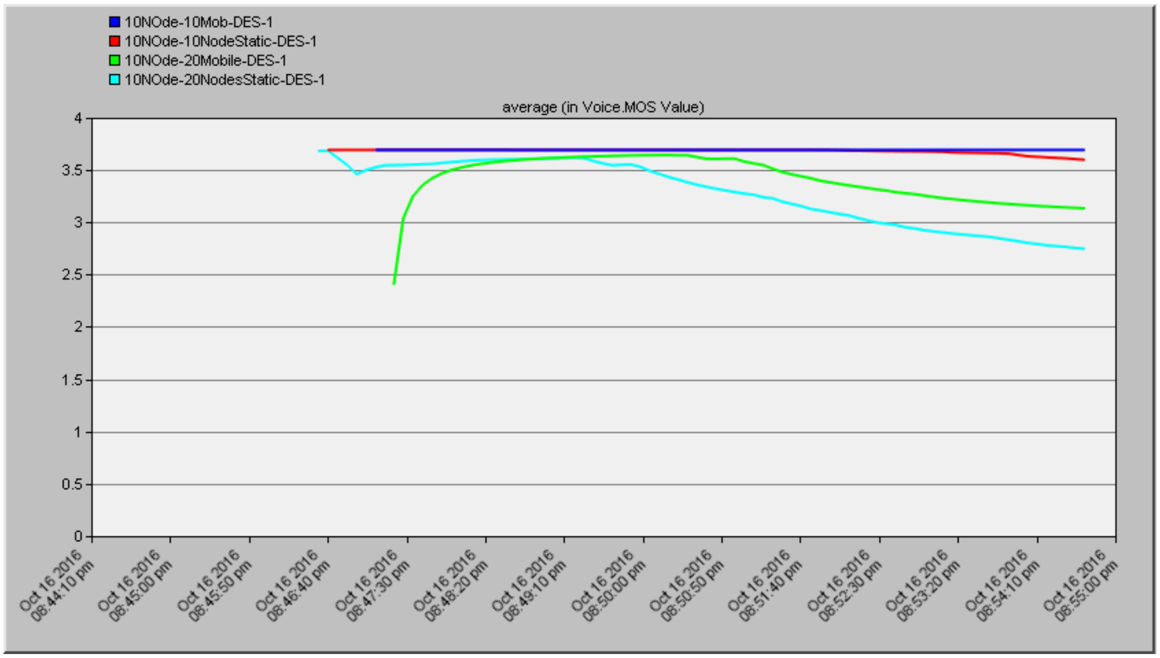

Figure 4-9 MOS for mobility 10 &20 Nodes

Figure 4.9 compares the effect of mobility on packet loss. As simulation time goes static scenarios got the higher packet loss. The x axis represents the simulation time period (10 minutes) and the y axis represents Traffic dropped and represent by packets/sec

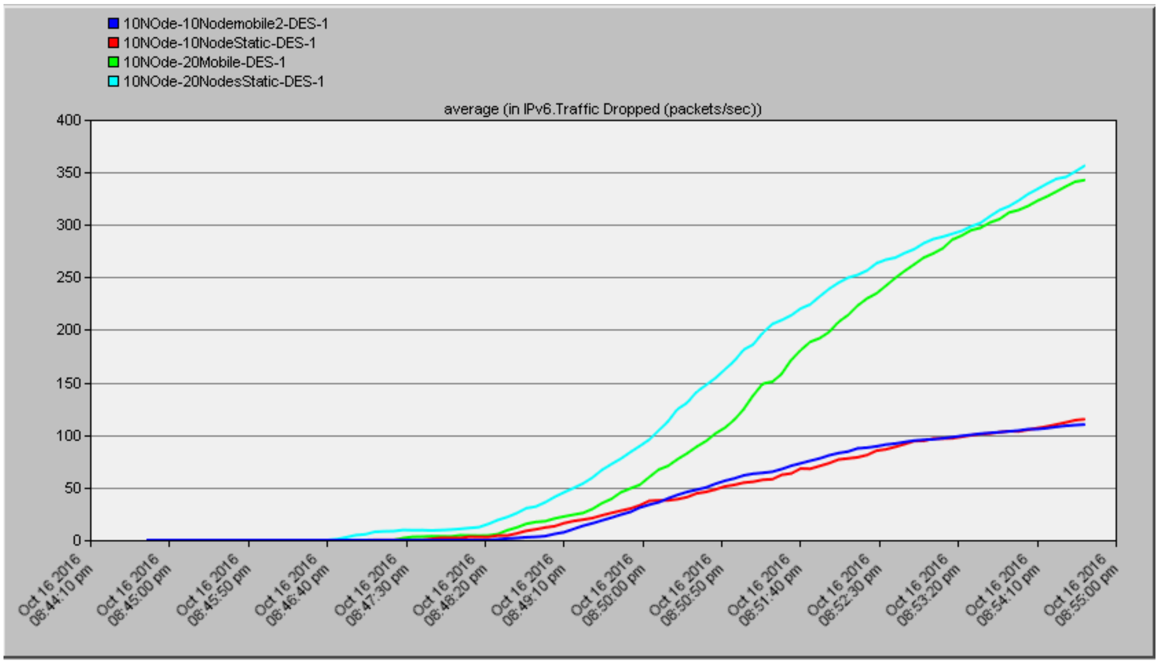

Figure 4-10 Traffic dropped for Mobility 10&20 Nodes

4.4 Analysis

Both node density and mobility affect the overall performance of OLSR routing protocol.

As the number of nodes increases the jitter increase and decrease the overall quality of the voice communication. Therefore, reduction in the node density impacts the network by causing a reduction in jitter. Node density also exerts severe impacts to network end-to-end delay as noted earlier; as the nodes number reduces the delay also tends to reduce. It implies that spaces allow for reduced collision of nodes, allowing for route establishments and (or) re-establishment of route and acknowledgement.

In this case the node density is inversely proportional to the MOS unlike in the Jitter The higher the node density the lower the MOS and the other way round. The voice quality rating here is classified as low. This means that communication in an ad hoc network using OLSR is more productive and effective with fewer nodes. As the environment or the system gets dense with nodes, the quality of voice and communication degrades.

While significant impact is noticed in the mobility, is noticed that jitter and end-to-end delay decrease due to more mobility in the MANET. Thus, OLSR is able to find best paths since its metric for route selection is shortest path (i.e., shortest number of hops from source to destination) resulting in paths with shorter propagation delays thus decreasing overall end-to-end delay and jitter.

Packet loss raw data is collected through OPNET in packets lost/second. This value is converted to percent of packets lost by

$$\text{PercentPacketLoss} = PL \div TS * 100$$

Where PL is packet loss obtained from OPNET and TS is the total amount of traffic sent.

Table 4.1 shows end to end delay, jitter and packet loss for all the scenarios simulated in this research.

Table 4-1 end to end delay, jitter and packet loss values

Scenario	**Jitter**		**End To End delay**		**Packet loss**	
	Static	Mobile	Static	Mobile	Static	Mobile
5 Nodes	0. 079 ms	0.00817 ms	65.9 ms	60.68 ms	2.4%	6.42%
10 Nodes	3.67 ms	0.4032 ms	440 ms	95.24ms	29.6%	25.28%
15 Nodes	6.89 ms	2.15 ms	837.5 ms	275.8 ms	31.5%	18.56%

20 Nodes	12.16 ms	5.36 ms	1373.2 ms	558.4 ms	44.8%	37.3%

Increase in mobility also decreases throughput, the movement of the nodes causes a reduction in the message periodically; nodes receive a great deal of routing traffic above normal in mobility.

Figure 4.1, figure 4.12 and figure 4.13 show the overall performance of all nodes.

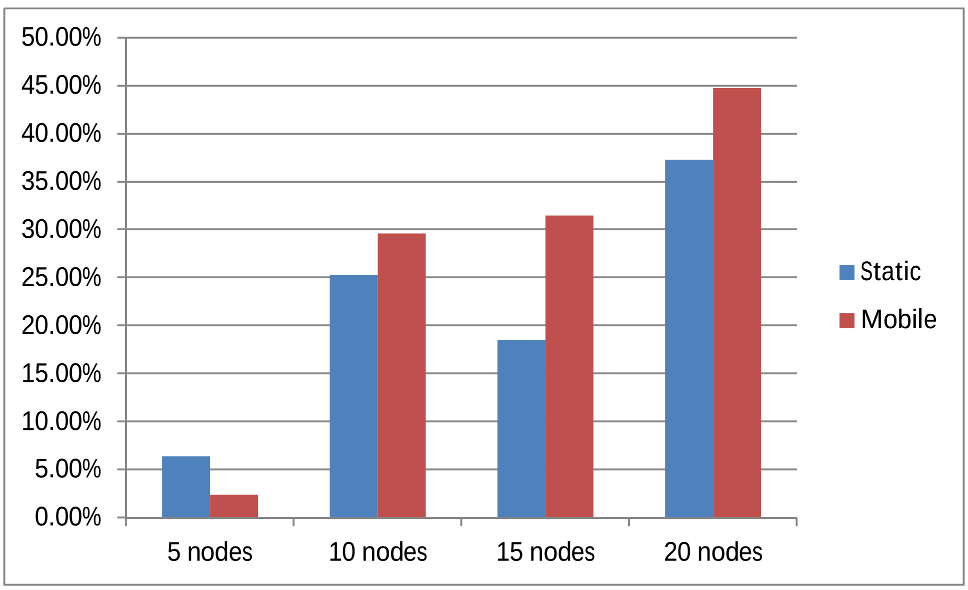

Figure 4-11packet loss for all nodes

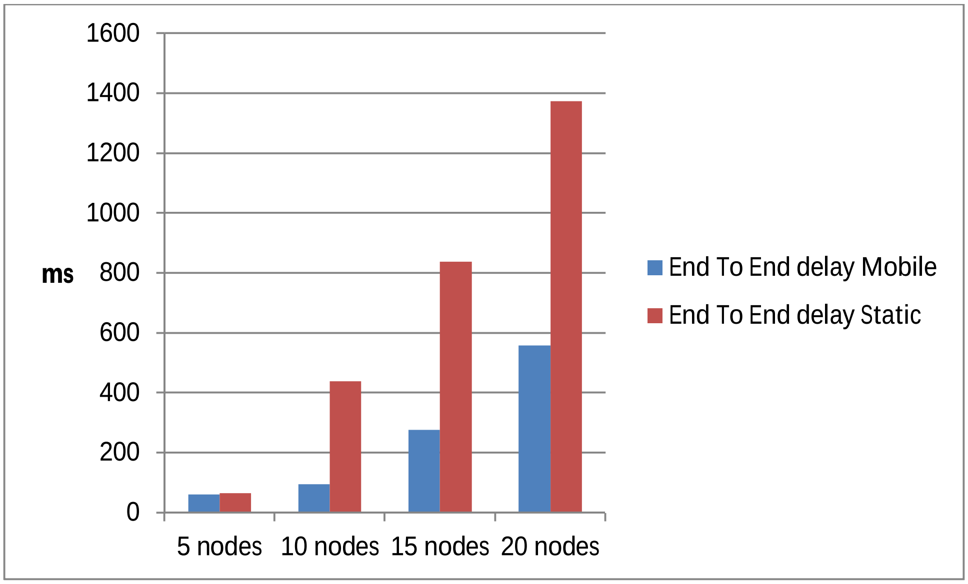

Figure 4-12 End to End delay for all nodes

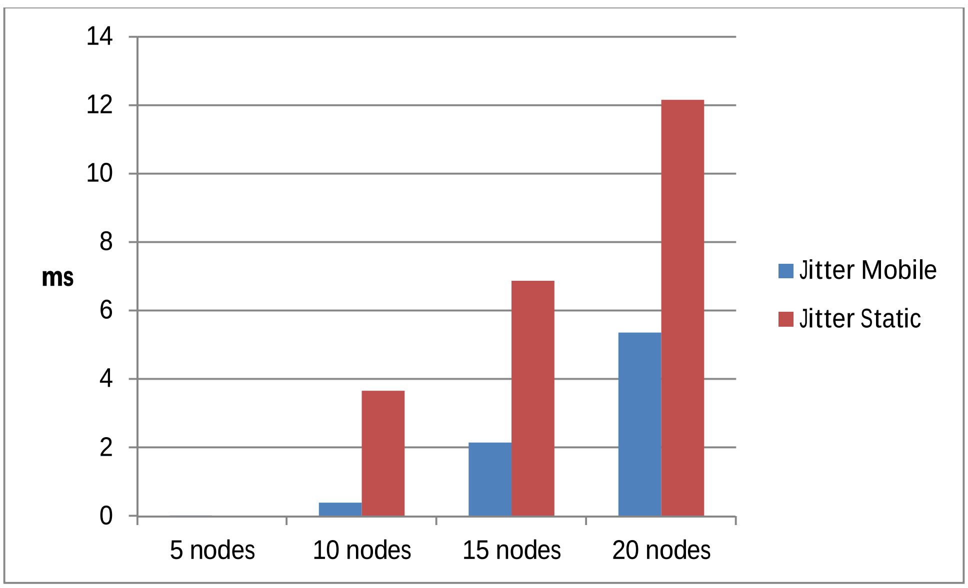

Figure 4-13 jitter for all nodes

5 Conclusion and Future Work

This research observes the performance of MANETs running OLSR while VoIP traffic is introduced into IPv6 network.

Representative VoIP traffic is submitted to a MANET, jitter and end-to-end delay and packet loss are observed. Node density and mobility are varied creating a full-factorial experimental design of 6 scenarios. OPNET modeler simulates the MANET, and VoIP traffic is introduced using all source nodes that send traffic to random destinations throughout the network.

Mobility and the Node Density are key factors that upset the behavior of OLSR enabled Mobile Ad hoc Network.

Conclusions:

Results show that node density and mobility affect delay, jitter, mean opinion Score (MOS), throughput and packet loss. Even with the increase in both packet loss and delay, OLSR is still a suitable routing protocol for VoIP traffic.

Higher number of nodes is seen to aggravate the delay such that packets cannot be transported effectively. However, as the nodes number reduces, the delay tends toward reduction, allowing for efficient communication among nodes. Although general voice quality is not very encouraging, fewer number of the nodes within the network make better results an average of 3.69 MOS value is obtained which is considered good when the nodes was 5.

These results shows that routing protocols do affect delay and packet loss in MANETs and also the total performance of OLSR is better selection for small networks.

Recommendations and future work:

This study focuses on only VoIP application with speech activity detection enabled/disabled, which also it reveals more systematic general understanding of how VoIP operate in MANET. The work comes useful to the academia and industries, as it would help the decisions for a most suitable routing protocol at any given ad hoc voice communication setup.

- Since simulation results tend to assume best case scenarios and perfect conditions, an ad hoc test-bed using OLSR to route VoIP traffic can be used and compare results with simulator also add more nodes to test-bed and tend to be more realistic environment.
-
- Future works could consider the behavior of other heavy multimedia applications over MANET.

6 Appendix

OPNET Simulation Setup

The following steps are needed in order to create and run a simulation in OPNET:

1. Create Project
2. Create Scenario
3. Add VoIP Packets
4. Configure Discrete Event Simulation (DES)
5. Run Simulation.

6.1 Scenario Creation and Setup

Deploying the wireless network in the scenario can be done using mobile nodes under MANET and configure IPv6 for each node.

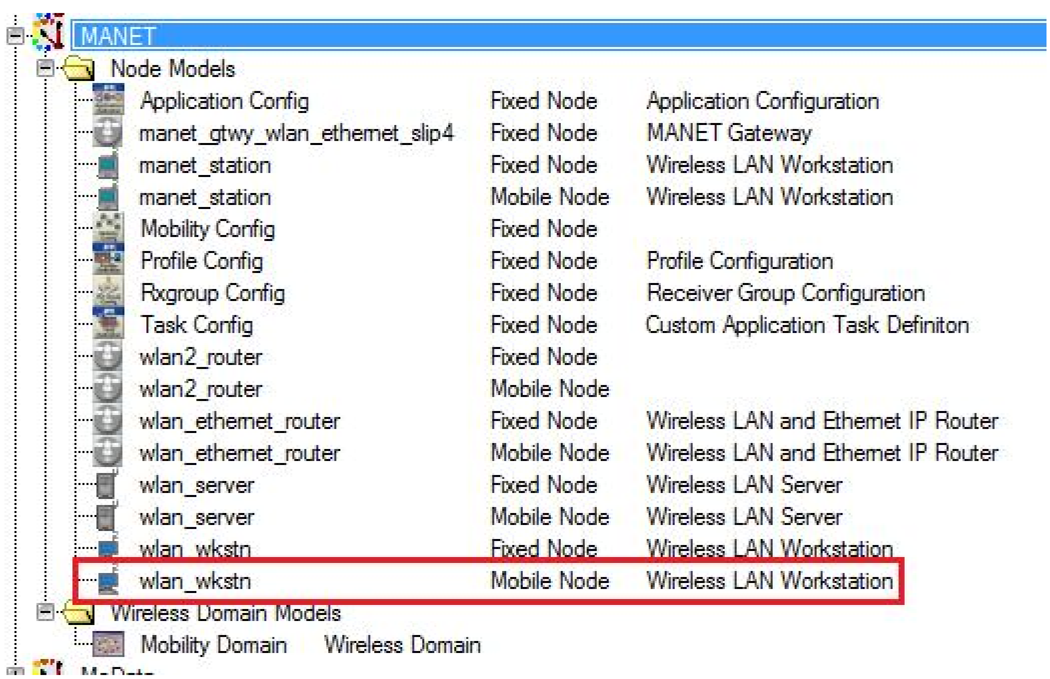

Figure 6-1 wireless workstation

6.2 Deploy VOIP application

In OPNET firstly define application profile and deploy defined application to selected nodes. Figure 6.2 shows the VOIP application profile.

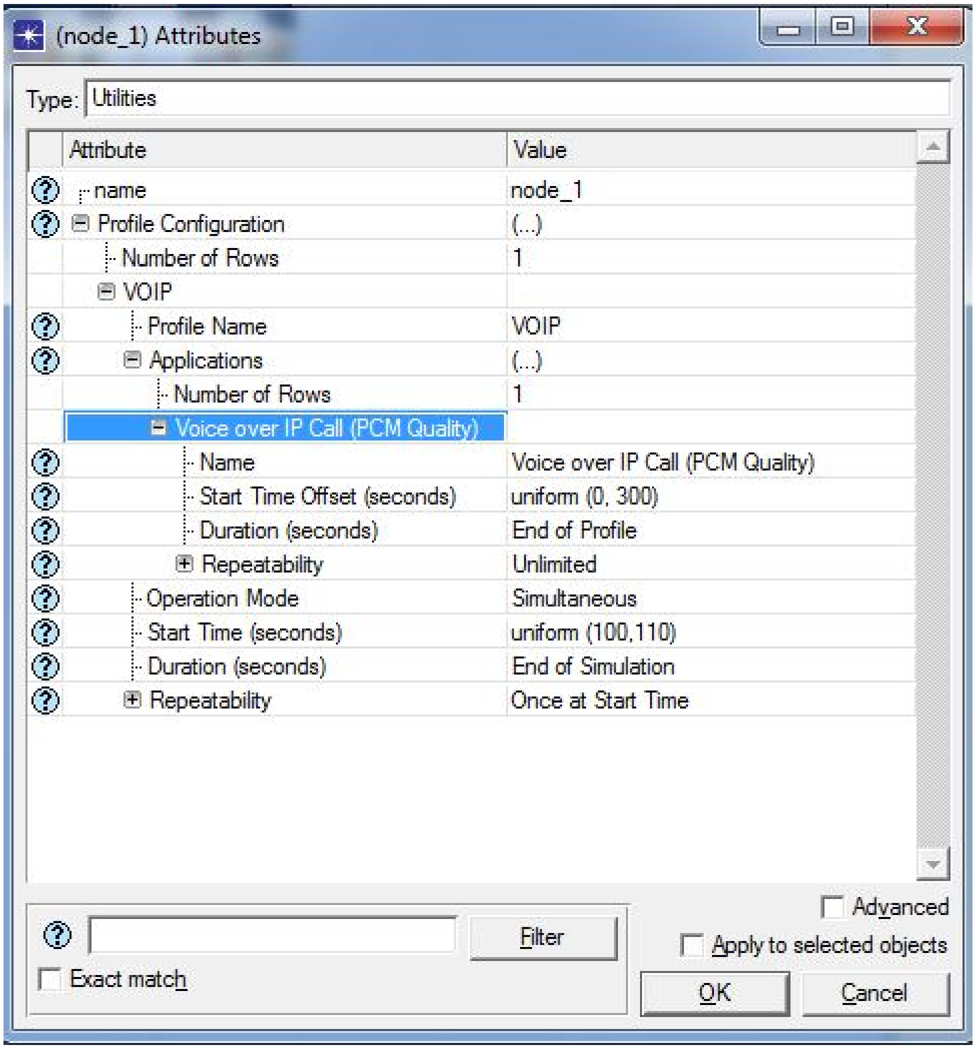

Figure 0-2 VOIP

6.3 Configure Discrete Event Simulation (DES)

Figure 6.3 shows the DES configuration for the scenario with 5 nodes, and no mobility. DES is when the operation of a system is represented as a sequence of events. Web reports are generated for each scenario for data collection.

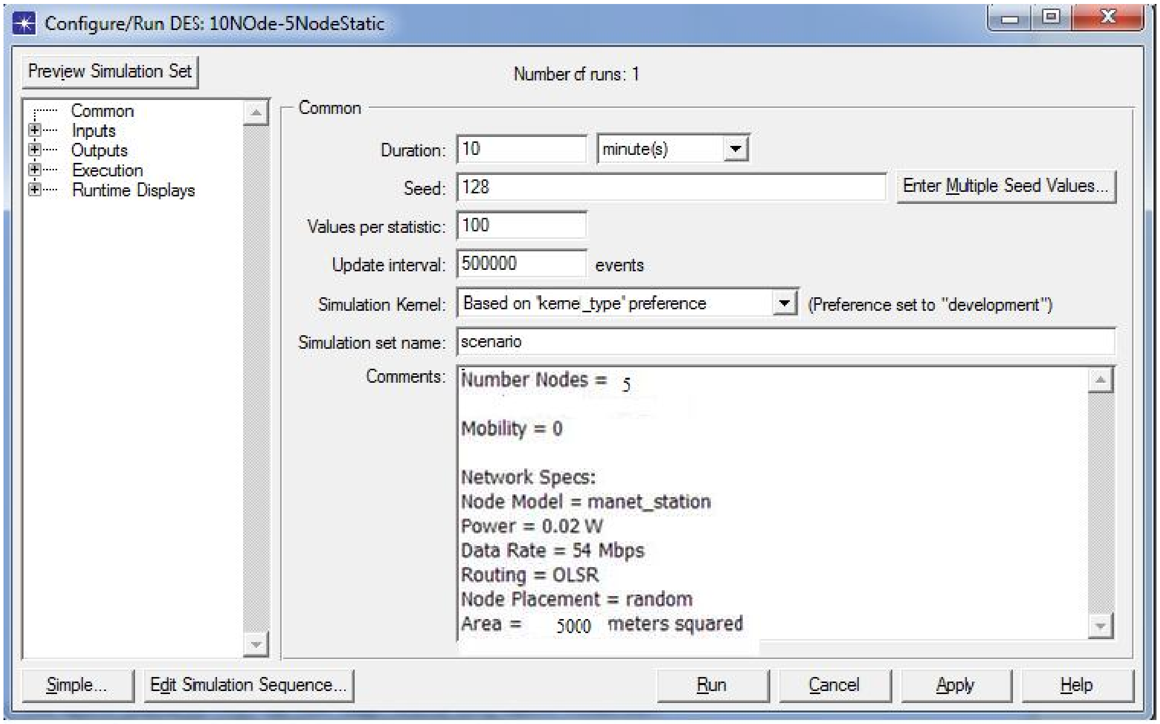

Figure 0-3 DES Configuration

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