

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND COMPUTER
ENGINEERING

**QUALITY-OF-SERVICE ROUTING IN MOBILE AD-HOC NETWORKS
FOR PROACTIVE PROTOCOLS**

By

Alexander Gebregziabher

Advisor

Dr Manoj VNV

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FACULTY OF TECHNOLOGY
APPROVAL BY BOARD OF EXAMINERS

Chairman Dept. of Graduate

Committee

Signature

Dr. Manoj VNV

Advisor

Signature

Internal Examiner

Signature

External Examiner

Signature

Declaration

I, the undersigned, declare that this thesis work is my original work, has not been presented for a degree in this or any other universities, and all sources of materials used for the thesis work have been fully acknowledged.

Name: Alexander Gebregziabher

Signature: _____

Place: Addis Ababa

Date of submission: March 2008

This thesis has been submitted for examination with my approval as a university advisor.

Dr. Manoj VNV

Signature: _____

Advisor's Name

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List of Acronyms

AED—Average End to End Delay
AODV—Ad hoc on Demand Distance Vector
CBR—Constant Bit Rate
DSDV—Destination Sequence Distance Vector
DSR—Dynamic Source Routing
MPR—Multi Point Relay
MANET—Mobile Ad hoc Network
MAC—Medium access Control
NPDU--Network protocol data unit
NS-2—Network Simulator
NRL—Normalized Routing Load
OLSR—Optimized Link State Routing
OTcl ---object oriented variant of Tool Command Language
PDF—Packet Delivery Fraction
Pkts—Packets
QoS—Quality of Service
QOLSR—Quality of Service Optimized Link State Routing
RFC—Request for Commence
RQ—Repeat Request
Rx—Receiver
TC--Topology control
TDMA—Time Division Multiplex Access
TORA—Temporary Ordered Routing Algorithm
TR—Transmitter
ZRP—Zone Routing Protocol

Abstract

Dealing with Quality-of-service (QoS) routing in a mobile Ad-Hoc network is difficult due to the fact that the network topology changes constantly and the available link state information for routing is naturally indefinite. QoS related with band width utilization is very interesting because band width is the most critical resource in mobile ad hoc networks. The QoS issue must also be studied with a growing node density. This is because the beauty of attaining wider band width link is highly appreciated when the band width resource is scarce due to congestion and high traffic. In this thesis, A comparative analysis of two proactive protocols: Destination Sequence Distance Vector (DSDV) and OLSR (Optimized Link State Routing) is conducted in their traditional best effort routing part. Evaluation of their performance is compared against with band width management metrics. Based on the result of the comparative analysis we develop QoS versions of the OLSR protocol. Algorithm is introduced that allow OLSR to find the maximum bandwidth path with optimal number of MPR, show through simulation and proof that this algorithm do improve QoS in the aspect of bandwidth using (Network Simulator-2) NS-2 simulator and observe the achievement obtained. The simulation results show that the QoS versions of the OLSR routing protocol do improve the available bandwidth ensuring about 2%-16.78% enhancement of Goodput and 2.5- 15.06 % of PDF, this is verified in a network scenario of different node density and node mobility when compared to Original OLSR.

Key Words: MANET, PRO ACTIVE PROTOCOL, QoS, DSDV, OLSR, NS-2.

Chapter 1: Introduction

1.1 Overview

Wireless MANETs consist of mobile nodes interconnected by wireless multi-hop communication paths. Unlike conventional wireless networks, ad hoc networks have no fixed network infrastructure or administrative support. The topology of such networks changes dynamically as mobile nodes join or depart the network or radio links between nodes become unusable. Conventional wireless networks require as prerequisites a fixed network infrastructure with centralized administration for their operation. In contrast, so called (wireless) MANET, consisting of a collection of wireless nodes, all of which may be mobile, dynamically create a wireless network amongst themselves without using any such infrastructure or administrative support [1]. Ad hoc wireless networks are self-creating, self-organizing, and self-administering [25]. They come into being solely by interactions among their constituent wireless mobile nodes, and it is only such interactions that are used to provide the necessary control and administration functions supporting such networks. MANET offer unique benefits and versatility for certain environments and certain applications. Since no fixed infrastructure, including base stations, is a prerequisite, they can be created and used “any time, anywhere.” Such networks could be intrinsically fault-resilient, for they do not operate under the limitations of a fixed topology. Indeed, since all nodes are allowed to be mobile, the composition of such networks is necessarily time varying. Addition and deletion of nodes occur only by interactions with other nodes; no other agency is involved. Such perceived advantages elicited immediate interest in the early days among military, police, and rescue agencies in the use of such networks, especially under disorganized or hostile environments, including isolated scenes of natural disaster and

armed conflict. More over people have recognized from the beginning that ad hoc networking has obvious potential use in all the traditional areas of interest for mobile computing. MANETs are increasingly being considered for complex multimedia applications, where various quality of service attributes for these applications must be satisfied as a set of predetermined service requirements. As a minimum, the QoS issues pertaining to Delay and bandwidth management are of paramount interest. In addition, because of the use of the ad hoc networks for military or police use, and of increasingly common commercial applications, various security issues need to be addressed. Cost effective solution of these issues at appropriate levels is essential for widespread general use of ad hoc networking.

1.2 Statement of the Problem

Quality-of-service (QoS) routing in a MANET network is difficult because the network topology may change constantly and the available state information for routing is inherently indefinite. To support QoS, the link state information such as Bandwidth (measured in terms of Goodput and PDF), Routing over head, Average End to end Delay (AED) and jitter in the network should be available and manageable. However, getting and managing the link state information in a MANET is by all means not simple because the quality of a wireless link changes with the surrounding circumstance. Furthermore, the resource limitations and the mobility of hosts add to the complexity.

However, the unpredictable nature of Ad-Hoc networks and the requirement of quick reaction to QoS routing demands make the idea of a proactive protocol more suitable. When a request arrives, the control layer can easily check if the

pre-computed optimal route can satisfy such a request. Thus, waste of network resources when attempting to discover infeasible routes is avoided. Based on this consideration, in the thesis, we study the approach of pro-active QoS routing, and study two of the most common proactive protocols (DSDV) [28] and OLSR [21] Protocols. And modify a best-effort pro-active routing protocol OLSR for QoS purpose. The QoS requirement studied in the thesis is the bandwidth constraint.

1.3 Objective of the Thesis

1.3.1 General Objective

Generally the Objective of this thesis is to Study two common Proactive protocols (DSDV & OLSR) for QoS incorporation, selecting a protocol with promising performance for QOS, proposing and implementing BW aware route discovery for the selected protocol and study the performance achieved using simulation.

1.3.2 Specific Objective

Specifically this thesis aims at

- 1) Pre Comparative analysis of traditional best effort DSDV and OLSR algorithms with respect to band width related metrics using NS-2 Simulator.
- 2) Developing an algorithm that allow OLSR to find the maximum bandwidth path with optimal number of Multipoint Relays, and show through simulations that this algorithm do improve OLSR
- 3) Run simulations in NS-2 to comprehensively evaluate and compare the Performance of QoS OLSR versions and the original OLSR protocol and discuss the results.

1.4 Methodology

Literatures are reviewed that discuss on traditional best effort proactive routing protocols DSDV and OLSR. Comparative analysis of DSDV and OLSR on the NS-2 simulator is conducted by taking QoS metrics pertinent to band width. Based on the documents and result of the comparative analysis, a decision is made to which of the two proactive protocols will incorporation of QoS done. Then related works of the protocol which is selected to be promising to incorporate QoS are closely surveyed with their limitations. Based on the limitation of the related works, a new version of the QoS algorithm is developed and implemented to attain the QoS enhancement intended. This is done by modifying the MPR selection method to attain maximum band width and optimal number of MPR. The performance of the algorithm selected as promising is analyzed with a NS-2 Simulator thereby discussing the performance enhancement with respect to the original protocol.

1.5 Thesis Outline

Chapter 2 discusses the basics of MANET, characteristics and applications. Chapter 3 talks about the types of routing protocols in brief and proactive protocols in detail for the reason that this thesis mainly focuses on proactive protocols. In Chapter 4, basics of QoS will be discussed including the QoS metrics, types and challenges of QoS in MANET. Related works of both the proactive protocols are discussed in chapter 5. Simulation Environment, parameters and QoS metrics to be captured and scenarios to be considered are described in chapter 6. The simulation results of comparative analysis of DSDV and OLSR are discussed in chapter 7. Chapter 8 describes the design analysis and methodology of the new proposed algorithm. The simulation results of OLSR and QOLSR are discussed in chapter 9. Finally, chapter 10 presents the conclusion and future work of this thesis.

Chapter 2: Mobile Ad hock Networks (MANET)

2.1 MANET Basics

Wireless MANET consist of mobile nodes interconnected by wireless multi-hop communication paths. Unlike conventional wireless networks, ad hoc networks have no fixed network infrastructure or administrative support. The topology of such networks changes dynamically as mobile nodes join or depart the network or radio links between nodes become unusable. Conventional wireless networks require as prerequisites a fixed network infra structure with centralized administration for their operation. In contrast, so called (wireless) MANETs, consisting of a collection of wireless nodes, all of which may be mobile, dynamically create a wireless network amongst themselves without using any such infrastructure or administrative support [17]. An ad-hoc network is a collection of mobile nodes, which forms a temporary network without the aid of centralized administration or standard support services regularly available on conventional networks. The nodes are free to move randomly and organize themselves arbitrarily; thus the networks wireless topology may change rapidly and unpredictably. Such a network may operate in standalone fashion, or may be connected to the larger internet. MANETs are infrastructure less networks since they do not require any fixed infrastructure such as a base station for their operation. In general routes between nodes in an ad-hoc network may include multiple hops and hence it is appropriate to call such networks as multi-hop wireless ad-hoc networks. Each node will be able to communicate directly with any other node that resides within the transmission range. For communication with nodes that reside beyond this range the node needs to use

intermediate nodes to relay the messages hop by hop [15]. MANETs are increasingly being considered for complex multimedia applications, where various qualities of service (QoS) attributes for these applications must be satisfied as a set of predetermined service requirements. As a minimum, the QoS issues pertaining to Delay and band width management are of paramount interest. In addition, because of the use of the ad hoc networks for military or police use, and of increasingly common commercial applications, various security issues need to be addressed. Cost effective resolution of these issues at appropriate levels is essential for wide spread general use of ad hoc networking.. In a mobile ad hoc network, by definition, all the network elements move [1]. As a result, numerous more stringent challenges must be overcome to realize the practical benefits of ad hoc networking. These include effective routing, medium (or channel) access, mobility management, power management, and security issues, all of which affect the quality of service experienced by the user.

The absence of a fixed infrastructure for ad hoc networks means that the nodes communicate directly with one another in a peer-to-peer fashion. The mobility of these nodes imposes limitations on their power capacity, and hence, on their transmission range; indeed, these nodes must often satisfy stringent weight limitations for portability. Mobile hosts are no longer just end systems; to relay packets generated by other nodes, each node must be able to function as a router as well. As the nodes move in and out of range with respect to other nodes, including those that are operating as routers, the resulting topology changes must somehow be communicated to all other nodes, as appropriate. In accommodating the communication needs of the user applications, the limited bandwidth of wireless channels and their generally hostile transmission characteristics impose additional constraints on how much administrative and control information may be exchanged, and how often. Ensuring effective

routing is one of the great challenges for ad hoc networking. The lack of fixed base stations in ad hoc networks means that there is no dedicated agency for managing the channel resources for the network nodes. Instead, carefully designed distributed medium access techniques must be used for channel resources, and, hence, mechanisms must be available to recover efficiently from the inevitable packet collisions. An effectively designed protocol for medium access control (MAC) is essential to the quest for QoS. [1]

2.2 Applications of Mobile Ad Hoc Networks

A MANET is a dynamic multi-hop wireless network that is established by a group of mobile nodes on a shared wireless channel. Mobile ad hoc networks can be in military use, emergency use, wireless sensor networks and also can have mesh wireless network architecture. [31]

2.2.1 Military applications

Use of ad hoc networks in military becomes more and more popular. Using ad hoc networks makes the setting up of communications between soldiers easy. In such applications, the used ad hoc networks need to be reliable and secure. The ability of multi-cast is required when the group leader in the army want to give order to all his soldiers.

2.2.2 Emergency operations

In emergency situation such as earthquakes, the wired networks could be destroyed. There will be a need of wireless network which could be deployed quickly for coordination of rescue.

2.2.3. Wireless mesh networks

Wireless mesh networks are ad hoc wireless networks which are formed to provide communication infrastructure using mobile or fixed nodes/users. The mesh topology provides alternative path for data transmission from the source to the destination. It gives quick re-configuration when the firstly chosen path fails. Wireless mesh network should be capable of self-organization and self-maintenance. The main advantages of wireless mesh networks are high speed, low cost, quick deployment, high scalability, and high availability. It works on 2.4 GHz and 5 GHz frequency bands, depending on the physical layer used. For example, if IEEE 802.11a is used, the speed can be up to 54 Mbps. An application example of wireless mesh network could be a wireless mesh networks in a residential zone, which the radio relay devices are built on top of the rooftops. In this situation, once one of the nodes in this residential area is equipped with the wired link to the internet, this node could be the gateway node. Others could connect to the internet from this node. Other possible deployments are highways, business zones, and university campus.

2.2.4 Wireless sensor networks

Wireless sensor networks use sensors to provide a wireless communication infrastructure. Sensor nodes are tiny devices used for sensing physical parameters, processing data, and communicating over the networks to the monitoring station. The application areas are military, health care, home security and environmental monitoring. There are some special characteristics which make sensor network different from other ad hoc networks. In the sensor network, nodes could be assumed to be static, that is, sensor networks need not to be in all cases designed to support the mobility. In addition, power constraint is one of the most important factors that have to be considered carefully. The limitation of power is mainly caused by the working environment of sensor network which is often harsh. As a result, it is impossible to recharge

a sensor node battery, so effective protocols are required. For example, in the network layer, people need to design a low power consumption routing protocol, and power consumption will give the first priority to be considered during the route selection phase.

2.3 Characteristics of MANET

MANETs have several salient characteristics: [12]

1) Dynamic topologies: Nodes are free to move arbitrarily; thus, the network topology which is typically multihop, may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links.

2) Bandwidth-constrained, variable capacity links: Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In addition, the realized throughput of wireless communications--after accounting for the effects of multiple access, fading, noise, and interference conditions, etc.--is often much less than a radio's maximum transmission rate. One effect of the relatively low to moderate link capacities is that congestion is typically the norm rather than the exception, i.e. aggregate application demand will likely approach or exceed network capacity frequently. As the mobile network is often simply an extension of the fixed network infrastructure, mobile ad hoc users will demand similar services. These demands will continue to increase as multimedia computing and collaborative networking applications rise.

3) Energy-constrained operation: Some or all of the nodes in a MANET may rely on batteries or other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.

4) Limited physical security: Mobile wireless networks are generally more prone to physical security threats than are fixed- cable nets. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. As a benefit, the decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches. In addition, some envisioned networks (e.g. mobile military networks or highway networks) may be relatively large (e.g. tens or hundreds of nodes per routing area). The need for scalability is not unique to MANETS. These characteristics create a set of underlying assumptions and performance concerns for protocol design which extend beyond those guiding the design of routing within the higher-speed, semi-static topology of the fixed Internet.

Chapter 3: Routing Protocols in MANET

3.1 Introduction (Routing Basics)

To facilitate communication within the network a routing protocol is used to discover routes between nodes. The goal of the routing protocol is to have an efficient route establishment between a pair of nodes, so that messages can be delivered in a timely manner. Bandwidth and power constraints are the important factors to be considered in current wireless network because multi-hop ad-hoc wireless relies on each node in the network to act as a router and packet forwarder. This dependency places bandwidth, power computation demands on mobile host to be taken into account while choosing the protocol. Routing protocols used in wired network cannot be used for mobile ad hoc networks because of node mobility. This thesis will focus on works related with band width aspect of Manet.

3.2 MANET Routing Protocol Performance Issues:

We must consider the networking *context* in which a protocol's performance is measured [12]. Essential parameters that should be varied include:

- 1) Network size--measured in the number of nodes
- 2) Network connectivity--the average degree of a node (i.e. the average number of neighbors of a node)
- 3) Topological rate of change--the speed with which a network's topology is changing
- 4) Link capacity--effective link speed measured in bits/second, after accounting for losses due to multiple access, coding, framing, etc.

- 5) Fraction of unidirectional links--how effectively does a protocol perform as a function of the presence of unidirectional links?
- 6) Traffic patterns--how effective is a protocol in adapting to non-uniform or bursty traffic patterns?
- 7) Mobility--when, and under what circumstances, is temporal and spatial topological correlation relevant to the performance of a routing protocol? In these cases, what is the most appropriate model for simulating node mobility in a MANET?
- 8) Fraction and frequency of sleeping nodes--how does a protocol perform in the presence of sleeping and awakening nodes? A MANET protocol should function effectively over a wide range of networking contexts--from small, collaborative, ad hoc groups to larger mobile, multihop networks.

3.3 Categories of Existing Routing Protocols for MANETs

Many protocols have been proposed for MANETs. These protocols can be divided into three categories: proactive, reactive, and hybrid. Proactive methods maintain routes to all nodes, including nodes to which no packets are sent. Such methods react to topology changes, even if no traffic is affected by the changes. They are also called table-driven methods. Further proactive protocols can be divided into protocols that update routing information in regular intervals and protocols that update on certain events [13]. Reactive methods are based on demand for data transmission. Routes between hosts are determined only when they are explicitly needed to forward packets. Reactive methods are also called on-demand methods. They can significantly reduce routing overhead when the traffic is lightweight and the topology changes less dramatically, since they do not need to update route information periodically and do not need to

find and maintain routes on which there is no traffic. Hybrid methods combine proactive and reactive methods to find efficient routes, without much control overhead. [15]

3.4 More on Proactive Protocols DSDV and OLSR

Routing protocols especially those of Proactive ones are broadly classified as distance vector and link state routing. Distance vector routing is a decentralized routing algorithm. Each node that participates in routing exchanges its estimated least cost path to its directly connected neighbors to all other nodes in the network. Since no single node has a global view of the network in the distance vector, convergence is slow. Link state routing is a global routing algorithm in which each node computes the shortest path to every other node in the network using global knowledge about the network. In link state routing protocols, each node reliably broadcasts the link state (cost) to its directly connected neighbors. This reliable flooding gives a global topology view to each node. Link state algorithms offer better reliability and solve count-to-infinity and looping issues associated with distance vector routing protocols. The widely-used Optimized Link state routing (OLSR) routing protocol is a link state protocol. [29]

Proactive routing protocols use periodic broadcasts to establish routes and maintain them; examples are Optimized Link State Routing (OLSR) [9][11] . Since they exchange topology information enabling each node to maintain an up-to-date view of the network, proactive protocols are also called table-driven protocols. The topology exchange can happen periodically (e.g. as in OLSR) or on an event driven basis (e.g. as in DSDV). Proactive protocols can effectively route packets immediately to any other node in the network and do not suffer

from a high starting latency. However, the periodic topology exchange results in a larger overhead especially when node mobility is high.

3.4.1 DSDV

(The following section is referred from [5] unless specifically mentioned other References)

3.4.1.1 Protocol Overview

Packets are transmitted between the nodes of the network using route tables stored at each node. Each route table, at each of the nodes, lists all available destinations and the number of hops to each. Each route table entry is tagged with a sequence number that is originated by the destination node. To maintain the consistency of route tables in a dynamically varying topology, each node periodically transmits updates, doing so immediately when significant new information is available. Since we do not assume that the mobile hosts are maintaining any sort of time synchronization, we also make no assumption about the phase relationship of the update periods between the mobile hosts. These packets indicate which nodes are accessible from each node and the number of hops necessary to reach them, following traditional distance-vector routing algorithms. It is not the purpose of this chapter to propose any new metrics for route selection other than the freshness of the sequence numbers associated with the route; cost or other metrics might easily replace the number of hops in other implementations. We permit packets to be transmitted containing either layer-2 (MAC) addresses or layer-3 (network) addresses. Routing information is advertised by broadcasting or multicasting the packets that are transmitted periodically and incrementally as topological changes are detected—for instance, when nodes move within the network. Data is also kept

about the length of time between the arrival of the *first* and the arrival of the *best* route for each particular destination. On the basis of this data, a decision may be made to delay advertising routes that are about to change, thus damping fluctuations of the route tables. The advertisement of possibly unstable routes is delayed to reduce the number of rebroadcasts of possible route entries that normally arrive with the same sequence number.

3.4.1.2 Route Advertisements

The DSDV protocol requires each mobile node to advertise, to each of its current neighbors, its own route table (for instance, by broadcasting its entries). The entries in this list may change fairly dynamically over time, so the advertisement must be made often enough to ensure that every mobile computer can almost always locate every other mobile computer in the collection[16]. In addition, each mobile computer agrees to relay data packets to other computers upon request. This agreement places a premium on the ability to determine the shortest number of hops for a route to a destination; we want to avoid disturbing mobile hosts unnecessarily if they are in sleep mode. In this way a mobile computer may exchange data with any other mobile computer in the group even if the target of the data is not within range for direct communication. If the notification about other mobile computers that are accessible from any particular computer in the collection is done at layer 2, DSDV will work with whatever higher-layer (e.g., network layer) protocol might be in use.¹ All the computers interoperating to create data paths between themselves broadcast the necessary data periodically, say, once every few seconds. In a wireless medium, it is important to keep in mind that broadcasts are limited in range by the physical characteristics of the medium, in ways that are difficult to characterize precisely. This is different from the situation with

wired media, which usually have a much more clearly defined range of reception.

3.4.1.3 Route Table Entry Structure

The data broadcast by each mobile computer will contain its new sequence number and the following information for each new route:

- The destination's address
- The number of hops required to reach the destination
- The sequence number of the information received regarding that

Destination, as originally stamped by the destination within the headers of the packet, the transmitted route tables will also contain the hardware address and (if appropriate) the network address of the mobile computer transmitting them. The route tables will also include a sequence number created by the transmitter. Routes with more recent sequence numbers are always preferred as the basis for forwarding decisions, but they are not necessarily advertised. Of the paths with the same sequence number, those with the smallest metric will be used. By the natural way in which the route tables are propagated, the sequence number is sent to all mobile computers, which may each decide to maintain a routing entry for that originating mobile computer. Routes received in broadcasts are also advertised by the receiver when it subsequently broadcasts its routing information; the receiver adds an increment to the metric before advertising the route, as incoming packets will require one more hop to reach the destination (namely, the hop from the transmitter to the receiver). Again, we do not explicitly consider here the changes required to use metrics that do not use the hop count to the destination. Wireless media differ from traditional wired networks because asymmetries produced by one-way "links" are more prevalent. Receiving a packet from a neighbor therefore does not indicate the existence of a single-hop data path back to that neighbor across

the wireless medium. To avoid problems caused by such one-way links, no mobile node may insert routing information received from a neighbor unless that neighbor shows that it can receive packets from the mobile node. Thus, our routing algorithms effectively use only links that are bidirectional. One of the most important parameters to be chosen is the time between broadcasting the routing information packets. However, when any new or substantially modified route information is received by a mobile node, the new information will be retransmitted soon (subject to constraints imposed for damping route fluctuations), effecting the most rapid as possible dissemination of routing information among all of the cooperating mobile nodes. This quick rebroadcast introduces a new requirement for our protocols to converge as soon as possible. It would be calamitous if the movement of a mobile node caused a storm of broadcasts, degrading the availability of the wireless medium.

3.4.1.4 Responding to Topology Changes

Mobile nodes cause broken links as they move from place to place. The broken link may be detected by the layer-2 protocol, or it may be inferred if no broadcasts have been received for a while from a former neighbor. A broken link is described by a metric of ∞ (i.e., any value greater than the maximum allowed metric). When a link to a next hop has broken, any route through that next hop is immediately assigned an ∞ metric and an updated sequence number. Since this qualifies as a substantial route change, such modified routes are immediately disclosed in a broadcast routing information packet. Building information to describe broken links is the only situation in which the sequence number is generated by any mobile node other than the destination mobile node. Sequence numbers generated to indicate ∞ hops to a destination will be one greater than the last sequence number received from the destination. When a node receives an ∞ metric, and it has an equal or later sequence number with a finite metric, it triggers a route update broadcast to disseminate the

important news about that destination. In this way routes containing any finite metric will supersede routes generated with the ∞ metric. In a very large population of mobile nodes, adjustments will likely be needed for the time between broadcasts of the routing information packets. To reduce the amount of information carried in these packets, two types will be defined. One, called a *full dump*, will carry all of the available routing information. The other, called an *incremental*, will carry only information changed since the last full dump. By design, an incremental routing update should fit in one network protocol data unit (NPDU). The full dump will most likely require multiple NPDUs, even for relatively small populations of mobile nodes. Full dumps can be transmitted relatively infrequently when no movement of mobile nodes is occurring. When movement becomes frequent and the size of an incremental approaches the size of a NPDU, a full dump can be scheduled so that the next incremental will be smaller. It is expected that mobile nodes will implement some means for determining which route changes are significant enough to be sent out with each incremental advertisement. For instance, when a stabilized route shows a different metric for some destination, which is likely to constitute a significant change that needs to be advertised after stabilization. If a new sequence number for a route is received but the metric stays the same, which is unlikely to constitute a significant change.

3.4.1.5 Route Selection Criteria

When a mobile node receives new routing information (usually in an incremental packet as just described), that information is compared to the information already available from previous routing information packets. Any route with a more recent sequence number is used; routes with older sequence numbers are discarded. A route with a sequence number equal to an existing route is chosen if it has a “better” metric, and the existing route is discarded or stored as less preferable. The metrics for routes chosen from the newly received

broadcast information are each incremented by one hop. Newly recorded routes are scheduled for immediate advertisement to the current mobile node's neighbors. Routes that show a more recent sequence number may be scheduled for advertisement at a later time, which time depends on the average settling time for routes to the particular destination under consideration.

3.4.2 Optimized Link State Routing Protocol (OLSR)

The information in this section concerning the Optimized Link State Protocol is taken from its RFC 3626 [10]. OLSR is a proactive routing protocol, so the routes are always immediately available when needed. OLSR is an optimization version of a pure link state protocol. So the topological changes cause the flooding of the topological information to all available hosts in the network. To reduce the possible overhead in the network protocol uses Multipoint Relays (MPR). The idea of MPR is to reduce flooding of broadcasts by reducing the same broadcast in some regions in the network, more details about MPR can be found later in this chapter. Hello messages are interchanged at 0.5 sec and TC messages at 2 sec interval [35]. The reducing the time interval for the control messages transmission can bring more reactivity to the topological changes. [35] OLSR uses two kinds of the control messages: Hello and Topology Control. Hello messages are used for finding the information about the link status and the host's neighbors. With the Hello message the MPR Selector set is constructed which describes which neighbors has chosen this host to act as MPR and from this information the host can calculate its own set of MPRs. the Hello messages are sent only one hop away but the TC messages are broadcasted throughout the entire network. TC messages are used for broadcasting information about own advertised neighbors which includes at

least the MPR Selector list. The TC messages are broadcasted periodically and only the MPR hosts can forward the TC messages [10].

3.4.2.1 Routing

While Neighbor Sensing the link in the ad hoc network can be either unidirectional or bidirectional so the host must know this information about the neighbors. The Hello messages are broadcasted periodically for the neighbour sensing. The Hello messages are only broadcasted one hop away so that they are not forwarded further. When the first host receives the Hello message from the second host, it sets the second host status to asymmetric in the routing table. When the first host sends a Hello message and includes that, it has the link to the second host as asymmetric, the second host set first host status to symmetric in own routing table. Finally, when second host send again Hello message, where the status of the link for first host is indicated as symmetric, then first host changes the status from asymmetric to symmetric. In the end both hosts knows that their neighbor is alive and the corresponding link is bidirectional. [22]

The Hello messages are used for getting the information about local links and neighbours. The Hello messages periodic broadcasting is used for link sensing, neighbour's detection and MPR selection process. Hello message contains: information how often the host sends Hello messages, willingness of host to act as a Multipoint Relay, and information about its neighbour. Information about the neighbours contains: interface address, link type and neighbour type. The link type indicates that the link is symmetric, asymmetric or simply lost. The neighbour type is just symmetric, MPR or not a neighbour. The MPR type indicates that the link to the neighbour is symmetric and that this host has chosen it as Multipoint Relay. [10]

3.4.2.2 Multipoint Relays

The Multipoint Relays (MPR) is the key idea behind the OLSR protocol to reduce the information exchange overhead. Instead of purflooding the OLSR uses MPR to reduce the number of the host which broadcasts the information throughout the network. The MPR is a host's one hop neighbour which may forward its messages. The MPR set of host is kept small in order for the protocol to be efficient. In OLSR only the MPRs can forward the data throughout the network. [10]

Each host must have the information about the symmetric one hop and two hop neighbours in order to calculate the optimal MPR set. Discussion on [34] is used to illustrate these concepts. Information about the neighbours is taken from the Hello messages. The two hop neighbours are found from the Hello message because each Hello message contains all the hosts' neighbours. Selecting the minimum number of the one hop neighbours which covers all the two hop neighbours is the goal of the MPR selection algorithm. Also each host has the Multipoint Relay Selector set, which indicates which hosts has selected the current host to act as a MPR. [23]

When the host gets a new broadcast message, which is need to be spread throughout the network and the message's sender interface address is in the MPR Selector set, then the host must forward the message. Due to the possible changes in the ad hoc network, the MPR Selectors sets are updated continuously using Hello messages. [10]

3.4.2.3 Multipoint Relays Selection

In this section the proposed algorithm for the selection of Multipoint Relay set is described. This algorithm is found from [10]. The algorithm constructs the MPR set which includes minimum number of the one hop symmetric neighbours from which it is possible to reach all the sym metrical strict two hop neighbours. The host must have the information about one and two hop

symmetric neighbours in order to start the needed calculation for the MPR set. All the exchange of information are broadcasted using Hello messages. The neighbours which have status of willingness different than WILL_NEVER in the Hello message can be chosen to act as MPR. The neighbour must be symmetric in order to become an MPR.

Algorithm for selecting MPR set:

1. Take all the symmetric one hop neighbours which are willing to act as an MPR.
2. Calculate for every neighbour host a degree, which is a number of the symmetric neighbours, that are two hops away from the calculating source and does not include the source or its one hop neighbours.
3. Add the neighbour symmetric host to the MPR set. If it is the only neighbour from which is possible to get to the ~~specific~~ two hop neighbours, then remove the chosen host neighbours from the two hop neighbour set.
4. If there are still some hosts in the two hop neighbour set, then calculate reachability of each one hop neighbor, meaning the number of the two hop neighbours, that are yet uncovered by MPR set. Choose the node with highest willing value, if the values are the same then takes the node with greater number of reachability. If the reachability is the same, then take the one with greater degree counted in the second step. After choosing the neighbour for MPR set remove the reach able two hop neighbour from the two hop neighbour set.
5. Repeat previous step until the two hop neighbours set is empty.
6. For the optimization, set the hosts in the MPR set in the increasing order basing on the willingness. If one host is taken away and all the two hop neighbours, covered by at least one host and the willingness of the host is smaller than WILL_ALWAYS, then the host may be removed.

3.4.2.4 Topology Information

In order to exchange the topological information and build the topology information base the host that were selected as MPR need to send the TC message. The TC messages are broadcasted throughout the network and only MPR are allowed to forward TC messages. The TC messages are generated and broadcasted periodically in the network. [10]

The TC message is sent by a host in order to advertise its own links in the network. The host must send at least the links of its MPR selector set. The TC message includes the own set of advertised links and the sequence number of each message. The sequence number is used to avoid loops of the messages and for indicating the freshness of the message, so if the host gets a message with the smaller sequence number it must discard the message without any updates. The host must increment the sequence number when the links are removed from the TC message and also it should increment the sequence number when the links are added to the message. The sequence numbers are wrapped around. When the hosts advertised links set becomes empty, it should still send empty TC messages for ~~for~~ a certain amount of time, in order to invalidate previous TC messages. This should stop sending the TC messages until it has again some information to send. [20].

3.4.2.5 Routing Table Calculations

The host maintains the routing table, the routing table entries have the following information: destination address, next address, number of hops to the destination and local interface address. Next address indicates the next hop host.

The information is obtained from the topological set (from the TC messages) and from the local link information base (from the Hello messages). So if any changes occur in these sets, then the routing table is recalculated. Because this

is proactive protocol then the routing table must have routes for all available hosts in the network. The information about broken links or partially known links is not stored in the routing table. [10]

The routing table is changed if the changes occur in the following cases: neighbour link appear or disappear, two hops neighbour is created or removed, topological link has appeared or lost or when the multiple interface association information changes. But the update of this information does not lead to the sending of the messages into the network. For finding the routes the routing table entry the shortest path algorithm is used. [10]

3.4.2.6 Advantages

OLSR is also a flat routing protocol, it does not need central administrative system to handle its routing process. The proactive characteristic of the protocol provides that the protocol has all the routing information to all participated hosts in the network. However, as a drawback OLSR protocol needs that each host periodically sends the updated topology information throughout the entire network, this increase the protocols bandwidth usage. But the flooding is minimized by the MPRs, which are only allowed to forward the topological messages.

The reactivity to the topological changes can be adjusted by changing the time interval for broadcasting the Hello messages. It increases the protocols suitability for ad hoc network with the rapid changes of the source and destinations pairs. Also the OLSR protocol does not require that the link is reliable for the control messages, since the messages are sent periodically and the delivery does not have to be sequential. [35]

Due to the OLSR routing protocol simplicity in using interfaces, it is easy to integrate the routing protocol in the existing operating systems, without

changing the format of the header of the IP messages. The protocol only interacts with the host's Routing Table. [35]

OLSR protocol is well suited for the application which does not allow the long DELAYs in the transmission of the data packets. The best working environment for OLSR protocol is a dense network, where the most communication is concentrated between a large number of nodes. [20] OLSR has also extensions to allow for hosts to have multiple OLSR interface addresses and provide the external routing information giving the possibility for routing to the external addresses [10]. Based on this information there is possibility to have hosts in the ad hoc network which can act as gateways to another possible network.

Chapter 4 Quality of Service Routing in a MANET

4.1 Basics of QoS

QoS is a term widely used in the last recent years in the area of wire-based networks. QoS stands for Quality of Services and the truth is that there is much debate on what exactly QoS is supposed to mean. Most vendors implement QoS protocols having in mind specific scenarios and taking into consideration different parameters, network topologies and variables. The United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) Recommendation E.800, has defined QoS as: "*The collective effect of service performance which determines the degree of satisfaction of a user of the service*". This is a widely accepted definition since it doesn't make any reference to any minimum characteristics, such as Bandwidth or DELAY, or mechanisms, such as Admission Control, SLA, Signaling Protocol. QoS is as a set of service requirements that needs to be met by the network while transporting a packet stream from a source to its destination [7]. The network needs are governed by the service requirements of end user applications. The network is expected to guarantee a set of measurable performance service attributes to the users in terms of end-to-end performance, such as delay, bandwidth, packet delivery fraction, delay variance (jitter), etc.

4.2 QoS Routing Protocols: Models and Classification

In this section, the different QoS models used in literature are presented. This is followed by a classification of the current QoS routing protocols according to the best effort routing protocol they extend as well as the model and environment they assume, and the communication layer within which they

operate. Depending on the application involved, the QoS constraints could be available bandwidth, end-to-end delay, delay variation (jitter), probability of packet loss, and so on. This kind of demand puts more pressure on the network and the routing protocols which are used to support the communications. Establishing multi-hop routes between nodes is not sufficient in this case. The discovered routes can only be considered if they provide guarantees of the QoS parameters, such as bandwidth required by the application. Let $m(u; v)$ be the performance metric for the link $(u; v)$ connecting node u to node v , and path $(u; u_1; u_2; \dots; u_k; v)$ a sequence of links for the path from u to v . Three types of constraints on the path can be identified [8][33]:

1. *Additive constraints*: A constraint is additive if $m(u; v) = m(u; u_1) + m(u_1; u_2) + \dots + m(u_k; v)$. For example, the end-to-end delay $(u; v)$ is an additive constraint because it consists of the summation of delays for each link along the path.
2. *Multiplicative constraint*: A constraint is multiplicative if $m(u; v) = m(u; u_1) \times m(u_1; u_2) \times \dots \times m(u_k; v)$. The probability of a packet $prob(u; v)$, sent from a node u to reach a node v , is multiplicative, because it is the product of individual probabilities along the path.
3. *Concave constraint*: A constraint is concave if $m(u; v) = \min\{m(u; u_1), m(u_1; u_2), \dots, m(u_k; v)\}$. The bandwidth $bw(u; v)$ requirement for a path between node u and v is concave. This is due to the fact that it consists of the minimum bandwidth between the links along the path. According to Wang and Hou [33] *Sequential filtering* is a commonly used approach, where multiple paths between two nodes u and v that satisfy a single metric first like band width are found, then a subset of these paths is eliminated by optimizing over a second metric (like end-to-end delay), and so on. In MANETs, node mobility often results in frequent topology changes, which presents a significant challenge

when designing QoS routing protocols. High node mobility can make satisfying QoS requirements unreachable. Consequently, it is required that the network be *combinatorically stable* in order to achieve QoS support. This means that the changes in network topology must be slow enough within a particular time window to allow the topology updates to propagate successfully as required in the network. QoS support of MANETs requires availability of network state. However, due to mobility and constant topology changes, the cost of maintenance of the network state is expensive especially in large networks. In [6] the *imprecise network state model* is introduced. It provides a cost-effective method for providing QoS support based on imprecise network information. The majority of QoS routing protocols are reservation-based. Probe messages are sent through the network from the source to the destination in order to discover and reserve paths which satisfy a given QoS requirement. Due to the dynamic nature of the network, reserved QoS paths must be reaffirmed periodically by sending special control packets, called *refreshers*, along the path. Another approach, called *soft state*, relies on periodic time out at each node for path maintenance. In addition, due to the difficulty of QoS support in the inherently dynamic environment of MANETs, some more”compromising principles” have been presented; *Soft QoS* and *QoS adaptation*. Soft QoS [32] indicates that there may be transient periods of time during which the QoS specifications are not honored. However, the QoS satisfaction is quantified by the total disruption time over the total connection time. This ratio must be above a specified threshold in order to fulfill the QoS requirements. In the *fixed;level QoS* approach, the reservation is defined in an n -dimensional space where the coordinates define the characteristics of the service [26]. On the other hand, QoS adaptation introduces the concept of *dynamic QoS*, where a range of QoS values, rather than a single point, is allowed to be specified by the application. This must be done through appropriate, flexible, and simple user

interface which effectively maps the perceptual parameters into QoS constraints. The use of dynamic QoS provides more flexibility to the system and gives the network the ability to adjust the allocation according to the current availability of the required resources. The higher networking layers can then adapt to these changes. This adaptation can be achieved in different ways at the different layers of the architecture. The physical layer, for example, can adjust the transmission power to react to more frequent bit errors. The link layer can incorporate more error control (detection and correction) codes as well as automatic repeat requests (ARQ) in reaction to changes in link error rates. At the other end of the OSI stack, namely the application layer (multimedia video conferencing for example), different compression techniques with varying compression ratios can be employed to adapt the application to the changes in bandwidth, DELAY, and error rates without drastically compromising the perceived audio and video quality. As more resources become available, the quality of the presentation can then be adjusted to take advantage of the added resources. In addition to compression algorithms, other techniques are being investigated at this level including layered encoding, rate shaping, adaptive error control, and bandwidth smoothing. It is important at this point to state that the QoS model defines the general approach, goals, and framework for providing QoS support in a network. It does not specify a particular protocol, design, or implementation details. Providing QoS support is done at each of the layers of the OSI model starting from the application layer and ending with the physical layer. Various protocols and specifications such as QoS user interface, routing, signaling, resource reservation, and error checking, measuring, and correcting must work and coordinate together in a collaborative and complementary fashion in order to satisfy the QoS requirements of the underlying applications. In this chapter, we focus on QoS routing, which is one of the most critical components in providing QoS support in MANETs.

4.3 QoS Routing Protocols

In order to support applications with QoS requirements, such as multimedia, different QoS routing protocols have been developed. Of the QoS parameters that are required by these applications minimum bandwidth is the most common. To support such requirement, the application layer of the source node sends a request to the lower layers (in the OSI model) with a specific destination and an amount of bandwidth which is required in order to satisfy the communication needs of that particular session. Depending on the communication requirements used, this desired amount of bandwidth is represented in different ways. In the synchronous Time Division Multiple Access (TDMA) environment, the bandwidth is represented by the number of slots needed to be reserved in the TDMA frame. In order for the route to satisfy this requirement, each of its links must reserve that number of slots for this particular session. When the session has ended, the reserved slots are freed and allowed to be reserved for other sessions. On the other hand, in the asynchronous environment, the slot size is variable and the amount of bandwidth reserved on particular links of the path is represented by duration and a start time within the super frame [18]. The location of the slots within the frames of the different links of a path have direct affect over the total end-to-end transmission delay of data for a particular source-destination pair during a session. Different algorithms which have been proposed which choose the start times and durations of the slots according to different policies. The policies can be minimize end-to-end delay, maximize the probability of success in applying the reservation algorithm, or compromise between the two objectives. QoS routing protocols for MANETs can be classified into different categories depending on the best effort routing algorithm which they extend or most

closely resemble (DSR, AODV, DSDV, TORA, etc.) Though most of the QoS routing protocols are designed to operate within the network layer, some of the implementations go below the network layer into the MAC layer. In the following sections, different QoS routing protocols are presented. Most QoS routing algorithms represent an extension of existing classic (or major) best-effort routing algorithms. Many routing protocols have been developed which support establishing and maintaining multi-hop routes between nodes in MANETs. These algorithms can be classified into three different categories: on-demand (reactive) such as DSR, AODV, and TORA, and table-driven (proactive) such as (DSDV). In the on-demand protocols, routes are discovered between a source and a destination only when the need arises to send data. This provides a reduced overhead of communication and scalability. In the table-driven protocols, routing tables which contain routing information between all nodes are generated and maintained continuously regardless of the need of any given node to communicate at that time. With this approach, the latency for route acquisition is relatively small, which might be necessary for certain applications, but the cost of communications overhead incurred in the continued update of information for routes which might not be used for a long time if at all is too high. Furthermore, this approach requires more memory due to significant increase in the size of the routing table. These requirements put limits on the size and density of the network. A third hybrid approach, the Zone Routing Protocol (ZRP), has also been proposed and attempts to reap the benefits of both methods. In ZRP, the network is divided into zones. A proactive table driven strategy is used for establishment and maintenance of routes between nodes of the same zone, and a reactive on-demand strategy is used for communication between nodes of different zones. This approach can be effective in larger networks with applications that exhibit a relatively high degree of locality of communication, where communication between nodes with

close proximity to one another is much more frequent than that between nodes which are further apart. Before presenting the current approaches for design and implementation of QoS routing protocols, it is important to briefly discuss the existing best-effort routing protocols which exist for MANETs. Many routing protocols have been designed to discover and maintain routes between source and destination nodes. Among the most important and classic routing algorithms for MANETs that have evolved are three basic types. Each of these three basic types has its own advantages, disadvantages, and appropriateness of use in certain types of ad hoc networks depending on the mobility, number of nodes involved, node density, underlying link layer technology, and general characteristics of the environment and applications being supported.

4.4 QoS in Different Layers

QoS of a network can be considered at different layers. QoS considered in physical layer means the quality in terms of transmission performance. For example, through transmission power control both the stations that are near the sender or far away from the sender could hear the signal clearly with different transmission power. Power control is used both to ensure the quality of reception and to optimize the capacity. QoS implemented in MAC layer is also important. It could provide high probability of access with low delay when stations with higher user priority want to access the wireless medium. For example, in wireless LANs shorter back off time is set to achieve it, based on IEEE 802.11e. QoS implemented in the routing layer aims to find a route which provides the required quality. [30]

4.5 Challenge of QoS routing in ad hoc networks

Mobile ad hoc networks differ from the traditional wired networks. They have certain unique characteristics which cause difficulties for providing QoS in such networks. The unique characteristics are dynamically varying network topology, lack of precise state information, shared radio channel, limited resource availability, hidden terminal problem and insecure medium [13]. Besides the above difficulties in QoS routing computation, it is also complex to evaluate the QoS routing performance – network topology or traffic characteristics can affect the performance of QoS routing. QoS routing may be more effective in networks with uneven traffic load; different network topologies may also have effect on the performance of routing algorithms [2]. Even if the QoS routing protocols successfully enhance the network performance, it is worthwhile to question if it is worthy of the cost.

Chapter 5: Related works

5.1 QoS Routing with DSDV

DSDV is a bi-directional protocol, which unavoidably has the unidirectional links problem in ad hoc networks. Many improvements of DSDV have been developed. But it is expected that further researches including multi-path routing, QoS multicasting in DSDV and ad hoc networks. [16] There are QoS routing algorithms, which are the QoS extensions of existing best-efforts routing algorithms. For example the QoS Route Information. Algorithm discussed in [24] proposes an algorithm that uses local bandwidth information and DSDV [27] to construct a path that satisfies the session bandwidth request.

Simulation results in [3] shows that DSDV fails to converge if nodes don't pause for at least 300 seconds during movement; the packet delivery ratio is also suffering at higher rate of mobility; packet loss is mainly caused by stale routing entries; in periodic updates transmission, routing overhead is constant with respect to the mobility rate; nearly optimal path can be selected in routing procedure.

Another simulation was done in [14] under the condition of 1000m X 1000m rectangular movement region, 350m constant radio range for each mobile node, 0.4-0.6 m/sec for low mobility, 3.5-4.5 m/sec for high mobility, 512 bytes for the packets length, 1-10 connections/node, and 30 mobile nodes. From the result, it can be seen that the end-to-end delay and the routing load increase

with the mobility; but the routing load decreases with the number of connections of each node at the same mobility.

5.1.1. Limitation of DSDV in QoS Routing

The main purpose of DSDV is to address the looping problem of the conventional distance vector routing protocol and to make the distance vector routing more suitable for ad hoc networks routing. However, DSDV arise route fluctuation because of its criteria of route updates. At the same time, DSDV does not solve the common problem of all distance vector routing protocols, the unidirectional links problem. [16]

5.1.1.1 Damping Fluctuation

Fluctuation is a general problem arising in DSDV by the following criteria of route updates:

- Routes are always preferred if the sequence numbers are newer, routes with older sequence numbers are discarded.
- A route with a sequence number equal to that of an existing route is preferred if it has a better metric, and the existing route is discarded or stored as less preferable.

5.1.1.2 Unidirectional Links

DSDV assumes that all wireless links in an ad hoc network are bi-directional. However, this is not true in reality. Wireless media is different from wired media due to its asymmetric connection. Unidirectional links are prevalent in wireless networks. The presence of unidirectional links creates the following problems for DSDV.

a) Knowledge Asymmetry: Over the unidirectional links, the sink nodes know the existence of the source nodes, but the source nodes cannot assume the existence of the sink nodes.

b) Sink Unreachability: In DSDV, the destination node initiates the path updates. Over a unidirectional link, there might be no way that a sink node can broadcast its existence.

5.1.1.3 Performance

DSDV requires that each node maintain two tables. The bulk of the complexity in DSDV is generating and maintaining these tables. The updates are transmitted to neighbors periodically or scheduled as needed. As growing of mobility and number of nodes in the network, the size of the bandwidth and the routing tables required to update these tables grows simultaneously. The overhead for maintaining and updating these tables will increase correspondingly. It is natural that heavy routing overhead will degrade the performance of the network. [16]

5.1.1.4 Stability and scalability

DSDV guarantees loop-free routes in routing packets. It uses incremental and full dump for updates. The incremental update is used so that the entire routing table needs not to be transmitted for every change in the network topology. However, DSDV requires the full dump update periodically, regardless of the number of changes in the network topology. In this aspect, DSDV is not efficient in route updating. It also limits the number of nodes that can join in the network [16]. In addition, whenever the topology of a network changes, DSDV is unstable until update packets propagate throughout the network.

Besides In a comparative analysis that has been made in this thesis work it has also be seen the DSDV is less performing than the OLSR with the band width management metrics PDF and Goodput. We also have seen that this comparison depicts similar result with increasing node density and high speed scenarios.

5.2 QoS routing in OLSR

As mentioned in section 3.4.2, OLSR is a routing protocol for best effort traffic, with emphasis on how to reduce the overhead. So in its MPR selection, the node selects the neighbor that covers the most unreached 2-hop neighbors as MPR. [19]. However, in QoS routing, by such MPR selection mechanism, the “good quality” links may be “hidden” to other nodes in the network. As an example, we will consider the network topology in Fig 5.1. The numbers along the lines indicate the available bandwidth over the links. As explained in Section 3.4.2.3, in the OLSR MPR selection algorithm, node A will select C as its MPR. So for all the other nodes, they only know that they can reach A via C. Also, when “bandwidth” is the QoS constraint, nodes can no longer use the “shortest hops path” algorithm as proposed in OLSR. Because of these limitations of OLSR in QoS routing, we revise it in two aspects: MPR selection and routing table computation.

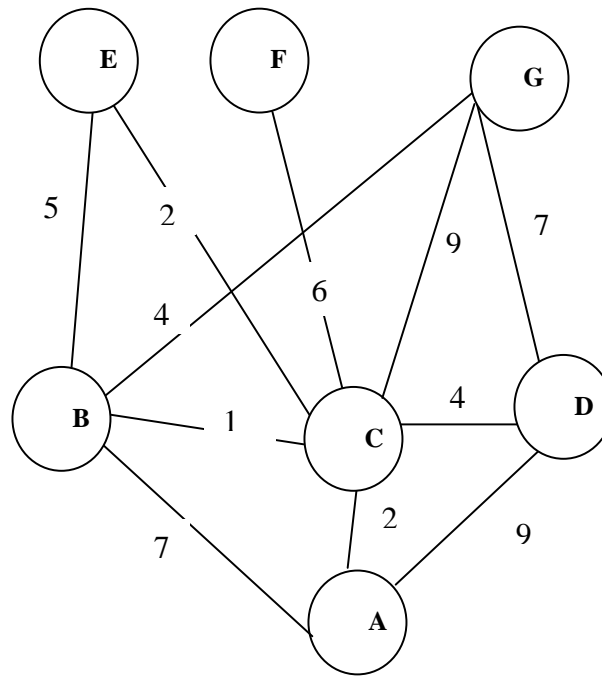


Figure 5.1 MPR Selection in OLSR

5.2.1 Limitations with Existing MPR selection criteria

The decision of how each node selects its MPRs is essential to determining the optimal bandwidth route in the network. In selecting the MPRs, a “good bandwidth” link should not be omitted. Based on this idea, two revised MPR selection algorithms are presented.

5.2.1.1 MPR selection Type 1

In this algorithm [35], MPR selection is almost the same as that of OLSR described in Section 3.4.2.3 However, when there are more than one 1-hop neighbors covering the same number of uncovered 2-hop neighbors, the one with the largest bandwidth link to the current node is selected as MPR.

The network in Figure 5.1 would select MPRs for node A as follows, based on MPR selection type1.

Source Node	1 hop neighbors	2 hop neighbors	MPR
A	B,C,D	E,F,G	C

Table 5.1: MPR selection in Type 1

C is selected as A's MPR because it is the only node covering all the 2 hop unreached nodes and has the larger bandwidth. But this approach is quite inefficient in terms of QoS because basically it works under the principle of pure OLSR. It is subject for QoS only when there appear two nodes with identical number of degree of coverage. Hence we can clearly see that this algorithm fails to meet the requirement of finding the optimal wider band width link.

5.2.1.2 MPR selection type 2

The idea behind MPR selection type2 [35] is to select the best bandwidth neighbors as MPRs until all the 2-hop neighbors are covered.

For example, using this algorithm, based on Figure 5.1, node A's MPR(s) would be:

Source Node	1 hop neighbors	2 hop neighbors	MPR
A	B,C,D	E,F,G	D,B,C

Table 5.2: MPR selection type 2

Among node A's neighbors, B, C, and D have a connection to its 2-hop neighbors. Among them, link AD has the largest bandwidth. Similarly B is also

selected as MPR for node E and Choosing C for node F is option less for it is the only node that can cover it, so all 2-hop neighbors are covered and the algorithm terminates.

This approach comes up with uncontrolled bigger size of MPR. This in turn will increase the number of forwarding nodes in the network and hence will affect the QoS. This uncontrolled approach of increasing size of the MPR will consequence in raising the over head of the network and deteriorate the data transfer metrics that this thesis is intended to work on.(i.e the packet delivery fraction and the good put) hence it is redesigned the MPR selection algorithm of the QoS versions of the OLSR so far developed in a way of basically looking into the larger band width link but controlling the number of MPR not to grow and has adverse effect on basic band width management QoS metrics and Routing over head. Simulation Results [35] of the above two QoS OLSR algorithms have clearly shown that pure OLSR perform better than these QoS versions of OLSR with regard to Packet Deliver fraction and routing overhead. Moreover literatures published [35] on this algorithms did not discuss the effect of jitter which is the most critical metrics in dealing with QoS.

5.3 Conclusion and thesis Approach

A DSDV protocol is viewed to associate with so many problems as mentioned above and is seen to perform low especially with high node density and mobility. Therefore it is not reliable to incorporate QoS for DSDV. This is because DSDV does not guarantee assurance of enhancing the band width management metrics, packet delivery fraction and Goodput. Moreover the unpredictable nature of Ad-Hoc networks and the requirement of quick reaction

to QoS routing demands make the idea of a “link-optimization routing” protocol more suitable. When a request arrives, the control layer can easily check if the pre-computed optimal route can satisfy such a request. Thus, wasting network resources when attempting to discover feasible routes can be avoided. Based on this consideration, unlike DSDV QoS routing protocols, we are studying “link-optimization routing”. The task is to re-compute a route, which is the best route, based on the QoS constraint among all the possible routes. The approach followed in this thesis work is to integrate the QoS feature into OLSR [21], which is a pro-active routing protocol in a way optimal and more effective than other approaches. In simulations, we will first show that the traditional best effort OLSR outsmart the DSDV in band width management metrics, packet delivery fraction and goodput. We then incorporate QoS into the promising OLSR, see the simulation and justify the results.

Chapter 6: Performance metrics and Simulation environment

6.1 Performance Evaluation Metrics

The metrics have been chosen in order to evaluate the routing protocols for QoS in terms of wider link band width measured as Goodput, low percentage of packet loss and low routing load. The main attention was given to evaluate the routing layer performances. This is because Goodput alone does not indicate whether a protocol A is better than a protocol B. How it achieves higher Goodput when combined with scalability is a good measure of a better performance. [29] The following three metrics capture the most basic overall performance of Routing protocols studied in this thesis work: -

6.1.1 Good put

Good put is defined as the amount of useful data, or payload that can be processed by, passed through, or otherwise put through a system when operating at maximum capacity and received at the correct destination address. Goodput can be thought of as throughput seen by the receiver.

$$\text{Goodput} = \frac{(\text{max no of pkts recvd by the Rx in sequence}) * \text{packet size}}{\text{Measurement interval}}$$

6.1.2 Packet Delivery Fraction (PDF)

The packet delivery ratio in this simulation is defined as the ratio between the number of packets sent by constant bit rate sources and the number of packets received by the CBR sink at destination.

$$\text{Packet Delivery Fraction (PDF)} = \frac{\text{CBR packets received by CBR sinks}}{\text{CBR packets sent by CBR sources}}$$

6.1.3 Normalized Routing Load (NRL)

Routing overhead is the number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission.

$$\text{Normalized Routing load} = \frac{\text{Number of Routing Packets sent}}{\text{Number of Data Packets Received}}$$

6.1.4 Average End-to-End Delay of data packets (AED)

The end-to-end delay is defined as time between the point in time the source want to send a packet and the moment the packet reaches it destination. It includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times

Average end to end Delay =

$$\frac{\sum T \text{ (destination receives packet)} - T \text{ (source wants to sent packet)}}{\text{Number of Packets}}$$

6.1.5 Jitter:

Jitter is defined as the difference in end-to-end delay between selected packets in a flow with any lost packets being ignored. Lower figure of jitter shows better performance.

6.2 Simulation Details

To obtain meaningful performance comparison results, a simulation study of a MANET routing protocol should be conducted using well tested mobility models, realistic radio ranges, traffic patterns, and physical layer interface effects such as collision, interface queues and parameters affecting radio propagation.

6.2.1 Mobility Model

Mobility models are sets of movement patterns generated to model the behavior of mobile nodes. The Random Waypoint mobility model use to generate the four scenarios is an entity mobility model [4], in which the node movements are independent of each other. In this model, a mobile node starts from its location in the simulation area and moves toward a random destination with a speed uniformly selected between Minimum speed and Maximum speed. On reaching the destination, the mobile node pauses for a period of time and then moves again in a newly selected direction and speed. According to [4] if the node movement speed is high and the pause time is large, then the scenario with the Random Waypoint model produces a more stable network than those with shorter pause times.

6.2.2 Network Simulator 2 (ns-2) Overview

NS2 is built using object oriented language C++ and OTcl (object oriented variant of Tool Command Language). NS2 interprets the simulation scripts written in OTcl. The user writes his simulation as an OTcl script. Some parts of ns2 are written in C++ for efficiency reasons. The data path (written in C++) is separated from the control path (written in OTcl). Data path object are compiled and then made available to the OTcl interpreter through an OTcl linkage. Results obtained by ns 2 (trace files) have to be processed further by other tools like Network Animator (NAM), perl, awk script etc. In ns-2 the various network components are designed as class objects called agents. These include the routing agent, application agent, channel agents and so forth. Based on the simulation setup ns-2 links the various agents (called plumbing in ns-2) to create a complete network. [29]

6.3. Simulation Methodology

6.3.1 Parameters

NS-2 simulator [36] has been used in this simulation since it supports simulating an ad-hoc mobile environment. Table 6.1 below lists the various parameters that were used in the simulation.

Simulator	NS-2
Transmission range of nodes	250 meters
Mac layer	802.11
Channel and network interface type	Wireless
Interface queue type	Priority queue
Interface priority queue length	50 packets
Propagation model	Two ray ground
Antenna type	Omnidirectional
Radio model	Lucent's Wave LAN
Link detection	link layer feedback

Table 6.1 Simulation Model Parameters

6.3.2 Traffic Generation models

Traffic-scenario generator script “cbrgen.tcl” is used to create CBR traffic connections between wireless mobile nodes. During the course of the simulation different size connections growing in accordance with the number of nodes considered were setup between the nodes in the network with the traffic rate of 4 packets per seconds where each packet size was 512 bytes.

6.3.3 Mobility Generation models

The movement scenario files used for each simulation are characterized by a Speed and pause time. The simulation carried out with movement patterns generated for different Velocity 1m/s,5m/s,10m/s and 15m/s. A set of four

movement scenario files were used for each value of number of nodes (30, 40, 50 and 60). The “setdest” program of NS-2 simulators used which generates node-movement files using the random waypoint algorithm.

Simulations are run for 300 simulated second. Simulation scenarios are generated and taken that is an average of at least five runs with identical traffic models and mobility models to make the confidence interval to be 92%. Identical mobility and traffic scenarios are used across protocols.

Performance evaluation of the proposed algorithm against the standard OLSR is done for different scenarios prepared by varying the environmental variables. The node density is controlled by both the number of nodes and the source to destination (maximum connection) in a fixed area. we analyzed the result by varying the number of nodes as :30,40,50,and 60 for a fixed area of 1000 *1000. The simulation scenarios used are explained in the following section.

6.4 Simulation scenarios

In this scenario we tried to evaluate the two protocols performance under increasing node density from relatively sparse to relatively dense network cases at which 30 nodes as a sparse and 60 as dense. This scenario is viewed under four different speed movements scenarios: 1m/s,5m/s,10m/s and 15m/s . The main aim of this scenario is measuring the performance of the algorithms for comparative analysis with respect to three QoS metrics PDF, Goodput, and AED under different node density. The density of the node is attained both by increasing the number of nodes and increasing the source traffic (CBR) correspondingly. The traffic of 30 node is 15, that of 40 node is 20, of 50 is 25

and 60 is 30. So as the number of nodes grow the number of source to destination connection also grows to simulate density very well.

Chapter 7: Comparative analysis of DSDV and OLSR.

7.1 Scenario 1

In this Scenario the behavior of both algorithms is compared and studied by varying node density under different node movement Speed. The metrics to be analyzed are Goodput, Packet Delivery Fraction (PDF), and AED. This is because Selection of a promising routing protocol mainly depends on how big data is transferred within a short possible period of time. Moreover the aim of this Comparative analysis is to choose a protocol which guarantee enhancement of a band width management QoS. The observation is categorized under four speed scenarios representing the respective average node hosts movement, 1m/s (person), 5m/s (Bicycle), 10m/s (motorcycle) and 15m/s (Car) to study the nature of the algorithms in different node density and node mobility.

7.1.1 Simulation result at a speed of 1m/s

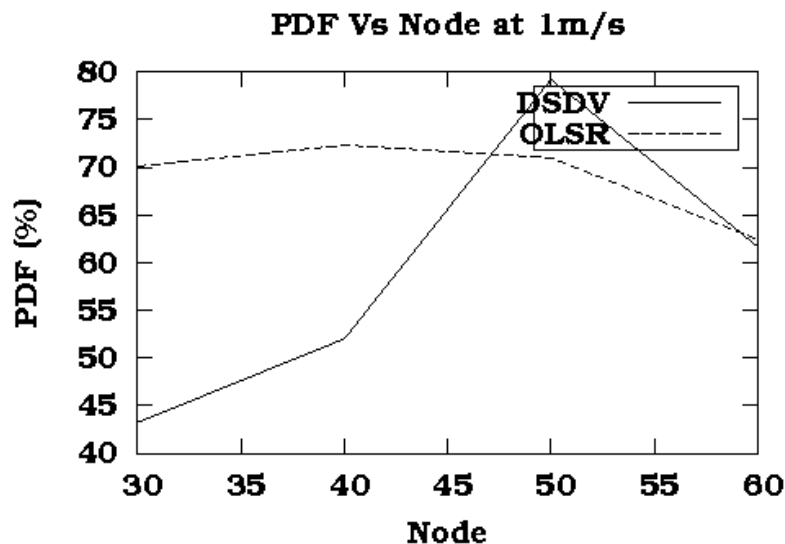


Figure 7.1 PDF Vs Node at 1m/s

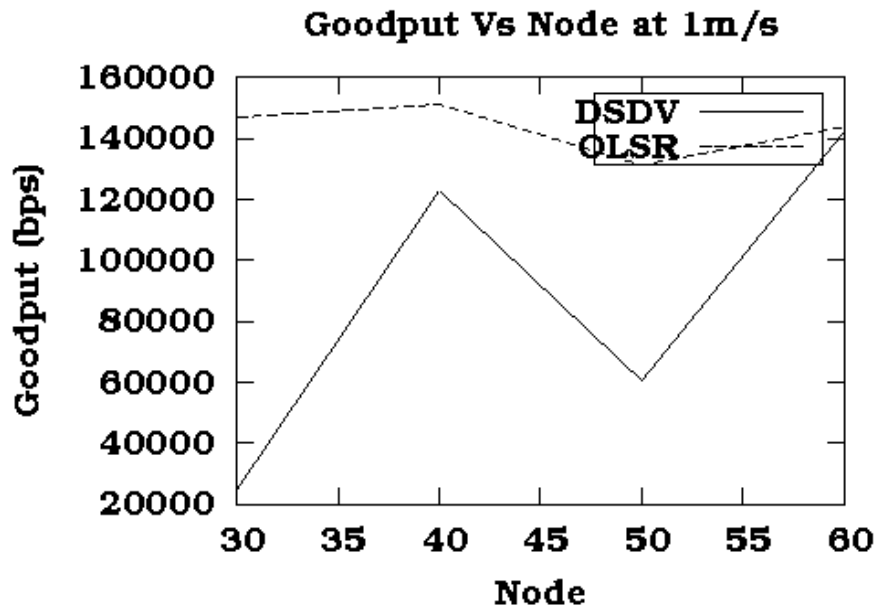


Figure 7.2: Good Put Vs Node at 1m/s
AED Vs Node at 1m/s

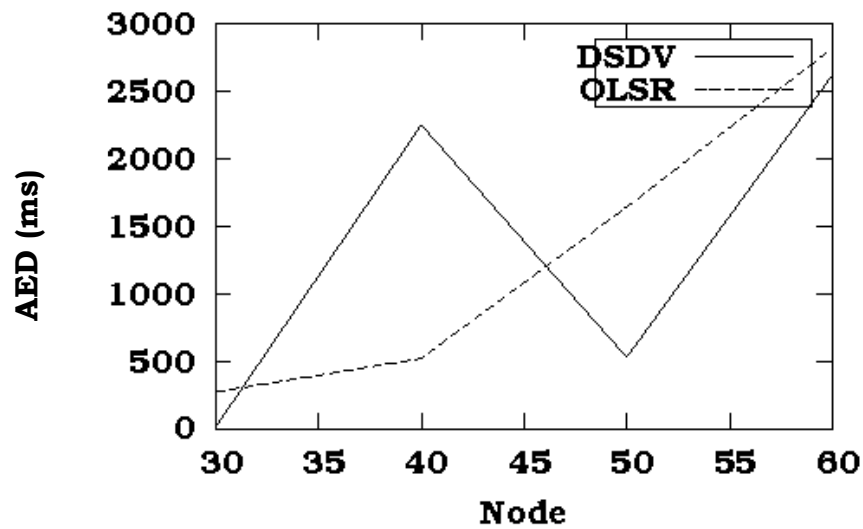


Figure 7.3: AED Vs Node at 1m/s

Discussion

In our simulation result we can see that the OLSR is better in Goodput and PDF. This is because OLSR uses TC message in addition to Hello message to exchange latest updates of routes. This will eliminate the possibility of stale routes and hence no attempt is made to send packets over a stale route. On the other hand DSDV suffer the problem of slow convergence and stale routes which in turn will cause to drop many packets by sending packets over the stale routes. This is the main cause for the packets to be dropped and end up in inefficient utilization of band width. This is characterized by a poor Goodput and PDF performance.

The AED for relatively sparse networks (below node size of 50) is smaller in OLSR as OLSR's TC message helps to avoid the stale route problem thereby facilitates wider band width and hence faster delivery at relatively sparse network. DSDV scores smaller AED for denser network (nodes 50 and above). The reason is when there is a large amount of control packets contenting for channel usage, the data packets have to back off a lot for a free slot. DSDV has fewer control packets than OLSR so the AED is shorter than OLSR.

Generally the Performance of both algorithms with the respective metrics falls with an increase in node density. Obviously as the node size grows the traffic density of the network, connectivity of nodes and interference of the network is high and degrades the performances of the metrics.

At node 50 DSDV scores better PDF not because it has efficiently used the band width but has sent few packets and relatively drops few packets. This is verified as OLSR has sent more packets and shows better figure in Goodput.

Besides at this is a speed scenario which is almost static network (0-1 m/s), The stability of the network with regard to node mobility endeavors the DSDV to escape the problems of stale route and convergence. Moreover OLSR sends huge amount of routing packets when the network grows large. Hence we can say that OLSR loses its advantages at this almost static speed scenario and relatively dense network cases (node 60).

7.1.2 Simulation Result at a speed of 5m/s

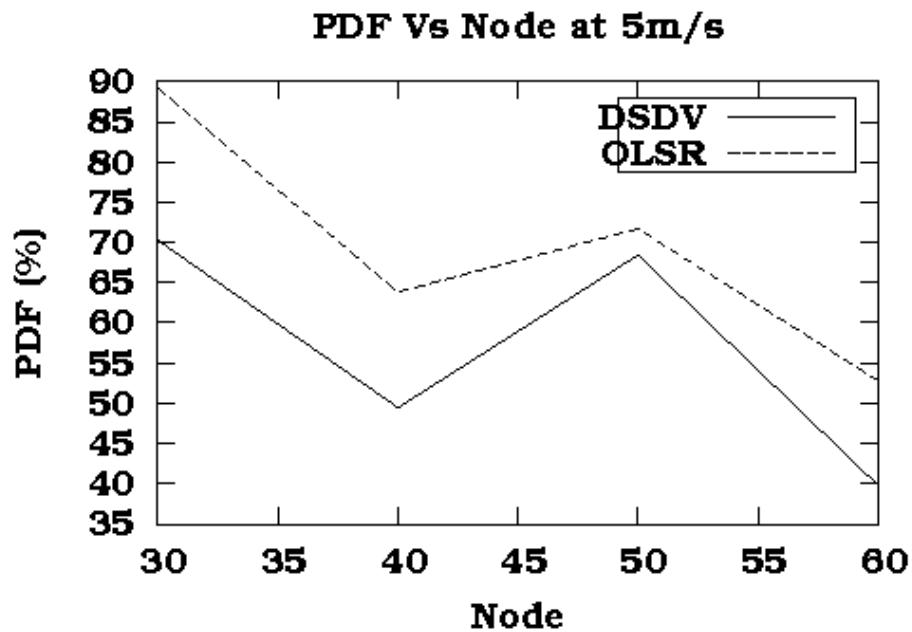


Figure 7.4: PDF Vs Node at 5m/s

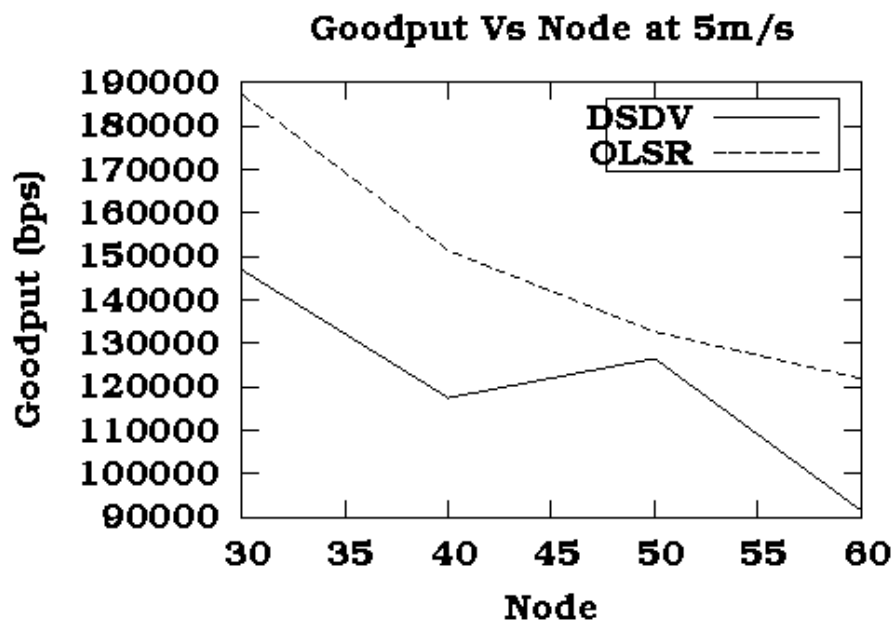


Figure 7.5: Goodput Vs Node at 5m/s

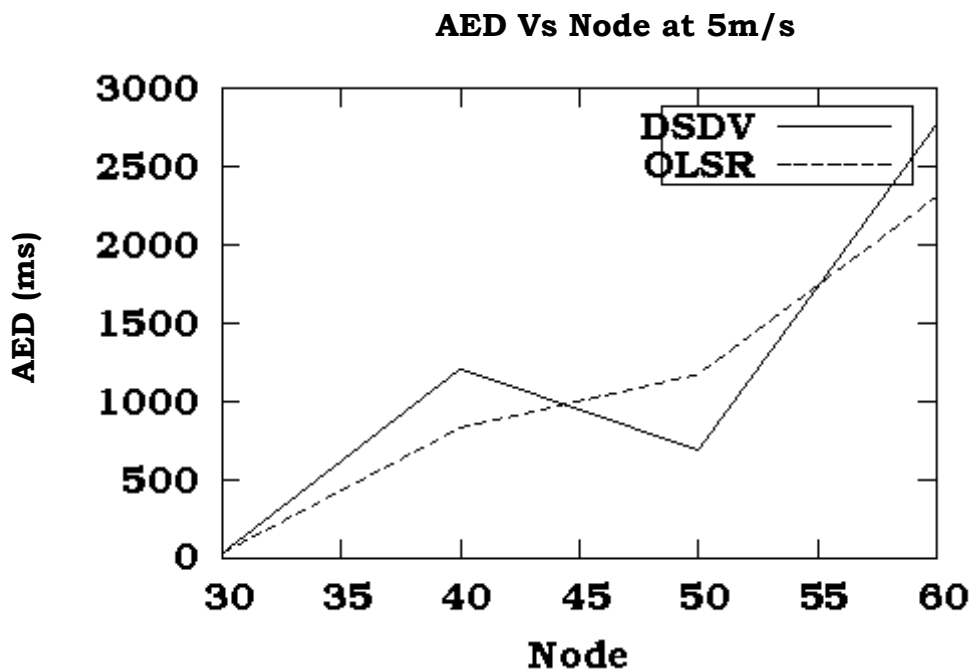


Figure 7.6: AED Vs Node at 5m/s

Discussion:

Similarly the PDF and Goodput of OLSR outsmart DSDV at each node density. AED is lower at relatively sparse networks for OLSR and at relatively dense network in DSDV. Generally the performance of the metrics falls with growing node size. This is due the same justification in section 7.1.1.

At this scenario OLSR seems to perform well with respect to AED at node density of 55 and above. We will try to justify this as follows: the denser the network, the fewer the MPRs are selected. As only MPR nodes will relay Link State update messages, the number of transmitted routing packets drops quickly. At cases where the additional overhead of OLSR is optimally lower, it may favor OLSR to deliver data packets with smaller AED than its counter part DSDV at this speed scenario.

7.1.3 Simulation Result at a speed of 10m/s

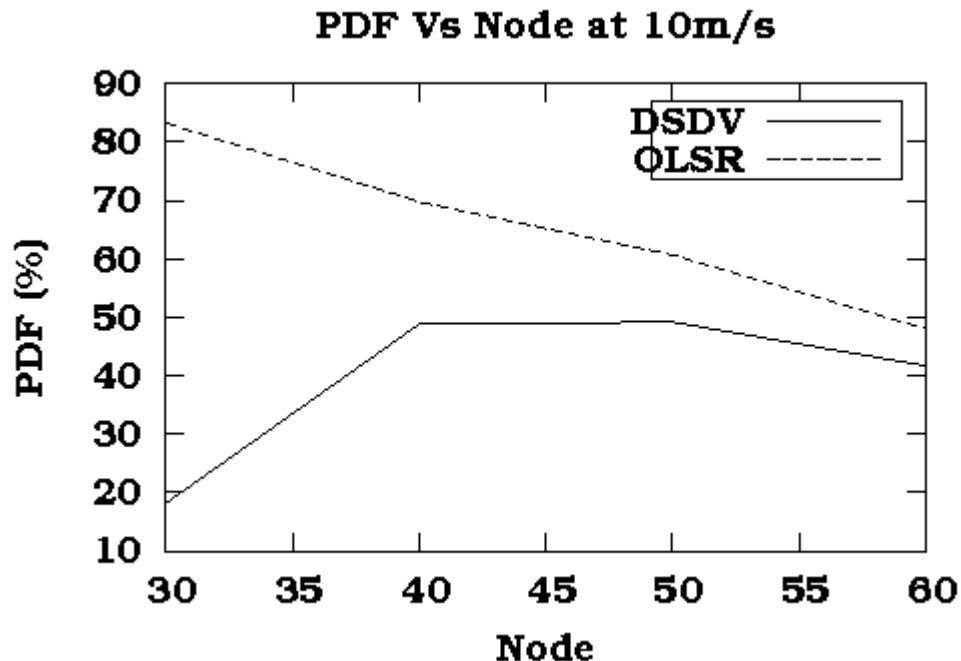


Figure 7.7: PDF Vs Node at 10m/s

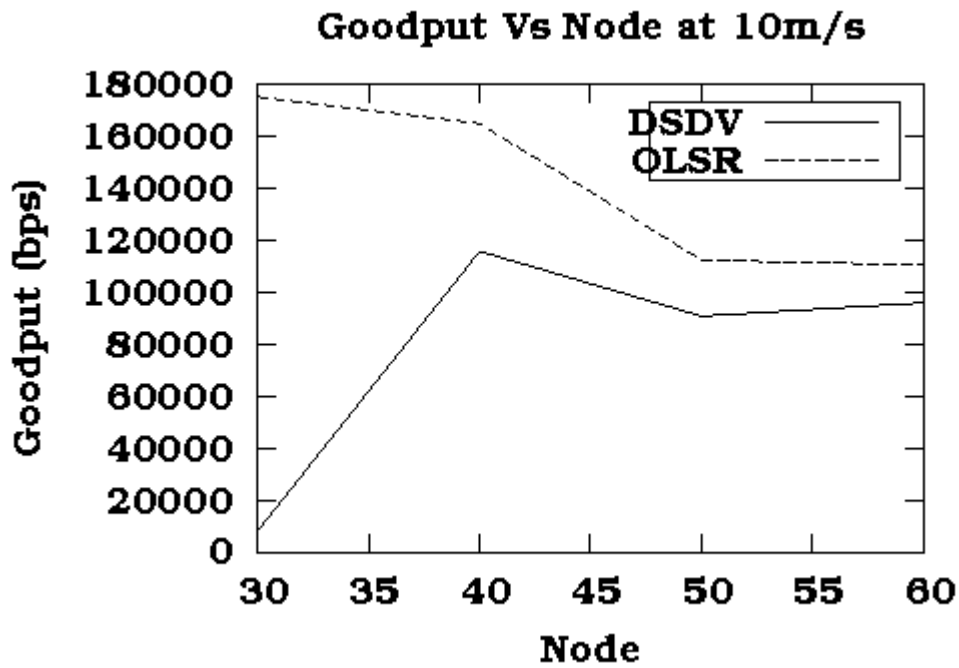


Figure 7.8: Goodput Vs Node at 10m/s

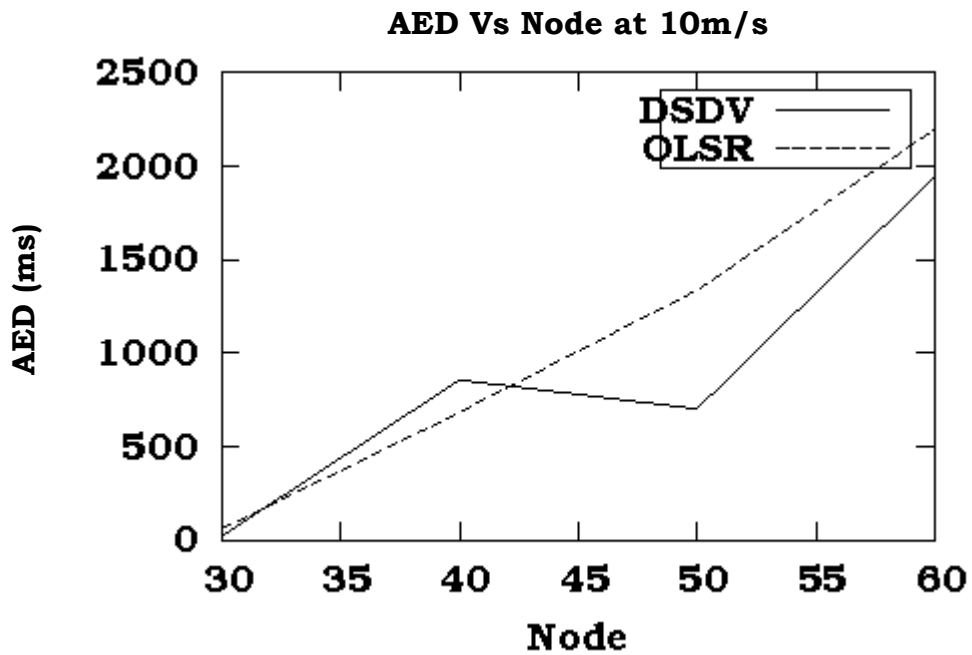


Figure 7.9: AED Vs Node at 10m/s

Discussion:

Similarly the PDF and Goodput of OLSR outsmart DSDV at each node density. AED is lower at relatively sparse networks for OLSR and at relatively dense network in DSDV. Generally the performance of the metrics falls with growing node size. This is due the same justification in section 7.1.1

7.1.4 Simulation Result at Speed of 15m/s

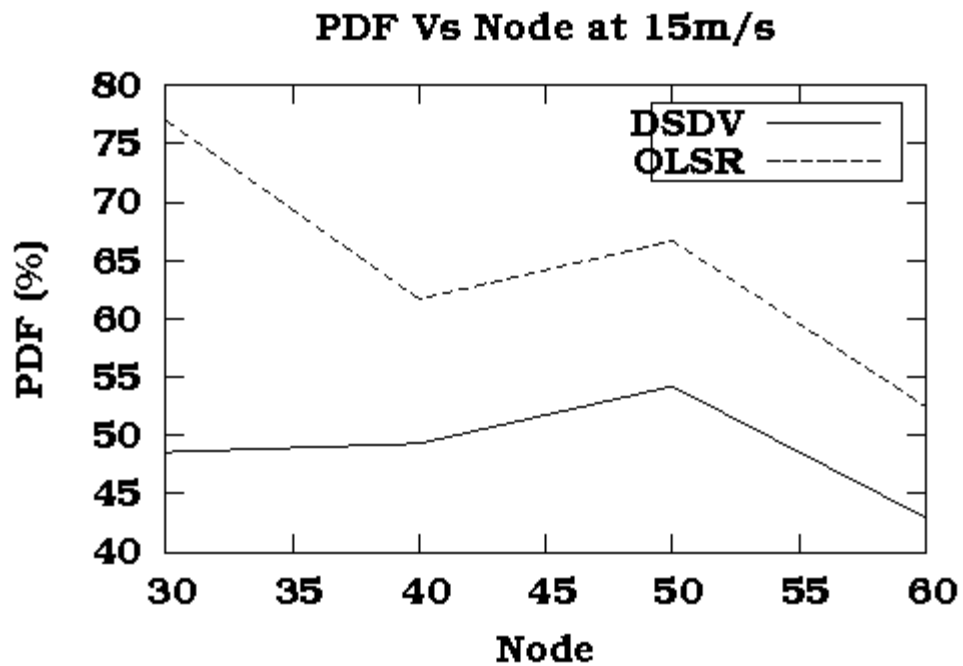


Figure 7.10: PDF Vs Node at 15m/s

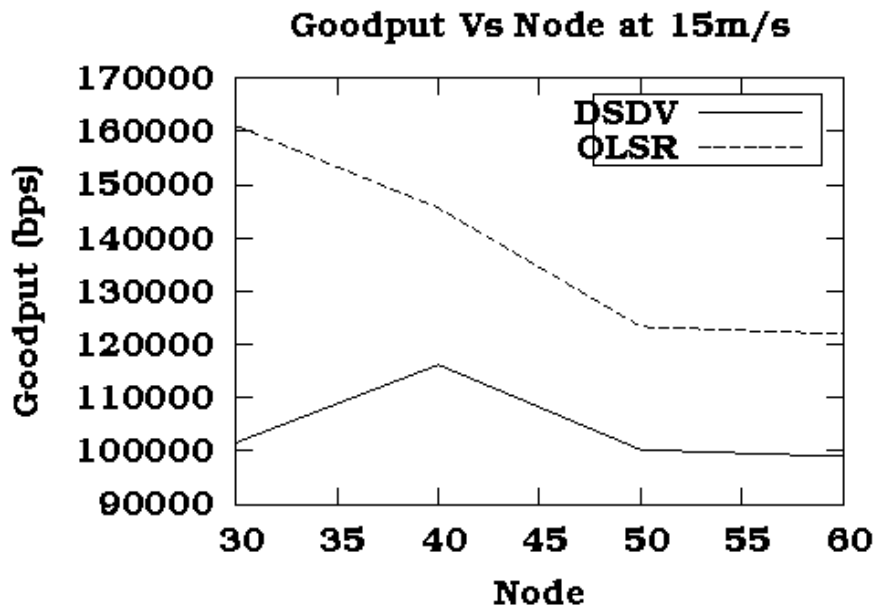


Figure 7.11: Goodput Vs Node at 15m/s

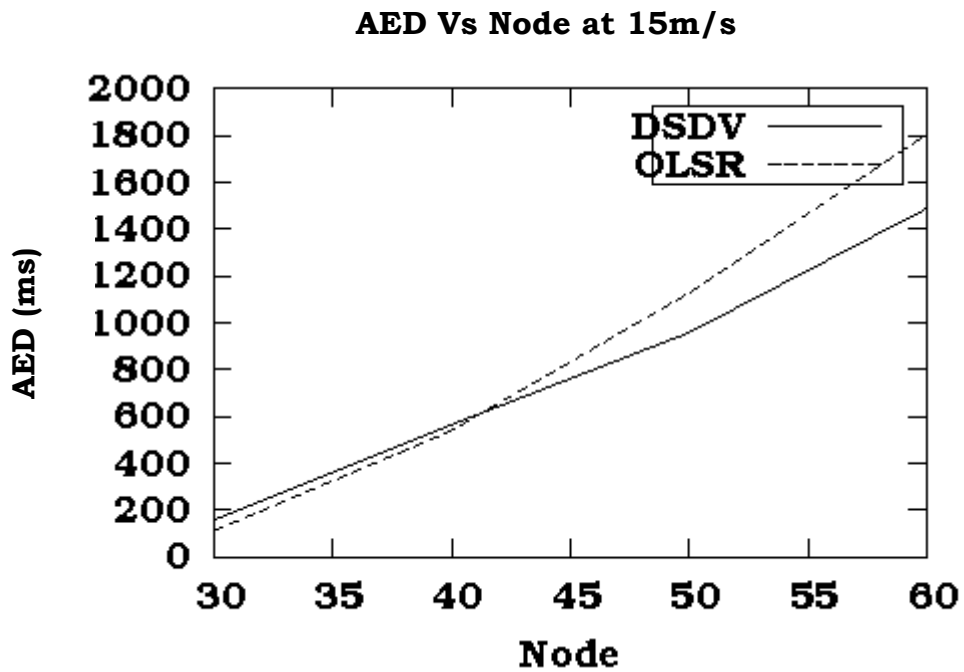


Figure 7.12: AED Vs Node at 15m/s

Discussion:

Similarly the PDF and Goodput of OLSR outsmart DSDV at each node density. AED is lower at relatively sparse networks for OLSR and at relatively dense network in DSDV. Generally the performance of the metrics falls with growing node size. This is due to the same justification in section 7.1.1. At high node mobility it can be seen that both the algorithms in general and DSDV in particular deteriorates. This is due to link breakage at high speed scenarios and particularly DSDV suffers more due to associated rise in stale route and convergence problems. More clearly DSDV is seen to show persistently lower performance than OLSR especially at this speed scenario.

Chapter 8: Design and Analysis of the Proposed Algorithm

8.1 QoS OLSR

The main objective of this thesis is to incorporate QoS into traditional best effort OLSR so as to obtain enhanced performance. A different approach is followed in both the MPR selection and route table computations from the OLSR. The new QoS OLSR proposed here computes the optimal number of MPR based on its own new way of computing MPR and employs a route table computation that best suits the MPR selection. Emphasis is given to the bandwidth related QoS Metrics PDF, Goodput and NRL. More over the effect of AED and Jitter is also considered.

8.2 Design of Algorithm

The idea behind this algorithm for New QoS OLSR is to select the highest bandwidth neighbors with optimal number of MPR: (N and N2 denotes all the 1 hop and 2 hop neighbor of the source node respectively)

1. Start with an empty MPR set
2. Select as MPRs nodes in neighbors N which provide the only path to some nodes in 2-hop neighbors N2
3. While there exist nodes in N2 which are not covered
 - {
 - 3.1. Select as MPR a node that has the highest bandwidth link connected with the current node and minimum possible set of MPR.
 - 3.2. Mark the neighbors of the newly selected MPR as covered in the 2-hop neighbor set of the current node
 - }

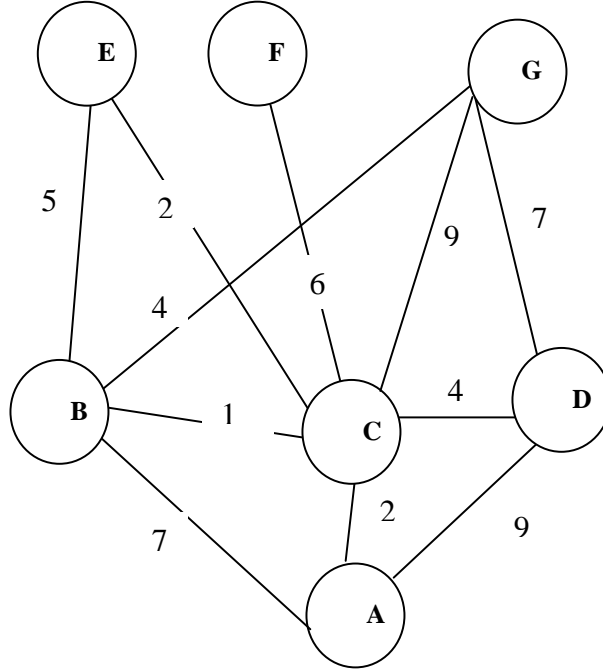


Figure 8.1: New MPR Selection

For example, using this algorithm, based on Figure 8.1, node A.s MPR(s) would be:

Source Node	1 hop neighbors	2 hop neighbors	MPR
A	B,C,D	E,F,G	B,C

Table 8.1 MPR selection in QOLSR

Among node A’s neighbors, B, C, and D have a connection to its 2-hop neighbors. Among them, even if link AD has the largest bandwidth we choose node B. This will reduce the number of MPR and maintain selection of optimal wider link band width. So B is first selected as A.s MPR, and the 2-hop Neighbor E & G are covered. Similarly, C is selected as MPR and F is covered, so all 2-hop neighbors are covered and the algorithm terminates.

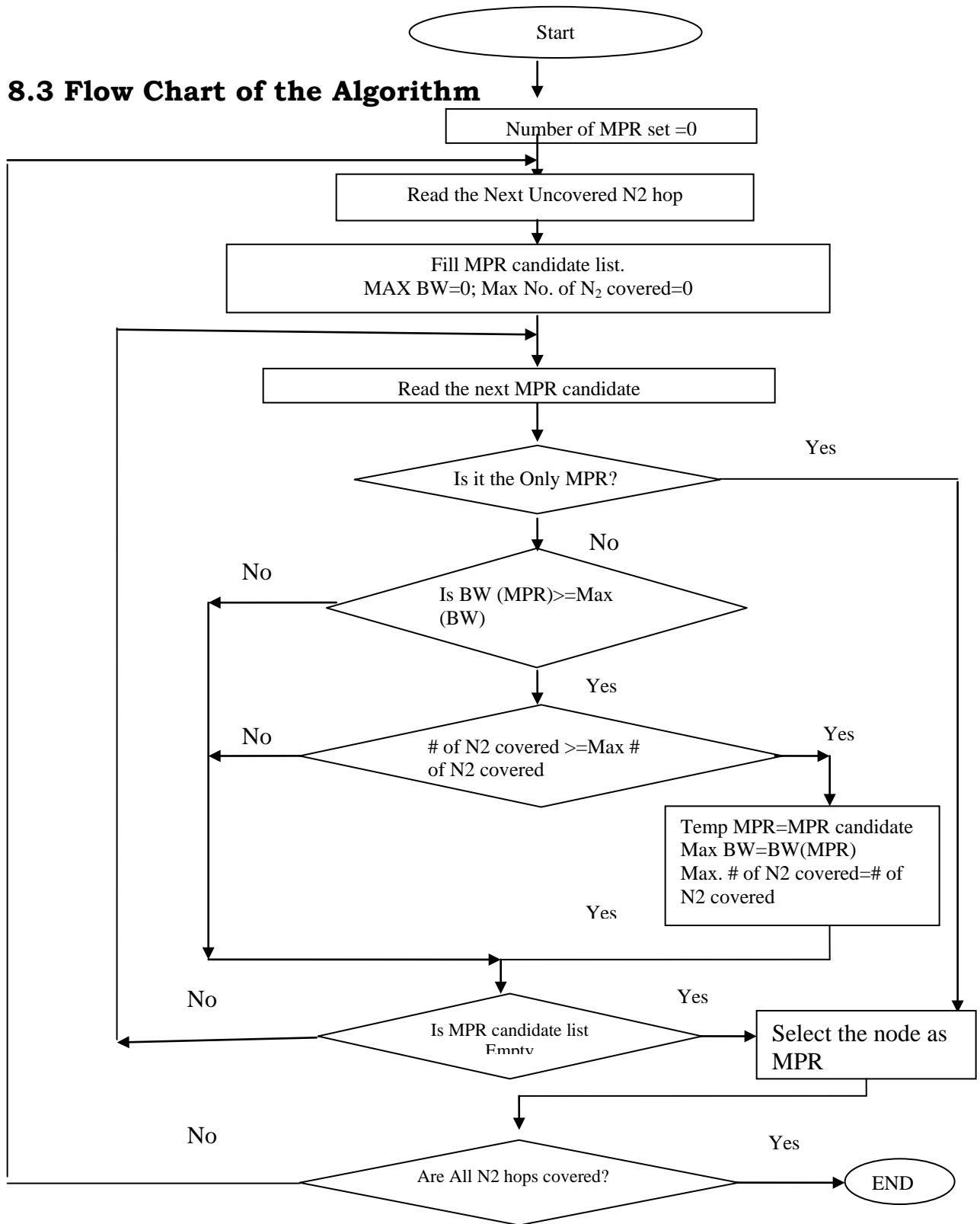


Figure 8.2: Flow Chart QOLSR

8.4 Implementation

8.4.1 Idle time propagation

The QoS OLSR version needs to know the available bandwidth on the neighbor link to select MPRs, and the available bandwidth of the far away link to compute the routing table. As idle time should be used to calculate the available bandwidth on the links, we revise the format of OLSR Hello and TC messages to include the idle time in it.

a. Hello message: in addition to the original information such as neighbor address and neighbor link type, a node also includes its own idle time in the Hello messages. Upon receiving a Hello message from its neighbor, a node reads the neighbor idle time, and selects MPRs using the QoS MPR selection algorithm.

b. TC message: the TC message originator not only puts its own idle time in TC messages, but also piggybacks its MPR selector's idle times, which are obtained from the Hello messages. When a node receives TC messages, it knows the idle time information of both the TC message originator and the MPR selectors thus gets information about the links and the link bandwidth between the TC message originator and its MPR selectors. In this way, it learns the partial network topology and the bandwidth condition of that partial network, and is ready to calculate the routing table. Also, QoS OLSR needs to decide when to originate a TC message. In the original OLSR, if a node detects changes in its MPR selector, it generates a new TC message to propagate the changes in the network topology. In QoS OLSR, however, changes in link bandwidth condition

must also be propagated for the correct computation of the best bandwidth routes.

In the implementation, a node keeps on informing its original idle time in its Hello messages until the latest idle time value it obtains from the Wireless LAN process model changes are compared with the original idle time. In such case, the node will propagate the new idle time in the Hello message, reflecting the change in the traffic condition on the wireless media. Upon receiving such Hello message, the neighbor node re-selects MPRs according to the latest idle time information. Consequently, TC messages are generated to reflect the bandwidth change. [35]

8.4.2 Available link band width calculation

QoS OLSR uses the media idle time to reflect the available bandwidth over a link. If the node is sending packets, its transmitter becomes busy. If there are other nodes beginning transmission within the interference range of the current node, its receiver senses the busy media and sends a media busy signal. As the NS-2 MAC Layer already defines functionalities to capture changes of the media, the available link bandwidth is computed as follows [35]: Each node is randomly assigned an idle time ranging from 0 to 1. The available link bandwidth between two nodes is equal to the minimum of their idle time multiplied by the maximum bandwidth. Here, we consider that in the Ad-Hoc network, each link has the same maximum bandwidth, 2 Mbps. For example, if node A's idle time is 0.5 and node B's idle time is 0.3, then the available bandwidth over link AB is: $0.3 * 2\text{Mbps} = 600 \text{ kbps}$. These randomly generated

idle times reflect the traffic condition in the network snapshot because the consumed bandwidth over each link reflects the traffic flows over that link.

8.4.3 MPR selection

The QoS OLSR promises to find the optimal bandwidth path with minimum possible number of MPR to have a Lower overhead compared with MPR selection type 1 and 2 discussed in Section 5.2.1 so in the implementation we use QoS OLSR as the MPR selection mechanism as discussed in section 8.2.

8.4.4 Routing table calculation

The Extended BF [21] algorithm is used to compute the routing table, as it not only finds shortest path but the best bandwidth path, as well.

Chapter 9 Simulation Result and Discussion

9.1 Scenario 1

In this Scenario the behavior of both algorithms OLSR and QOLSR is compared and contrasted by varying node density under different speed scenarios. The metrics to be analyzed are Goodput, Packet Delivery Fraction (PDF), Normalized Routing Load (NRL), Average End to End Delay (AED) and Jitter. The size of nodes to be taken is 30, 40, 50 and 60. The observation is categorized under four speed scenarios 1m/s,5m/s,10m/s and 15m/s as explained in section 7.1. this is because the main objective of this thesis work is to study the nature of the algorithms in different node density and node mobility.

9.1.1 Evaluation of metrics under maximum speed of 1m/s

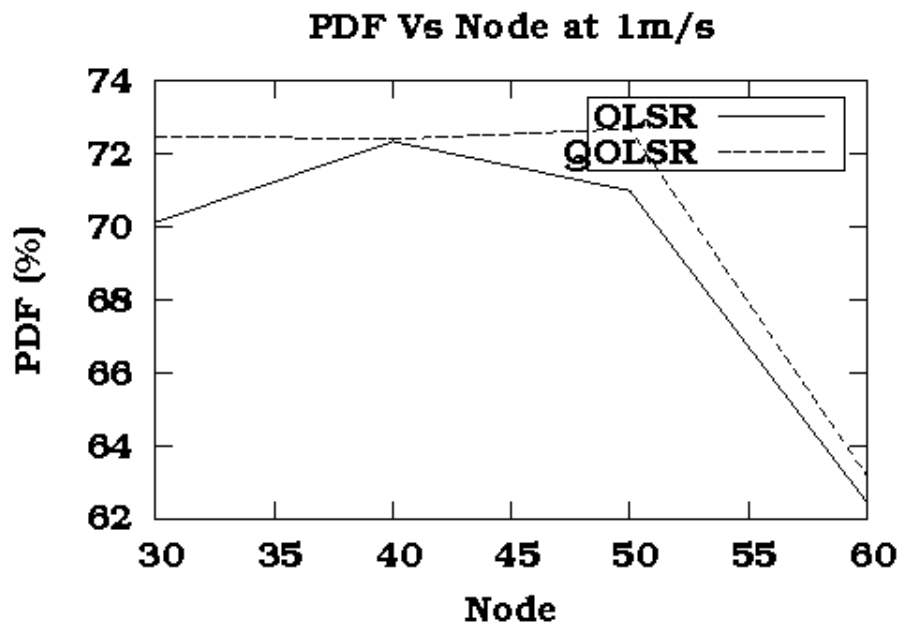


Figure 9.1: PDF Vs Node at 1m/s

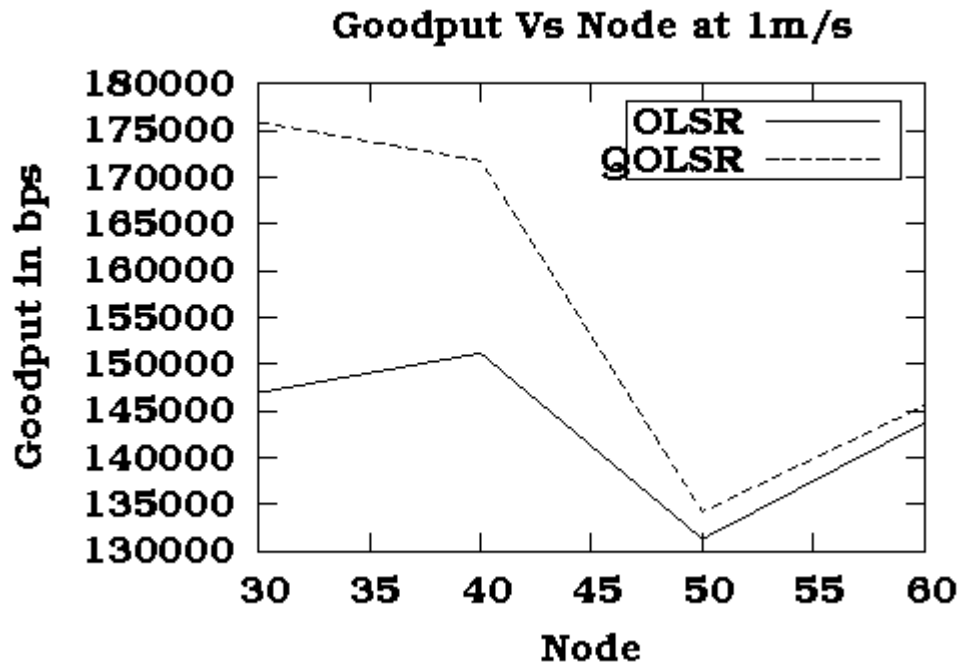


Figure 9.2: Good put Vs Node at 1m/s

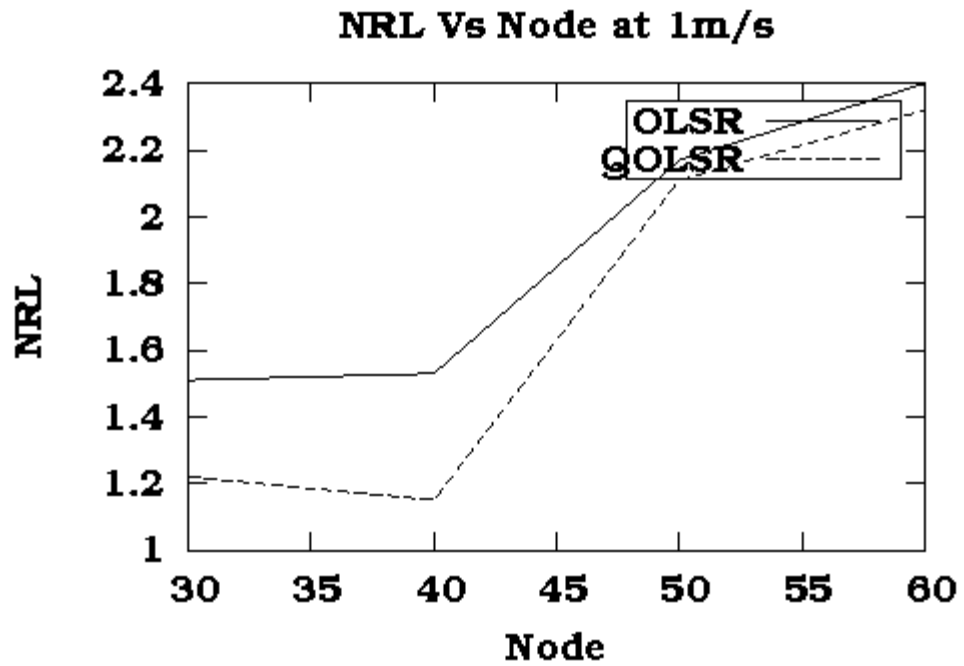


Figure 9.3: NRL Vs Node at 1m/s

AED Vs Node at 1m/s

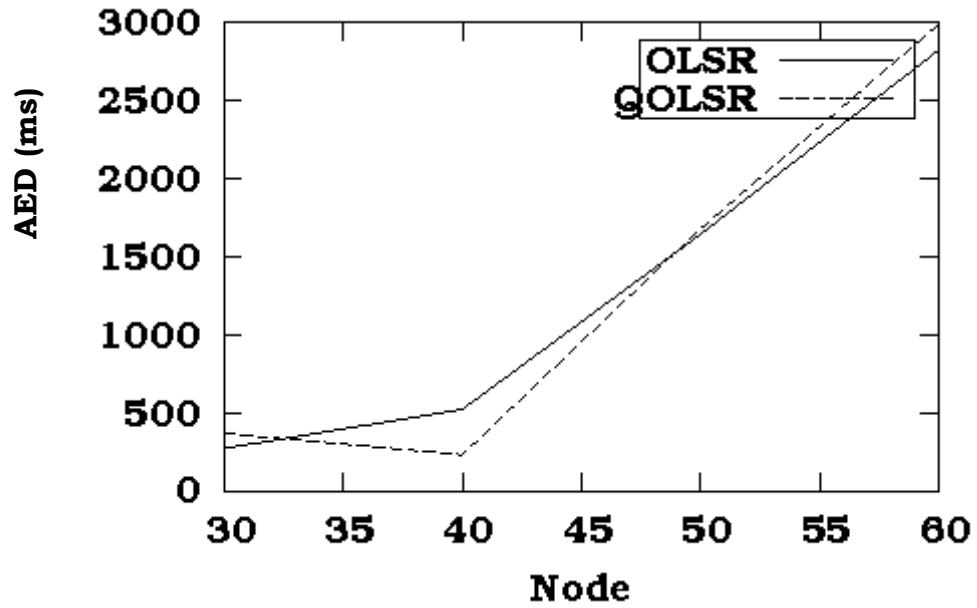


Figure 9.4: AED Vs Node at 1m/s

Jitter Vs Node at 1m/s

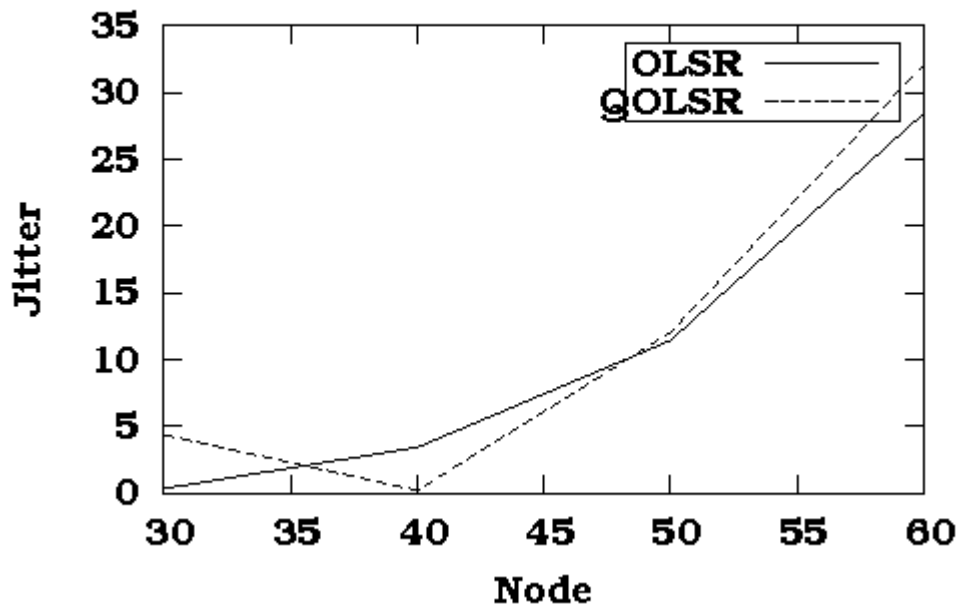


Figure 9.5: Jitter Vs Node at 1m/s

Discussion:

The PDF and Goodput are both showing improvement with the QOLSR at this speed scenario because the QOLSR searches for a wider band width link and hence can transfer more packets to the destination and similarly can transfer data bits better than the OLSR. A maximum of 3.55 % and 16.45 % improvements are seen (at node 30) in PDF and Goodput respectively. Since QOLSR performs better in delivering packets and data bits than OLSR by selecting better link which is comparatively less congested (i.e wider band width) it outperforms in NRL. (I.e. it uses less control messages of routing overhead to deliver a data packet). Nevertheless As the node size increases routes will be more congested due to an abrupt increment in control messages. So it is expected that both the algorithms will strictly decline in their performance with the above metrics (i.e. PDF, Goodput and NRL).

The AED and Jitter are not showing regular trend in our simulation result. In some cases the QOLSR shows better figure in AED metrics this can be explained by the fact that the algorithms in search of better link band width will transfer its packets in reduced end to end average Delay. Nevertheless while searching for an optimal bandwidth link, the QOLSR may also be forced to choose a route which is not shortest and hence the average end to end Delay will definitely be more than the OLSR which always computes the shortest path. Similarly Jitter shows irregular trend as in some cases QOLSR is better and in some other cases the OLSR is better. It can also be seen that there is similar effect of jitters as that of AED from the simulation graphs and the effect of jitter can be discussed like wise.

9.1.2 Evaluation of metrics under maximum speed of 5m/s

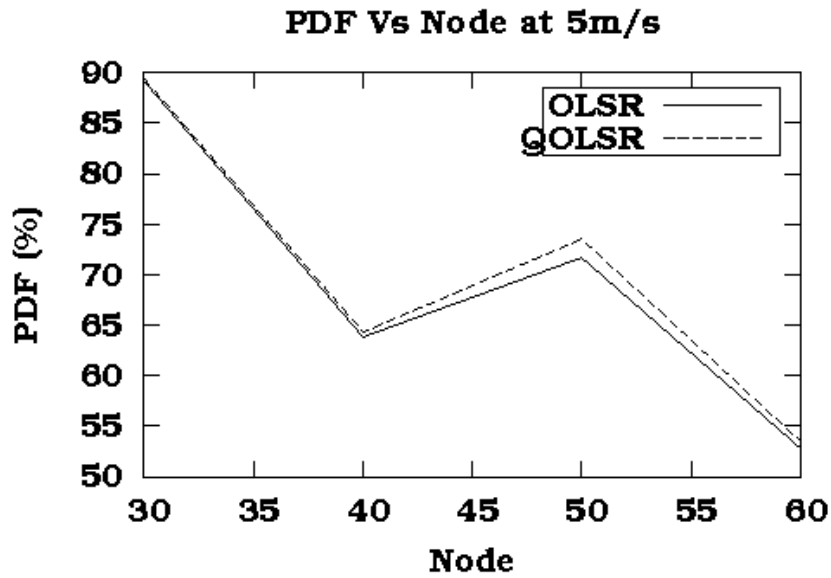


Figure 9.6: PDF Vs Node at 5 m/s

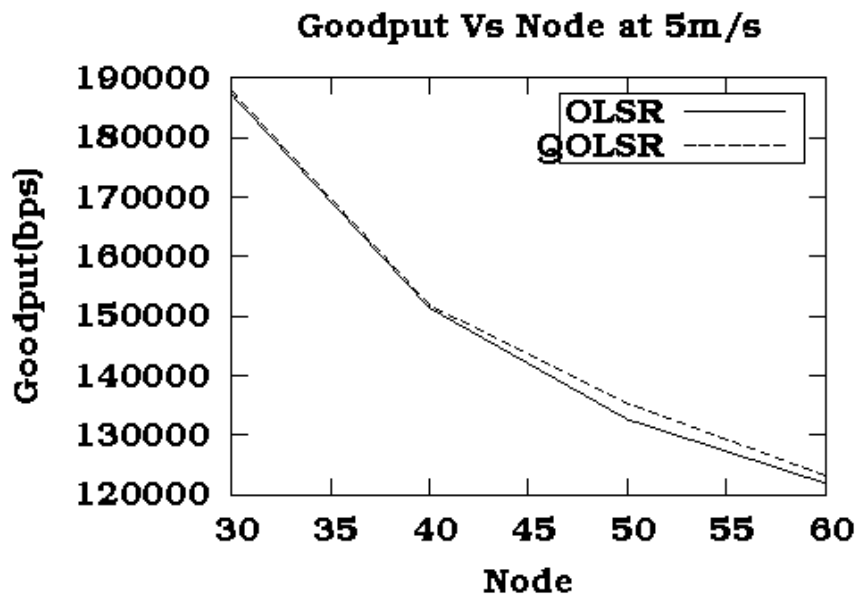


Figure 9.7: Goodput Vs Node at 5m/s

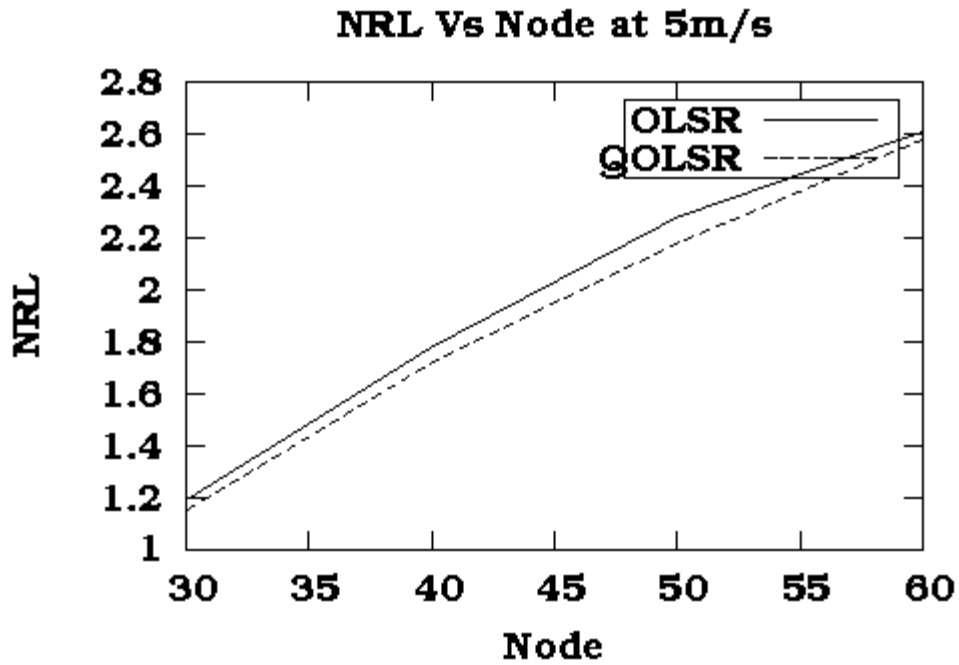


Figure 9.8: NRL Vs Node at 5m/s

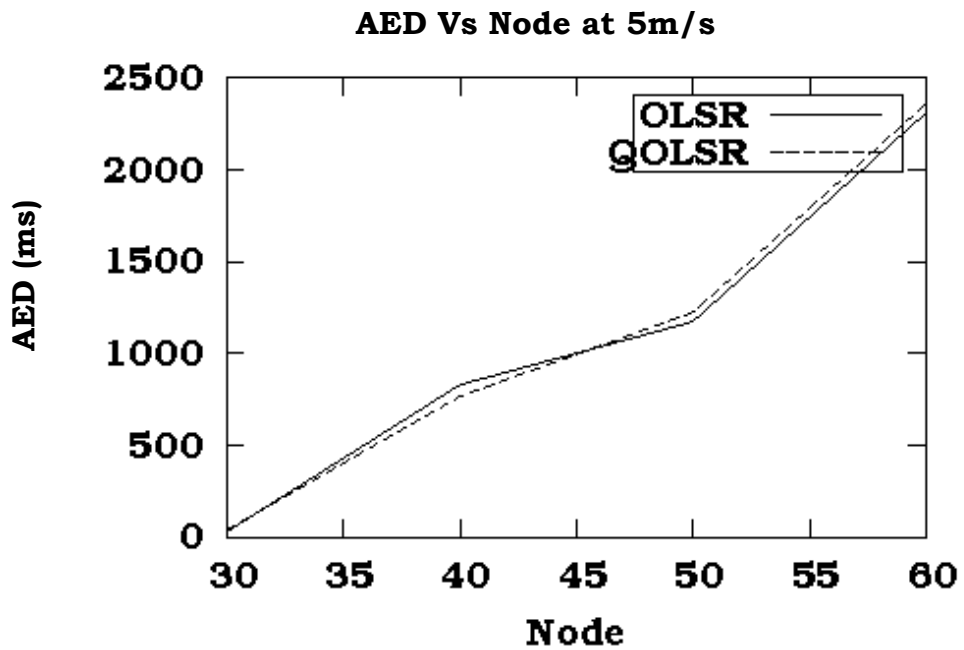


Figure 9.9: AED Vs Node at 5m/s

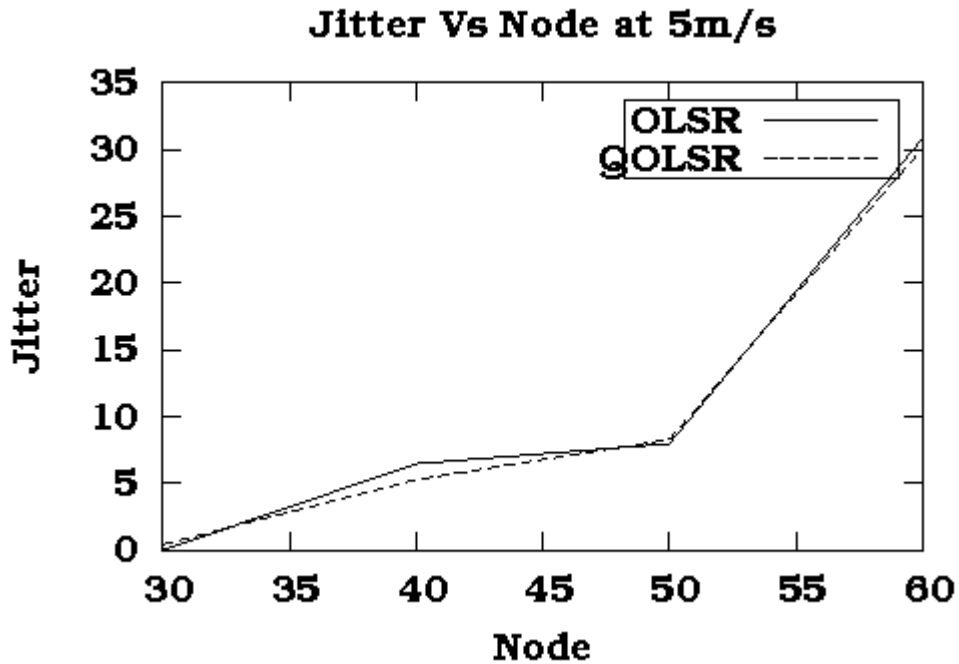


Figure 9.10: Jitter Vs Node at 5m/s

Discussion:

The PDF (maximum of 2.5% at node 50) and Goodput (maximum of 2% at node 50) are both showing improvement with the QOLSR at 5m/s speed scenario. Similarly the NRL of QOLSR outsmarts the OLSR in all cases. But at dense networks the performance of both algorithms with respect to the above metrics (i.e PDF, Goodput and NRL) strictly declines with increasing node density. All The above conclusions are justified by the same reason in section 9.1.1. At this speed scenario though we can notice that the progress made by QOLSR over OLSR in PDF, Goodput and NRL metrics is relatively small when compared to 1m/s scenario. We can also see that , the deteriorated effects of AED and Jitter is small too.

9.1.3 Evaluation of metrics under maximum speed of 10m/s

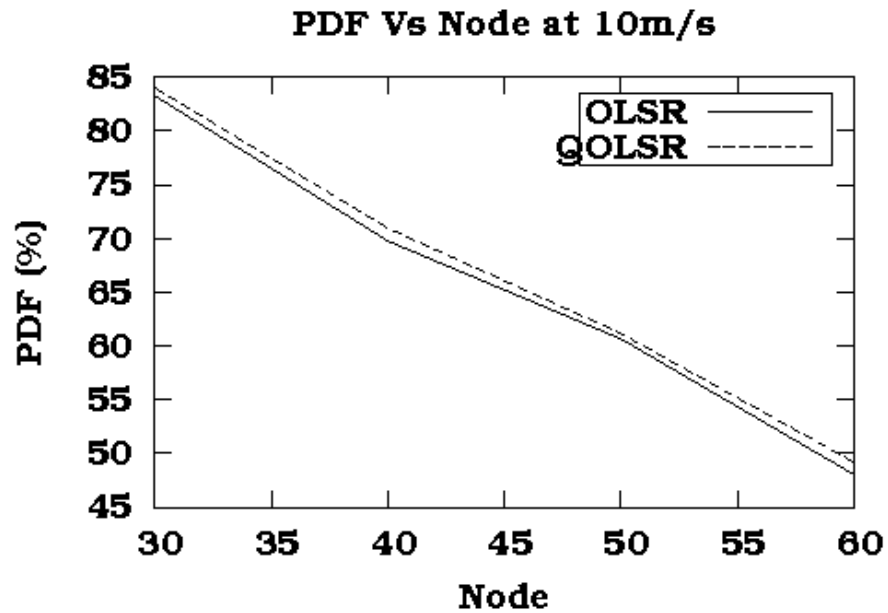


Figure 9.11: PDF Vs Node at 10m/s

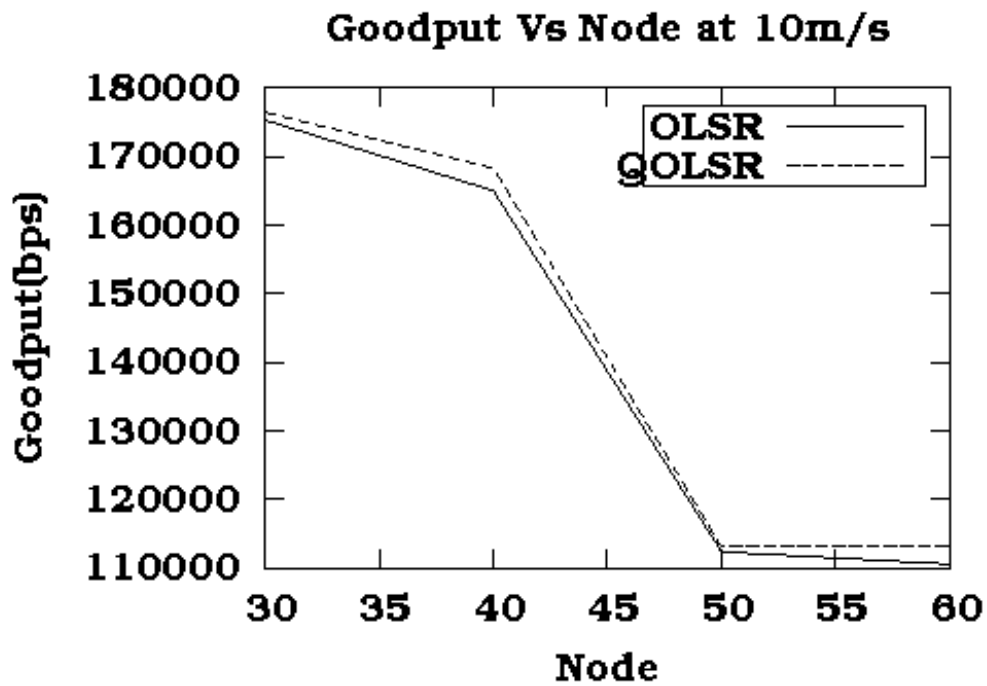


Figure 9.12: Goodput Vs Node at 10m/s

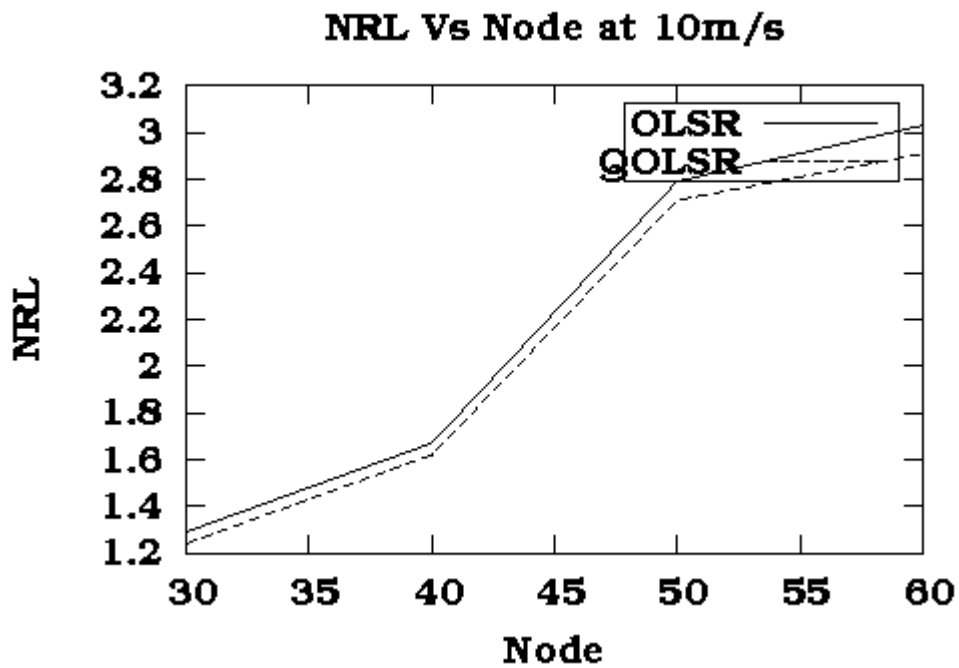


Figure 9.13: NRL Vs Node at 10m/s

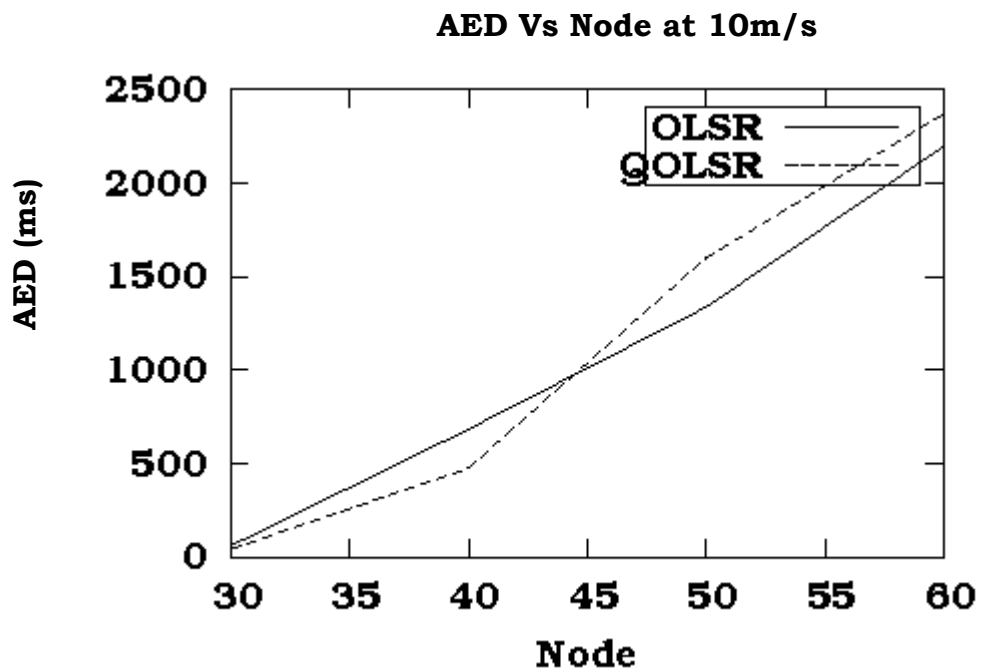


Figure 9.14: AED Vs Node at 10m/s

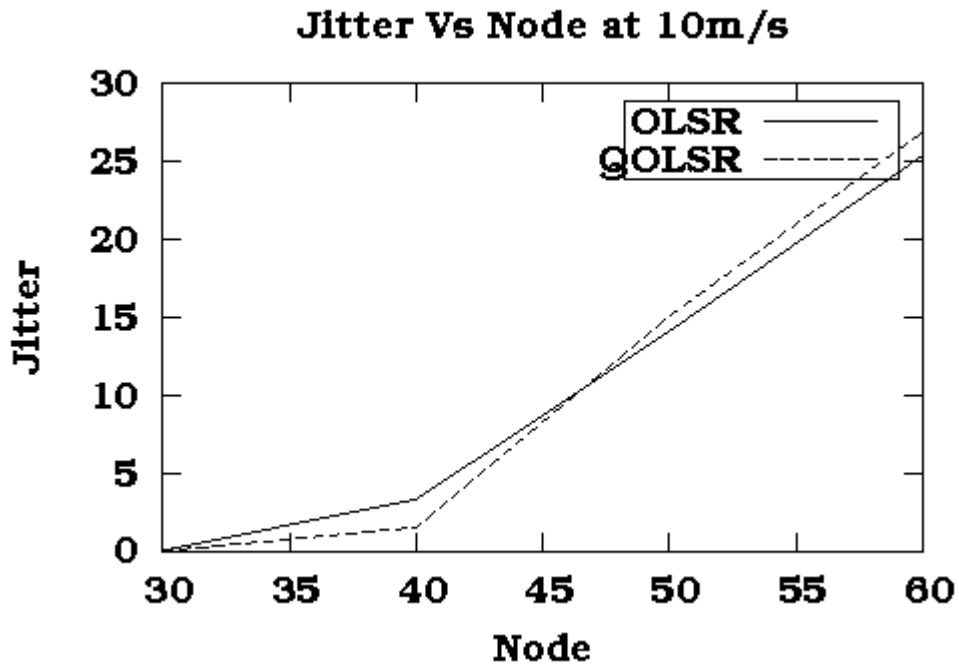


Figure 9.15: Jitter Vs Node at 10m/s

Discussion:

The PDF and Goodput are both showing improvement with the QOLSR at 10m/s speed scenario. A maximum enhancement is attained at node 40 i.e. 1.69 % for PDF and 1.96 % for Goodput. Similarly the NRL of QOLSR outsmarts the OLSR in all cases. But at dense networks the performance of both algorithms with respect to the above metrics (i.e PDF, Goodput and NRL) strictly declines with increasing node density. The above conclusions are justified by the same reason in section 9.1.1. At this speed scenario we can notice that the progress made by QOLSR over OLSR in PDF, Goodput and NRL

metrics is relatively small when compared to 1m/s scenario. The AED and Jitter are not showing regular trend in this simulation result too. Generally We can also see that at this speed scenario, the deteriorated effects of AED and Jitter is small.

9.1.4 Evaluation of metrics under maximum speed of 15m/s

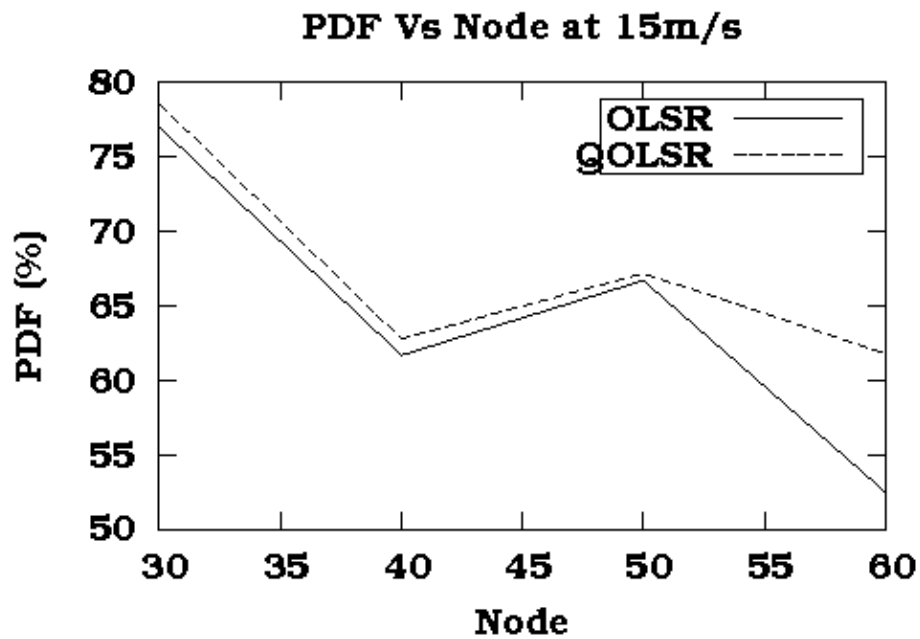


Figure 9.16: PDF Vs Node at 15m/s

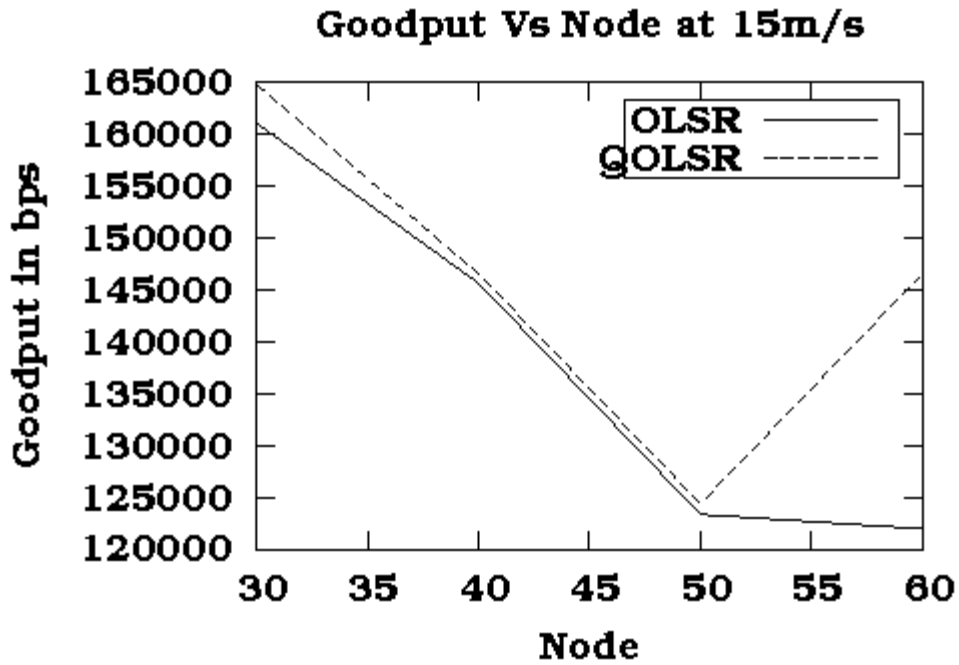


Figure 9.17: Goodput Vs Node at 15m/s

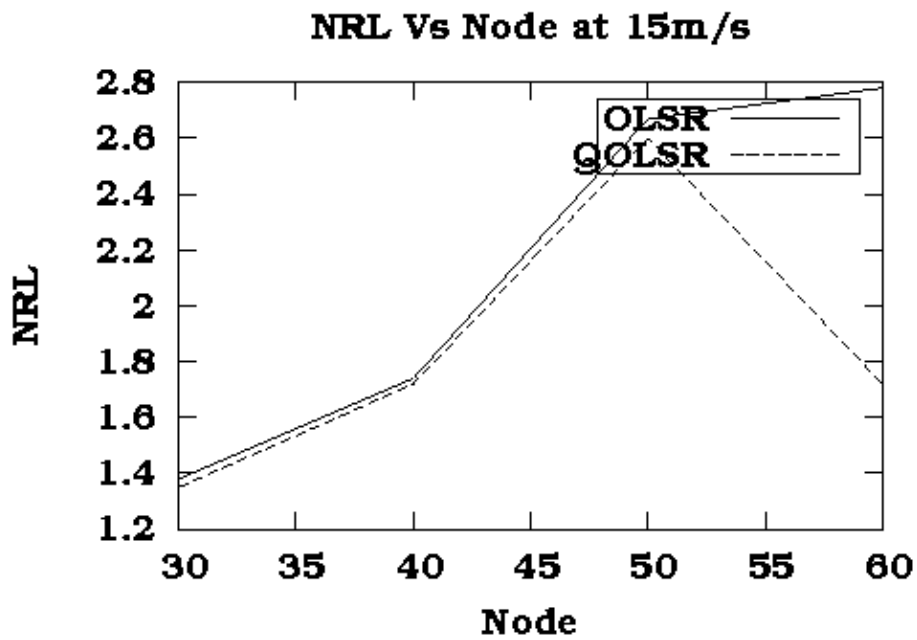


Figure 9.18: NRL Vs Node at 15m/s

AED Vs Node at 15m/s

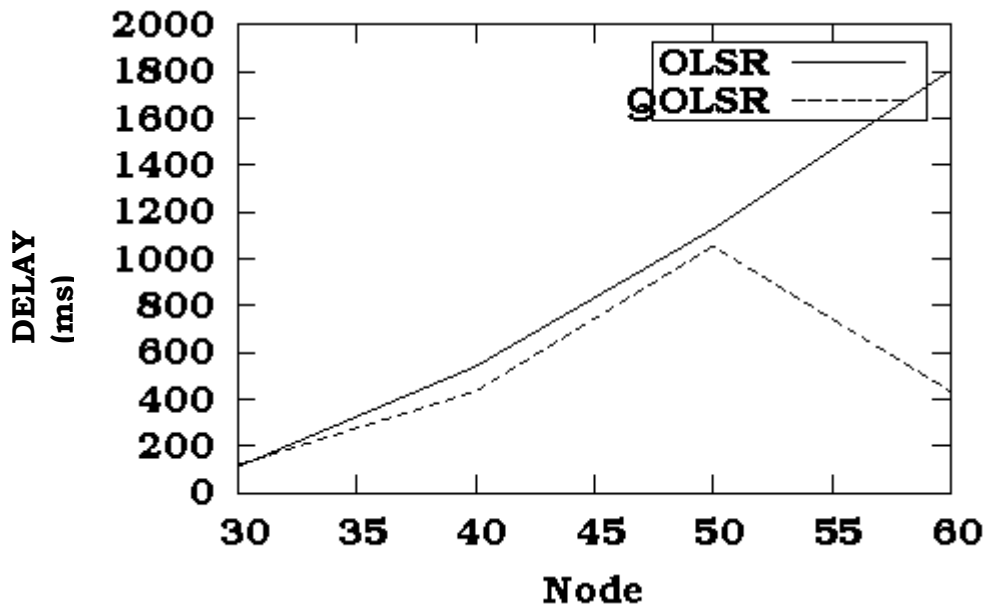


Figure 9.19: AED Vs Node at 15m/s

Jitter Vs Node at 15m/s

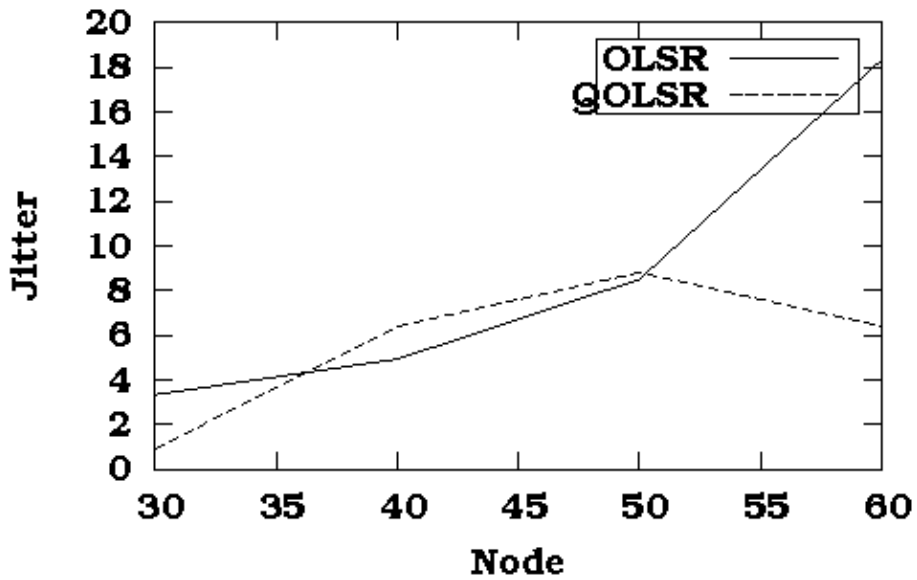


Figure 9.20: Jitter Vs Node at 15m/s

Discussion:

The PDF and Goodput are both showing exceedingly greater improvement with the QOLSR at 15m/s speed scenario. PDF scores a maximum of 15.06 % raise and Good put 16.78 % raise both at node 60. Similarly the NRL of QOLSR outsmarts the OLSR in all cases. But at dense networks the performance of both algorithms with respect to the above metrics (i.e PDF, Goodput and NRL) declines. All the above mentioned conclusions can be justified by the same reason in section 9.1.1.

The AED and Jitter are not showing regular trend in this simulation result too. Exceptionally we can also see that at this speed scenario there is an abrupt increment of performances of QOLSR over OLSR particularly at denser networks (nodes 50 and above) for all metrics. i.e including AED and Jitter. This may be due to the following reasons: At dense network the degree of connectivity of nodes rise in spite of the increased overhead. This will reduce the number of MPRs selected. Hence this will abruptly increase the efficiency of PDF, Goodput and NRL. At high speed the frequency of TC message exchange is high as the topology will change frequently and hence result in search of better band width and associated improvement on the metrics. The paired effect of both the abovementioned reasons will justify the outsmarting performances of AED and Jitter.

Chapter 10: Conclusion and future work

Based on the general observation of the simulation results and support of literature review the following conclusion is made:

10.1 Conclusion

In this thesis work, the principles of mobile ad hoc networks focusing on how to incorporate QoS is discussed. The importance of band width management QoS metrics in growing node density and mobility is significant in mobile Ad-Hoc network. Two of the most commonly used Proactive routing protocols DSDV and OLSR protocols are studied. In order to decide which of the two proactive protocols will QoS suit more, several literature reviews have been reviewed and comparative analysis has been done using NS-2 simulator. Both the reviewed literature and the results of the comparative analysis have proved OLSR to be a promising candidate to best perform in QoS incorporation. This is because the band width management metrics have shown promising figures in OLSR than in DSDV and it is this set of Metrics that the thesis work is working up on. We discuss in detail our idea of adding QoS into the OLSR protocol. Our algorithm allows OLSR to find the maximum bandwidth path with optimal number of MPR. Simulation results of this algorithm in various node densities and node mobility have ensured that an average of (2.5%- 15.06 %) of PDF and (2%- 16.78%) improvement of Goodput has been attained. Besides this thesis work has shown that AED and jitter has improved. Nevertheless other related works has described AED as a cost that must be paid and ignores the effect of jitter.

10.2 Future Work

Here are some of the recommendations as a future work of the thesis.

- ✓ The QOLSR we have developed by changing a new MPR set consider the link band width and can be redesigned to adapt the bottleneck band width till the uncovered 2 hop neighbors.
- ✓ The frequency of change of available band width is rapid causing extremely high overhead. So it will be more efficient if the QoS OLSR to define an optimal threshold of bandwidth change and find MPR if and only if the change crosses the threshold.
- ✓ The Random Way Point model we have used is problematic in simulating the real mobility scenario. When a maximum of 15 m/s is set it distributes from 0 to 15m/s and may concentrate below 10m/s and overlap the simulation results.
- ✓ Currently, we are using 2 Mbps data rate, it is interesting to explore if by using 802.11b, with 11 Mbps data rate, the performance of the QoS OLSR could not fail as much as we simulated especially with increasing node density.

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Appendix A: TCL Script for OLSR

```
# =====
# Define options
# =====
set opt(chan)      Channel/WirelessChannel      ;# channel type
set opt(prop)      Propagation/TwoRayGround    ;# radio-propagation model
set opt(netif)     Phy/WirelessPhy            ;# network interface type
set opt(mac)       Mac/802_11                 ;# MAC type
set opt(ifq)       Queue/DropTail/PriQueue    ;# interface queue type
set opt(ll)        LL                          ;# link layer type
set opt(ant)       Antenna/OmniAntenna        ;# antenna model
set opt(ifqlen)    50                          ;# max packet in ifq
set opt(nn)        30                          ;# number of mobilenodes
set opt(adhocRouting) OLSR                    ;# routing protocol

set opt(cp)        "./traffic/cbr30by10"      ;# connection pattern file
set opt(sc)        "./scenario/scen30by10"    ;# node movement file.

set opt(x)         1000                        ;# x coordinate of topology
set opt(y)         1000                        ;# y coordinate of topology
set opt(seed)      1.0                        ;# seed for random number gen.
set opt(stop)      300                        ;# time to stop simulation

#set opt(cbr-start) 30.0
# =====

#
# check for random seed
#
if {$opt(seed) > 0} {
puts "Seeding Random number generator with $opt(seed)\n"
ns-random $opt(seed)
}

# create simulator instance
set ns_ [new Simulator]
$ns_ use-newtrace
# control OLSR behaviour from this script -
# commented lines are not needed because
# those are default values
Agent/OLSR set use_mac_ true
#Agent/OLSR set debug_ false
#Agent/OLSR set willingness 3
#Agent/OLSR set hello_ival_ 2
#Agent/OLSR set tc_ival_ 5

# open traces
set tracefd [open olsr30.tr w]
set namtrace [open olsr30.nam w]
```

```

$ns_ trace-all $tracefd
$ns_ namtrace-all-wireless $namtrace $opt(x) $opt(y)
# create topography object
set topo [new Topography]

# define topology

$topo load_flatgrid $opt(x) $opt(y)

# create God
#
set god_ [create-god $opt(nn)]

#
# configure mobile nodes
#
$ns_ node-config -adhocRouting $opt(adhocRouting) \
-llType $opt(ll) \
-macType $opt(mac) \
-ifqType $opt(ifq) \
-ifqLen $opt(ifqlen) \
-antType $opt(ant) \
-propType $opt(prop) \
-phyType $opt(netif) \
-channelType $opt(chan) \
-topoInstance $topo \
-wiredRouting OFF \
-agentTrace ON \
-routerTrace ON \
-macTrace OFF

for {set i 0} {$i < $opt(nn)} {incr i} {
set node_($i) [$ns_ node]
}

#
# source connection-pattern and node-movement scripts
#
if { $opt(cp) == "" } {
puts "*** NOTE: no connection pattern specified."
set opt(cp) "none"
} else {
puts "Loading connection pattern..."
source $opt(cp)
}
if { $opt(sc) == "" } {
puts "*** NOTE: no scenario file specified."
set opt(sc) "none"
} else {

```

```

puts "Loading scenario file..."
source $opt(sc)
puts "Load complete..."
}

#
# define initial node position in nam
#
for {set i 0} {$i < $opt(nn)} {incr i} {
$ns_ initial_node_pos $node_($i) 20
}

#
# tell all nodes when the simulation ends
#
for {set i 0} {$i < $opt(nn)} {incr i} {
$ns_ at $opt(stop).0 "$node_($i) reset";
}

$ns_ at $opt(stop).0002 "puts \"NS EXITING...\" ; $ns_ halt"
$ns_ at $opt(stop).0001 "stop"

proc stop {} {
global ns_ tracefd namtrace
$ns_ flush-trace
close $tracefd
close $namtrace
# exec nam olsr_example.nam &
}

#
# begin simulation
#
puts "Starting Simulation..."

$ns_ run

```

Appendix B: Script for Metric Calculation

```
BEGIN {
    sends=0;
    flag=0;
    recvs=0;
    routing_packets=0.0;
    droppedBytes=0;
    check=0;
    droppedPackets=0;
    highest_packet_id =0;
    sum=0;
    summean=0.0;
    count=0;
    avghop=0;
    recvnum=0;
    noerrors=0;
    nodied=0;
    firsttime=0.0;
    EnergyConsume=0.0
    variance=0.0;
}

{

time = $3;
packet_id = $41;
NodeId=$9;
NodeEnergy=$17;

# CALCULATE PACKET DELIVERY FRACTION

if (( $1 == "s" ) && ( $35 == "cbr" ) && ( $19=="AGT" ))
    {
        sends++;
    }

if (( $1 == "r" ) && ( $35 == "cbr" ) && ( $19=="AGT" ))
    {
        recvs++;
    }

# CALCULATE AED

if ( start_time[packet_id] == 0 ) start_time[packet_id] = time;

if (( $1 == "r" ) && ( $35 == "cbr" ) && ( $19=="AGT" )) {
```

```

        end_time[packet_id] = time; }
    else { end_time[packet_id] = -1; }

# CALCULATE TOTAL OLSR OVERHEAD

    if (($1 == "s" || $1 == "f") && $19 == "RTR" && $35 == "OLSR")
        routing_packets++;

# DROPPED OLSR PACKETS

if (( $1 == "d" ) && ( $35 == "cbr" ) && ( $3 > 0 ))
    {
        droppedBytes=droppedBytes+$37;
        droppedPackets=droppedPackets+1;
    }

    if (packet_id > highest_packet_id)
        highest_packet_id = packet_id;
}

END {

for ( i in end_time )
{
start = start_time[i];
end = end_time[i];

packet_duration = end - start;

if ( packet_duration > 0 )
{
sum += packet_duration;
duration[i]=packet_duration;
}
}
}

```

```

        recvnum++;
    }
}

    DELAY=sum/recvnum;
# Calculate the Jitter (DELAY Variance)

for(i in duration)
{
    variance+=(duration[i]-DELAY)*(duration[i]-DELAY);
}
Jitter=variance/recvnum;

    NRL = routing_packets/recvs; #normalized routing load

    PDF = (recvs/sends)*100; #packet delivery ratio[fraction]

printf("SEND    RECEIVE    ROUTING_PKT    PDF    NRL    E_E_DELAY    JITTER    GOODPUT
droppedpacket        DroppedByte\n");

printf("_____
____\n");
    printf(" %.2f",sends);

    printf("    %.2f",recvs);

    printf("    %.2f",routing_packets++);

    printf("    %.2f",PDF);

    printf(" %.2f",NRL);

    printf("    %.2f",DELAY*1000);

    printf("    %.8f",Jitter);

    printf(" %.2f bps",recvs*512/30);

    printf("    %d",droppedPackets)

    printf("    %d\n",droppedBytes);

}

```

Appendix C: Script for Plotting Graphs

```
# Graph plotter of GNUPLOT for Goodput at 5 m/s
set term postscript enhanced color solid "Times New Roman" 14
set output "Goodput at 5 mps"
set size 0.5,0.5
set origin 0.5,0.5
set title "Goodput Vs Node"
set xlabel "Node"
set ylabel "PDF (%)"
set xrange [30:60]
set nokey
set key box
set key top right
plot "/qolsr/node30/olsr5" u 1:9 t "OLSR" w l, "/qolsr/node30/qolsr5" u 1:9 t "QOLSR" w l
```