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QoS Aware Routing Protocol for MANETs

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Dedicated to

My families

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Acronyms:

- AODV: Ad hoc Distance Vector
- CBR: constant bit rate
- DREAM: Distance routing effect algorithm for mobility
- DSDV: Destination Sequenced Distance Vector
- DSR: Dynamic Source Routing
- FSR: fisheye state routing
- IEEE: Institute of Electrical Electronics Engineering
- IETF:Internet engineering Task Force
- MANETs: Mobile Ad hoc Networks
- MPR: Multi Point Relay
- OLSR: Optimized link state routing
- QoS :Quality of Service
- QoS Aware OLSR: Quality of Service aware Optimized link state routing
- QoS-AODV: Quality of service ad’hoc on demand distance vector
- RFC: Request For Comments
- TBRPF:Topology broadcast based on reverse path forwarding
- TC: Topology Control message
- TORA: Temporary ordered routing algorithm
- ZRP: Zone routing protocols

Abstract

The current trend of connectivity anywhere, anytime, and any how brings a new paradigm of accessing multimedia services (voice, video, and text) via MANETs specifically in areas of military, emergency, automotive application e.t.c. However, the available bandwidth for supporting these applications is rather limited, and proper management of the bandwidth is necessary to accommodate the envisaged high-bandwidth applications and, thus, provide QoS. In other words it is a must to have QoS support routing protocol that find a feasible path between source/destination pair (i.e. a path that has sufficient available resources capable of satisfying the QoS requirements).

In this work, a survey on selected best effort routing protocols (OLSR, DSDV, and AODV) is conducted using qualitative and quantitative multi metrics and shows protocols that work in proactive mode are more suitable for QoS routing than reactive ones. Since routes are maintained, proactive protocols have lower latency where as reactive protocols may have higher latency because a route from source to destination will be found only when sender attempts to send to the receiver. However, proactive protocols can (but not necessarily) result in higher overhead due to continuous route updating. The result finally shows OLSR is a good candidate for QoS improvement.

Therefore, reengineering of best effort OLSR proactive protocol using new MPR selection approach is found as the best alternative to add QoS features and the result is a corresponding QoS Aware version of OLSR. Even though a number of variant approaches are available, they are not optimal in selecting MPRs covering 2 hop neighbors and a good quality links. Therefore, we have devised a new selection mechanism that takes in to account the number of MPRs and bandwidth to have a relatively better QoS support. With the help of scenario based simulation analysis, we finally proved that QoS aware OLSR is better than the original OLSR in delivering QoS services. Thus, the algorithm we proposed in architecting QoS Aware OLSR shows improvement to the best effort OLSR in terms of QoS support.

Key words: MANETs, Qos Routing, best effort OLSR, QoS Aware OLSR, MPR

CHAPTER ONE

INTRODUCTION

1.1.Background

Ad hoc networking [1, 2] began in the early times when the US Department of Defense (DoD) sponsored the Packet Radio Network (PRNET) research program. This program aimed to provide packet-switched networking to the mobile battlefield in a hostile *environment* with no infrastructure and with soldiers, tanks, aircraft, etc, forming the nodes in the network as in Figure 1.1.

The popular IEEE 802.11 ("Wi-Fi") wireless protocol incorporates an ad-hoc networking system when no wireless access points are present, which only handles traffic within a local "cloud" of wireless devices [1,2,3]. IEEE adopted the term ‘ad hoc networks’ for the IEEE802.11 Wireless LAN standards and IEEE802.11b, a, n and g e.t.c. are the most widely used types of versions available. In addition, today, Bluetooth, HiperLAN2 are among other alternatives that offer further technologies that can be used in ad hoc communications.

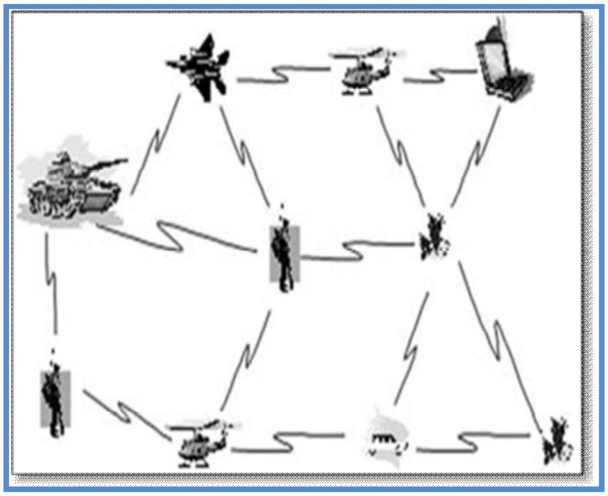


Figure 1.1 Tactical Networks

According to [7], MANETs are complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary, ‘‘ad-hoc’’ network topologies, allowing people and devices to seamlessly internetwork in areas with no pre-existing communication infrastructure.

Alternatively, MANET can be defined as an autonomous collection of heterogeneous mobile devices (laptops, smart phones, sensors, MP3 players, digital cameras e.t.c.) like in Figure 1.2 that communicates with each other over wireless links and cooperate in a distributed manner in order to provide the necessary network functionally in the absence of a fixed infrastructure. They are called also infrastructureless networks, or Nomadic networks [7,8].

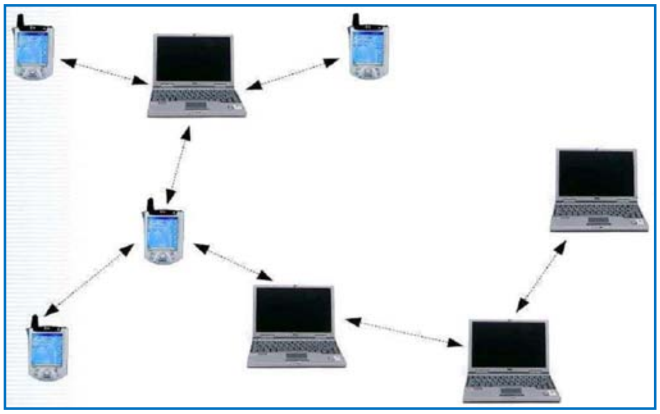


Figure 1.2 A simple MANET

The goal of mobile ad hoc networking is to extend mobility into the realm of autonomous, mobile, wireless domains, where a set of nodes, which may be combined routers and hosts themselves forms the network routing infrastructure in an ad hoc fashion. Ad hoc networking will play an important role in the evolution of “internet of things”. Its intrinsic flexibility, ease of maintenance, lack of needed infrastructure, auto configuration, self administration capabilities and significant cost advantages make it a prime candidate for becoming the stalwart technology for personal pervasive communication. In addition, ad hoc networking is at the center of the evolution towards the fourth generation of wireless technology. MANET Work group proposes a view of MANETs as the evolution of the Internet.

Like wired ones, MANETs use different routing algorithms to move data from one node to the other optimally. Over the past few years, a variety of new routing protocols targeted specifically at the ad hoc networking environment have been proposed [3, 4]. Generally, the available proposed routing algorithms fall into three main categories, the first type is proactive which nodes store route information even before it is needed, by keeping track of routes for all destinations in the network. The other type is reactive protocols; obtain routing information when needed, by calculating route/paths only before the data transmissions takes place. A hybrid of the two can be used to assimilate the advantages of purely proactive and reactive protocols.

Today, MANETs can be widely used in various domains such as military, commercial applications, conferencing, personal networking, emergency services and extending wired networks. But, they have still certain limitations to fully utilize the potential benefit provided by MANETs [4, 5].

The IETF work group currently sets out potential research directions on MANETs so as to deploy massively and use efficiently on the aforementioned domains. Some of these are Quality of Service (QoS), route Optimization, Security, power management which are the primary ones.

1.2.Statement of the Problem

MANETs are increasingly being considered for complex multimedia applications where various QoS parameters must be predefined to satisfy the user requirements. Quality of Service is a set of service requirements that needs to be met by the network while transporting a packet stream from source to destination. i.e. the network is expected guarantee to a set of measurable service attributes to users in terms of end to end performance parameters such as delay, bandwidth, jitter, and error rate.

Real time multimedia communication in Mobile Ad hoc networks is characterized by imposing QoS constraints due to minimum bandwidth, maximum delay and jitter requirements. In addition, 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, routing over head, latency 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.

Even though a number of routing algorithms are developed, delivering quality of service in MANETs fully still persists as a problem due to inherent feature which makes a nonstop area of research.

In this thesis, we will study the approach of most common QoS routing protocols that are more suitable to multimedia communication and also to design a new algorithm that enhances the existing protocols satisfying better for QoS requiring applications.

1.3.Objective

1.3.1. General Objective

The general objective of this thesis is to explore routing protocols that support QoS feature in MANETs and to came up QoS support protocol that can be used for real time multimedia communication such as audio, and video in a better way.

1.3.2. Specific Objective

The specific objectives of this thesis are:

- Review the basic concepts, technologies, status, trends and prospects of MANETs.
- Analyze, and evaluate MANET routing protocols conceptually and experimentally from the perspective of delivering efficient QoS.
- Redesign a MANET QoS aware routing algorithm that satisfies best QoS constraints such as delay, packet loss, routing overhead in time sensitive applications.
- Evaluate and compare the performance of the designed algorithm for suitability in QoS requiring applications such as real time communications.

1.4. Scope and limitation

The scope of this thesis is to design and implement routing protocols that support QoS using simulation tools and proposing a new algorithm that will improve the performance of existing protocols to better support applications that require quality of service.

Due to in availability of physical laboratory system and resources, we are obliged to use simulations to test our algorithm.

1.5.Methodology

1.5.1. Literature Review

Literature review is conducted on previous works in mobile ad hoc networks (MANETs) routing protocols in general and QoS support protocols in particular. This comparison will be made carefully and those protocols that have good performance will be selected for the simulation.

1.5.2. Modeling and Simulation

Comparative analysis of selected QoS support protocols is conducted using the NS-2 simulator [32, 33] by taking QoS metrics pertinent to bandwidth related stuffs. The result obtained from the experiment is analyzed and interpreted to finally obtain the best performing protocols for further improvement. The newly designed algorithm for improving the selected protocol is modeled and evaluated using simulation.

1.6. Significance of the research

The significance of the research is to improve the performance of MANETs routing protocols for delivering QoS services in more demanding applications such as video conferencing, voice over IP, multimedia streaming e.t.c.

1.7.Thesis Organization

Chapter two highlights important points pertinent to MANETs in general and QoS routing in MANETs in particular. Chapter three presents survey and experimental works are conducted on those routing protocols that are supposed to suitable for QoS constrained applications for selection of promising routing algorithms for further study. In Chapter four, detail about the proposed approach is presented. Chapter five, presents the simulation based experiment of the new approach. Chapter six presents Conclusion and recommendations.

CHAPTER TWO

LITERTURE REVIEW

2.1.Overview

Mobile ad hoc networks (MANETs) are collection of mobile devices which form a communication network with no pre-existing wiring or infrastructure. They allow the applications running on these wireless devices to share data of different types and characteristics.

The IETF working group charter defines a mobile ad hoc network (MANET) as"... *an autonomous system of mobile routers (and associated hosts) connected by wireless links — the union of which forms an arbitrary graph [6]. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such networks may operate in a stand-alone fashion, or may be connected to the larger Internet ..."* as shown in Figure 2.1 .These networks form on the fly from the communications devices themselves without needing any infrastructure or centralized control.

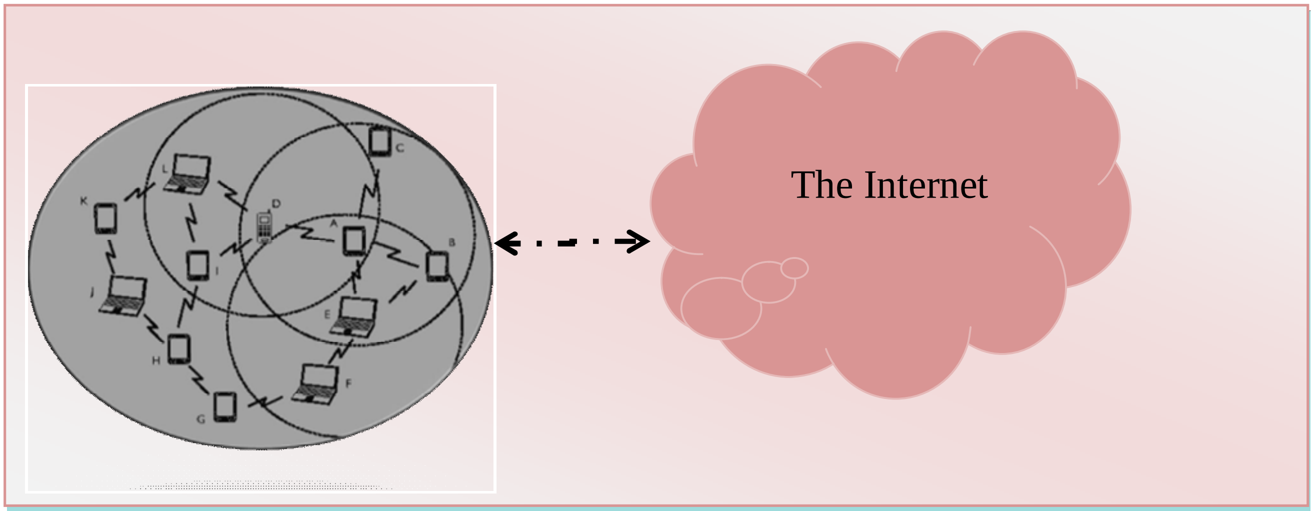


Figure 2.1 MANETs and the Internet

2.2.Protocol Stack and Architecture

The MANET protocol stack, [2, 4] which is similar to the TCP/IP suite - is shown in Figure 2.2.1. The main difference between these two protocols stacks lies in the network layer. Mobile nodes (which are both hosts and routers) use an ad hoc routing protocol to route packets. Ad hoc routing is handled by the network layer which in turn is divided into network and ad hoc routing.

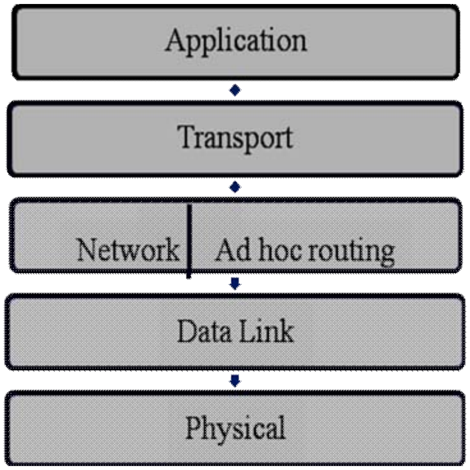


Figure 2.2.1. MANET Protocol Stack

The specific MANET issues and constraints described significant challenges in ad hoc network design. A large body of research has been accumulated to address these specific issues, and constraints. In this thesis, we describe the ongoing research activities and the challenges in some of the main research areas within the mobile ad hoc network domain. To present the huge amount of research activities on ad hoc networks in a systematic/organic way, we will use, as a reference, the simplified architecture presented in Figure 2.2.2

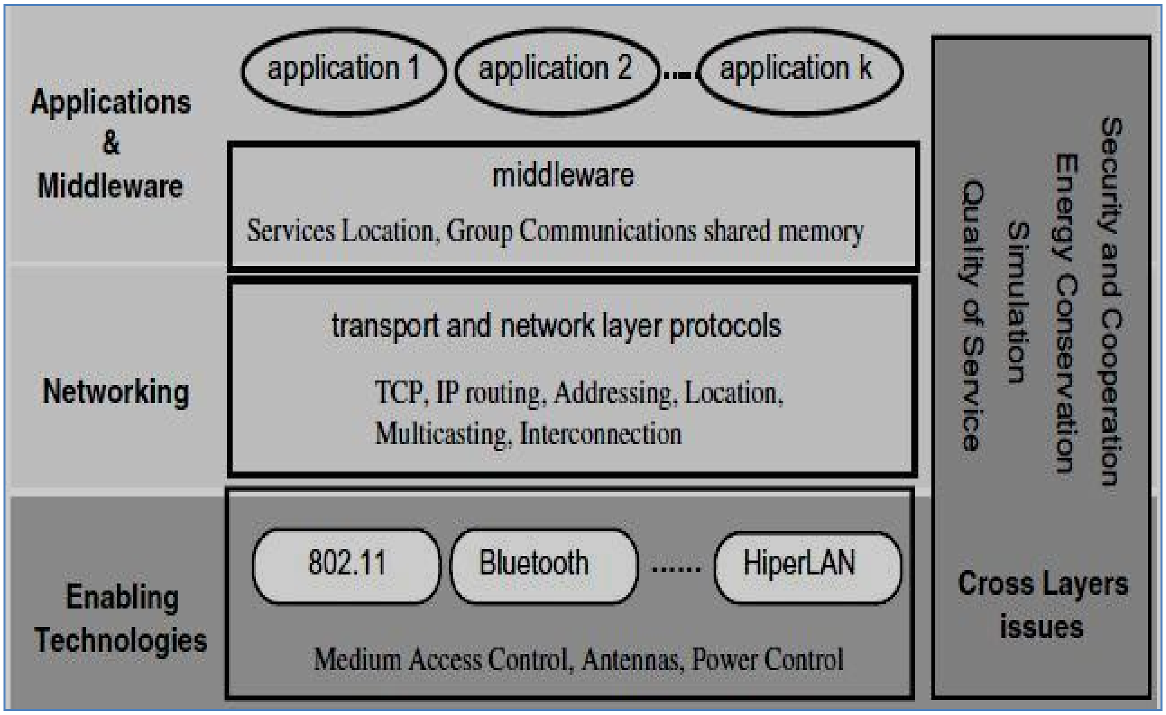


Figure 2.2.2 MANETs Architecture

2.3.Enabling Technologies

Wireless networking hardware requires the use of underlying technology that deals with radio frequencies as well as data transmission as shown in Table 2.1.

802.11 is a standard defining all aspects of Radio Frequency for 802.11 based wireless networking. Especially, the widespread use of IEEE802.11b WLAN technology now offers a low-cost, mass deployment opportunity for ad hoc networks.

Bluetooth is another standard for a short-range wireless technology operates in the 2.4 GHz ISM (industrial, scientific and medical) band, which is license-exempt on a global basis. Bluetooth’s ability to form ad hoc connections to other users means that it can be used for a wide range of ‘Social networking’ applications such as for sharing files (e.g. business cards, photos) and for linking together devices for activities such as multi-player games.

In addition, HIPERLAN/2 is a solution for the 5 GHz band offering a number of air interface data rates up to 54 M bit/s, mobility and QoS for applications such as multimedia, VoIP and real-time video that improved quality of service, increased throughput, and reduce interference.

Table 2.1. MANETs Enabling Technology

Technology	Theoretical bit rate	Frequency	Range	Remark
IEEE 802.11b	1,2,55 Mbits/s	2.4 GHz	25-100m(indoor) 100-500(outdoor)	
IEEE 802.11g	Up to 54Mbit/s	2.4 GHz	25-50m(indoor)	
IEEE802.11a	6,9,12,24,36, 49 , 54Mb/s	5 GHz		
IEEE802.11n	600Mb/s	2.4GHZ		
IEEE802.11e	------	------	------	Addresses QoS
IEEE802.11i	------	------	------	Addresses security
IEEE802.11p	------	------	------	Provides wireless access to vehicular environment(WAVE)
IEEE802.11k	------	------	------	Specifies network Performance.
Bluetooth (IEEE 802.15.1)	1 Mbit/s	2.4 GHz	10m(up to 100m)	
HiperLAN2	Up to 54Mbit/s	5 GHz	30-150m	

2.4. Potential Application Areas

With the increase of portable devices as well as progress in wireless communication, ad hoc networking is gaining importance with the increasing number of wide spread applications. Ad hoc networking can be applied anywhere where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use [5, 6]. Ad hoc networking allows the devices to maintain connections to the network as well as easily adding and removing devices to and from the network. The set of applications for MANETs is diverse, ranging from large-scale, mobile, highly dynamic networks, to small, static networks that are constrained by power sources.

2.4.1. Military battlefield

The modern digital battlefield demands robust and reliable communication in many forms [2]. Most communication devices are installed in mobile vehicles, tanks, trucks etc. like in Figure 2.3. Also soldiers could carry telecom devices that could talk to a wireless base station or directly to other telecom devices if they are within the radio range. However, these forms of communication are considered to be primitive.

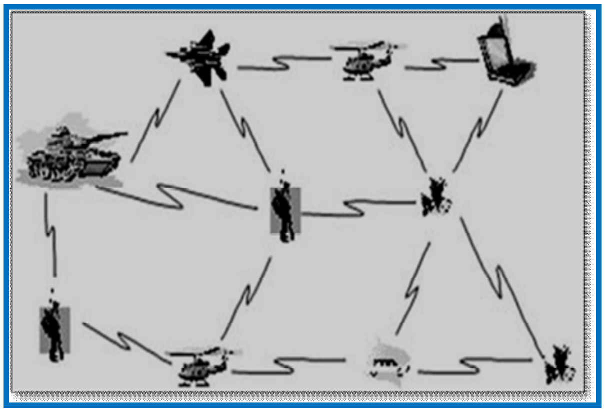


Figure 2.3. Mobile battle field

2.4.2. Sensor Networks

A Sensor network is composed of a very large number of small sensors. These can be used to detect any number of properties of an area such as temperature, pressure, toxins, pollutions, etc. Applications are the measurement of ground humidity for agriculture, forecast of earthquakes.

2.4.3. Automotive Applications

Cars should be enabled to talk to the road, to traffic lights, and to each other, forming ad-hoc networks of various sizes. The network will provide the drivers with information about road conditions, congestions, and accident-ahead warnings, helping to optimize traffic flow. For example, Vehicular Ad Hoc Networks (VANETs) [3,5] are used for communication among vehicles and between vehicles and roadside equipment so as to provide vehicular traffic management as shown in Figure 2.4.

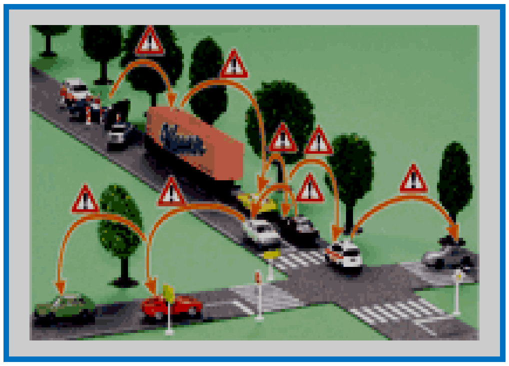


Figure 2.4. VANETs

2.4.4. Personal Area Network (PAN)

Personal Area Networks [2, 3, 5] are formed between various mobile (and immobile) devices mainly in an ad-hoc manner, e.g. for creating a home network. These networks involve communications between PCs, laptops, PDAs, cordless phones, smart appliances, and entertainment systems in and around the home. Peer-to-peer communication among these devices will reduce the overhead of going through a centralized node and thus makes ad hoc networks a natural choice for implementing home networking applications. It enables computers to talk to, and share, peripherals such as printers and scanners for providing users convenience of not having to wire up their house.

2.4.5. Emergency Service

In emergency situation such as earthquakes, ambulance and police, the wired networks could not work well. There will be a need of wireless network which could be deployed quickly for coordination of rescue. MANET technology can provide an extremely flexible method for establishing communications for fire/safety/rescue operations or other scenarios requiring rapidly-deployable communications with survivable, efficient dynamic networking.

2.4.6. Conferencing

Ad-hoc networks can be useful in conferences as in Figure 2.5 where people participating in the conference can form a temporary network without engaging the services of any pre-existing network.

Figure 2.5. A person attending a webinars at Cafe

2.5. Characteristics of MANETs

The MANET working group has defined some unique properties of ad hoc networks. The properties do not directly relate to performance. However, they describe the very nature of ad hoc networks and in that sense they formulate the boundary conditions to ad hoc networking [6, 9]. The following are some of bright features of MANETs.

Ad hoc

Devices form a network as needed on an ad hoc basis. The wireless mobile nodes may dynamically enter the network as well as leave the network. The network is not engineered in advance.

Zero Administration/P2P/

Unlike other types of networks, in MANETs there is no central component that controls and administers others. Each node has equal status on the network which serves as both a host and router.

Multi hop Routing

This is a network where information is relayed from one device to another. Each packet may undergo many hops before reaching its destination. This has many benefits. It supports communications beyond the line of sight (LOS) at high frequencies. In addition, because of short communications (multi hop node to node communication instead of long distance node to central base station communication), radio emission level can be kept low. This reduces interference levels, increases spectrum reuse efficiency. In addition, multiple paths can provide load balancing, fault-tolerance, and higher aggregate bandwidth.

Self Created, Administered, Configured

Nodes in MANETs are mobile and band width change always, configuration is done automatically and no central entity that manages/ controls.

Economical

It is less expensive, as they eliminate the use of infrastructure costs and reduce power consumption at mobile nodes. In addition, it makes it possible to use unlicensed frequency spectrum.

Integration

A MANET can be a standalone network or it can be connected to external networks.

2.6. Open issues and Challenges in MANETs

Routing Overhead

In ad hoc networks, nodes often change their location within the network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead.

Physical layer Limitation

Communication through the wireless medium is unreliable and subject to errors. Also, due to varying environmental conditions such as high levels of electro-magnetic interference (EMI) or inclement weather, the quality of the wireless link may be unpredictable.

Asymmetric links

Most of the wired networks rely on the symmetric links which are always fixed. But this is not a case with ad-hoc networks as the nodes are mobile and constantly changing their position within the network. For example, consider a MANET (Mobile Ad-hoc Network) where node B sends a signal to node A but this does not tell anything about the quality of the connection in the reverse direction.

Dynamic changing Topology

Nodes are free to move arbitrary; thus the network topology which is typically multi hop may change randomly and rapidly at unpredictable times.

Quality of Service

Delivering quality of service in MANETs is difficult. Because, it needs to fulfill QoS requirements in advance, this is impossible usually due to its inherent nature.

Network Scalability

Currently, popular network management algorithms are mostly designed to work on fixed or relatively small wireless networks. Many mobile ad hoc network applications involve large networks with tens of thousands of nodes, as found for example, in sensor networks and tactical networks. Scalability is critical to the successful deployment of these networks. The steps toward a large network consisting of nodes with limited resources are not straightforward, and present many challenges that are still to be solved in areas such as: addressing, routing, location management, configuration management, interoperability, security, high capacity wireless technologies.

Bandwidth-constrained, variable 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.

Energy-Constrained Operation

MANETs are typically battery powered or use other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.

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 DoS attacks should be carefully considered. These characteristics create a set of underlying assumptions and performance concerns for protocol design in MANETs.

2.7.Routing

2.7.1. Routing in MANETs

Routing [5, 6, 7] is the process that a node uses to forward packets toward the destination network and routing protocol allows one node to share information with other nodes regarding the networks it knows about as well as its proximity to other routers. The information a node gets from another node, using a routing protocol, is used to build and maintain a routing table so that the node can make decisions on forwarding a packet to its destination.

Conventional wired routing algorithms are clearly not efficient for the type of dynamic changes which may occur in an ad-hoc network. In conventional networks, routers do not generally move around and only rarely leave or join the network. In an environment with mobile nodes, the changing topology will not only trigger frequent re-computation of routes but the overall convergence to stable routes may be infeasible due to the high-level of mobility.

There are different criteria for designing and classifying routing protocols for wired and wireless ad hoc networks. For example, what routing information is exchanged; when and how the routing information is exchanged, when and how routes are computed and so on.

Depending on when the route is computed, routing protocols can be divided into two categories: proactive or pre-computed routing and reactive on-demand routing. MANETs use different routing algorithms to move data from one node to the other optimally. Over the past few years, a variety of new routing protocols targeted specifically at the ad hoc networking environment has been proposed. Generally the available proposed routing algorithms fall into three main categories as shown in Figure 2.6 [6, 9].

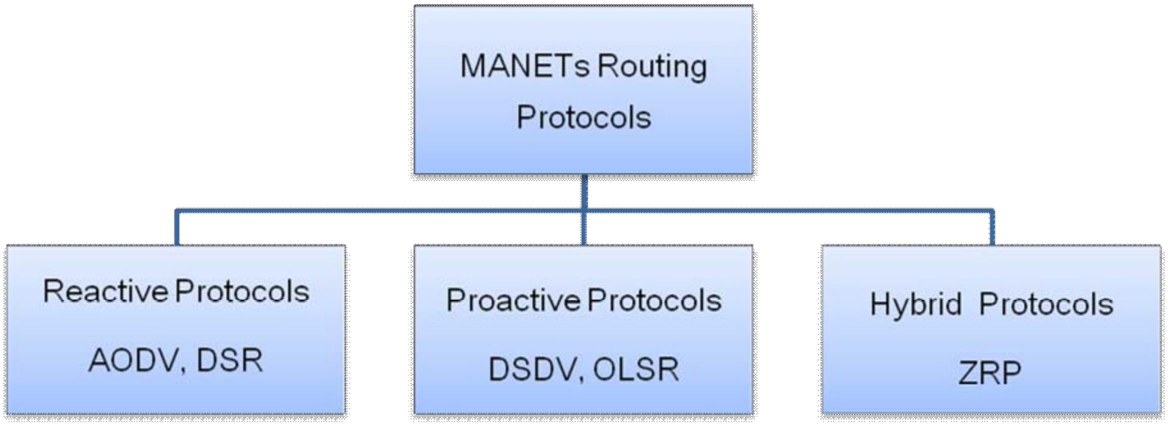


Figure 2.6. Types of MANETs routing Protocols

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.

The first type is proactive, in which nodes store route information even before it is needed, by keeping track of routes for all destinations in the network. The other type is reactive protocols which obtain routing information when needed, by calculating route/paths only before the data transmissions takes place. A hybrid of the two can be used to assimilate the advantages of purely proactive and reactive protocols. Currently, the development efforts in the IETF focused on following routing protocol drafts which will be submitted as experimental RFCs or Internet standards. These are AODV, DSR from proactive and OLSR, DSDV and TBRPF from reactive routing protocols.

Apart from these, advanced form of routing known as location aware routing protocols such as GRID, DREAM are coming in to being that incorporate location information for facilitating route discovery process and hence improve its performance.

2.7.2. QoS Routing in MANETs

As MANETs gain popularity, their need to support real time and multimedia applications is growing as well [10, 11, 12]. Such applications have stringent quality of service requirements such as bandwidth, delay, and delay variance (jitter). Design and development of routing algorithms with QoS support is experiencing increased research interest. Several approaches which propose various routing algorithms with QoS support for MANETs have been presented in the research. Due to the dynamic nature of MANETs, designing communications and networking protocols for these networks is a challenging process. While this might be sufficient for a certain class of MANET applications, it is not adequate for the support of more demanding applications such as multimedia audio and video. Such applications require the network to provide guarantees on the Quality of Service.

Figure 2.7 shows clearly the effects of routing on QoS support routing protocols with that of non QoS supports. That is, the first which does not show clear video as it uses non QoS support routing protocols while the later uses QoS satisfying protocols.

a) Video data with QoS support routing b) Video data without QoS support routing

Figure 2.7. Video data with and without QoS support routing

According to [12, 13, 14], Quality of Service is defined as a set of service requirements that needs to met by the network while transporting a packet stream from source to destination. In other words, it is the qualitatively or quantitatively defined performance agreement between the service provider and user applications based on the connection requirements. That is, the network is expected guarantee to a set of measurable service attributes to users in terms of end to end performance parameters such as delay, bandwidth, jitter, error rate. Intrinsic to the notion of QoS is an agreement or a guarantee by the network to provide a set of measurable pre-specified service attributes to the user. The agreement can be described using quantitive and qualitative metrics presented in Table 2.2. which shows a given network satisfies QoS requirements or not.

Table 2.2. Different Metrics of QoS

Quantative Metrics	Qualitative Metrics
End to end delay	Loop freedom
Throughput	Route stability
Overhead	reactive /proactive
Packet Delivery Ratio	Scalability
Mobility	Reliability

2.7.3. QoS Support for Mobile Ad hoc Networks

The Internet has only supported “best effort” service — best effort in the sense that it will do its best to transport the user packets to their intended destination, although without any guarantee. Although substantial work has been done for quality of service in the Internet, none of the existing proposals can be readily applied to mobile ad hoc networks due to limitations and constraints intrinsic to MANETs. The QoS requirements in MANET are quite different from that of the classical approach and existing QoS works predominantly designed for the traditional networks are unfit for MANETs. These QoS provisions are derived from wireline networks where the control and signaling rely on a circuit model that requires explicit connection management and the establishment of hard-state in the network prior to communication.

Supporting QoS requires the link state information such as delay, bandwidth, cost, loss rate, and error rate have to be available and manageable. However, satisfying these requirements is very challenging in MANET because the quality of a wireless link can abruptly change with the dynamic of surrounding circumstances.

The traditional QoS approaches are loosely based on the virtual circuit model that requires explicit connection management and the establishment of hard-state in the network prior to communication. The virtual circuit model also assumes the route and the reservation between source-destination pairs remain fixed for the duration of a session. However, the virtual circuit lacks the intrinsic flexibility needed to adapt to the dynamics found in mobile ad hoc networks where the path and reservation need to dynamically respond to topology and resource changes in a timely manner.

Consider Figure 2.8, where the numbers next to the links represent their respective bandwidths, say in Mb/sec. To minimize delay and for better use of network resources, minimizing the number of intermediate hops is one of the principal objectives in determining suitable routes. However, suppose that the packet flow from A to E requires a bandwidth guarantee of 3 Mb/sec. The most important element among them is QoS routing, i.e., the process of choosing the routes to be used by the flow of packets of a logical connection in attaining the pre established QoS guarantee. QoS routing will then select the route [A→B→C→E] over the route [A→D→E] because the latter is unable to meet the bandwidth need although it has fewer hops. The only other alternative, [A→B→D→E], will also be rejected for failing to meet the bandwidth need.

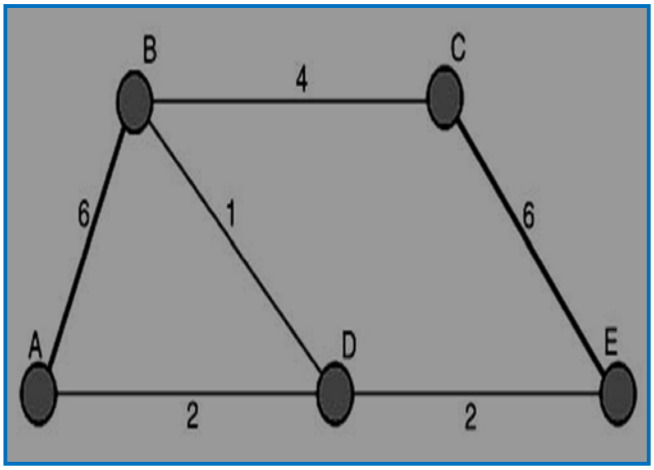


Figure 2.8. QoS Route

2.7.4. QoS Service Models

Best-effort service model do not provide any guarantees regarding packet loss or delay, available bandwidth, jitter etc. This method is efficient for applications that do not require bounds on packet delay or other QoS metrics. However, real-time applications, such as video-on-demand (VoD), videoconferencing and Internet telephony, are sensitive to packet loss and delay and may have minimum bandwidth requirements. Consequently, the best-effort service may not be suitable for these applications.

Technically, there are three ways in which QoS can be achieved [11, 12, 16]:

1. The virtual circuit model: It assumes the route and the reservation between source-destination pairs remain fixed for the duration of a session.
2. Over-provisioning: It utilizes the best-effort approach and simply increases the available resources (e.g. bandwidth, buffers etc.) as Figure 2.9.

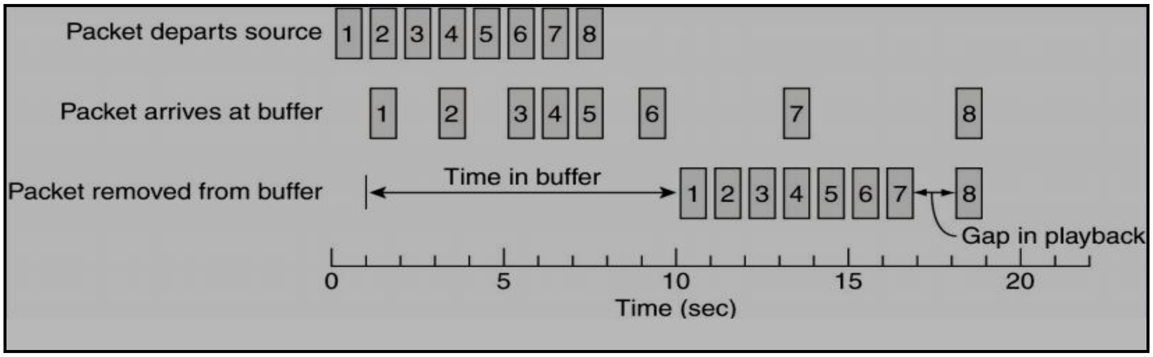


Figure 2.9. Best effort QoS model operation

3. Traffic engineering: It utilizes resources efficiently to make the network QoS aware.

A more realistic direction for QoS provisioning in ad hoc network is based on an adaptive QoS model: applications must adapt to the time varying resources offered by the network. The QoS model for a MANET is defined as providing a set of parameters in order to adapt the application to the ‘‘quality’’ of the network.

Providing a complete QoS solution for the ad hoc networking environment requires the interaction and cooperation of several components. These components include a QoS routing protocol, a resource reservation scheme and a QoS capable medium access control. QoS routing refers to the discovery and maintenance of routes that can satisfy QoS objectives under given resource constraints, while QoS signaling is responsible for actual admission control, scheduling, and resource reservation along the route determined by QoS routing, or other routing protocols. Both QoS routing and QoS signaling coordinate with the QoS MAC protocol to deliver the required QoS. However, the paper focuses on QoS routing to network layer.

2.7.5. QoS guarantying Methods

Different Quality-of-Service (QoS — in the sense, multimedia) applications require different QoS guarantees: some require stringent end-to-end delay, some require a minimal transmission rate, while others with no strict delay and/or bandwidth requirements may simply require high throughput. In the following, some of these QoS requirements are described in detail.

Delay Guarantees

A broad class of applications, e.g., interactive multimedia, Internet telephony, and video conferencing, may require stringent delay, delay jitter (or delay variation), and loss guarantees. For example, in real time playback applications, packets arriving after the playback point will be useless, and the loss of a certain number of packets will seriously degrade the quality of voice and pictures. The end-to-end delay includes the propagation delay, which is determined by the physical distance between the source and the destination; the transmission delay, which is determined by the capacity of the bottleneck link on the path; and queuing delay, which is determined by the network load, the busyness of the traffic source, and the service disciplines employed in the network.

Bandwidth Guarantees

Transmissions of multimedia streams require a minimum bandwidth to ensure end-to-end QoS guarantees. Bandwidth guarantees can be requested for different time intervals depending on applications. For example, if an application is adaptive and has sufficiently large buffer space at its source and destination, the bandwidth provided by the network can vary over time, as long as the average bandwidth provided is higher than the minimum bandwidth required by the application.

High Throughput

Traditional best-effort applications, e.g., RPC, electronic mail, ftp, and telnet, usually send messages as small as a few kilo bytes. The main performance index for these applications is the end-to-end per packet delay. As the sophistication of networked applications has grown, so too has the amount of data transmitted.

It is now not uncommon to observe applications in which the data payload reaches from several hundred megabytes to several terabytes. In contrast to the transmission of small messages, these new applications can consume as much network bandwidth as is available. It is the end-to-end throughput rather than the per packet end-to-end delay that is the main performance concern. The throughput is determined by the total number of bytes transmitted over the elapsed time, where the elapsed time includes the end- to-end delay experienced by the first packet and the time interval from the arrival of the first packet to the arrival of the last packet.

2.7.6. QoS Metrics

QoS parameters differ from application to application. For example, for multimedia applications (real time data traffic), the data rate and delay are the key factors where timing is a critical issue. And some of parameters are additive (sum of the value of the metric on all links along the path like delay and jitter), others are concave (the minimum metric value over a path like data rate). There are others named multiplicative which represent the product of the metric values on all links over a path[15,16,17].

Packet Delivery Fraction (PDF)

The packet delivery ratio is defined as the ratio between the number of (packets sent by constant bit rate (CBR) sources and received by the CBR sink at destination. A high value of PDF indicates a positive sign of the protocol performance.

Normalized Routing Load (NRL)

Routing overhead is the number of routing packets transmitted per data packet delivered at the destination. The bandwidth consumed by all the control packets of the routing protocol is measured as control packet overhead. This quantity helps to determine the scalability of a given routing protocol. A lower control packet overhead with a higher throughput is a much desired optimization in MANETs. Each hop-wise transmission of a routing packet is counted as one transmission.

Average End-to-End Delay (AEED)

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 its 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. This metric describes the packet delivery time: the lower the end-to-end delay the better the application performance.

Hop Count

The number of hops a packet takes to reach from its source to a destination node is the hop count. This quantity helps to determine the path optimality of a given routing protocol over another.

Jitter/delay variance

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.

CHAPTER THREE

RELATED WORK

3.1.Overview

In this chapter, we describe the importance and objective of QoS routing in ad-hoc networks, behavior of well known MANETs QoS routing algorithms, conceptual and experimental comparison and then, selection of promising algorithm for redesigning of QoS protocols.

3.2.Related work

QoS routing is a routing under which paths for flows are determined on the basis of some knowledge of resource availability in the network as well as the QoS requirements of the flows or connections [11, 12, 13]. For example how do we choose a route when we drive? may be the condition of your car and the road, the shortest one, the one that is not congested, the one with less traffic lights, avoid forbidden paths.

Multimedia services (voice, video, and text) support over wireless/mobile networks is the hottest telecommunications buzz word today. The current trend of connectivity anywhere, anytime, anyhow brings a new paradigm of accessing these services via wireless connectivity. However, the available bandwidth for supporting these applications is rather limited, and proper management of the bandwidth is necessary to accommodate the envisaged high-bandwidth applications and, thus, provide QoS.

The objectives of QoS routing are three fold: [12, 13, 14]

- If one exists, find a feasible path between a source destination pair (i.e. a path that has sufficient available resources capable of satisfying the QoS requirements),
- Optimize the use of network throughput and network resources and

- Adapt to network congestion, providing smooth performance degradation to lower-priority traffic.

The native routing protocols of MANETs can be redesigned for QoS requiring domains with some modification suitable for real time communication which satisfies the QOS requirements for each admitted connection and optimizes the use of network resources [13, 14].

Figure 3.1 shows the possible route between the source (A) and the destination (G). Even though the first route (A, D, G) is very short, it does not satisfy the QoS requirement which require a bandwidth of greater than or equal to 4. But the second route (A, B, C, F, and G) is the feasible path that satisfies QoS requirement. This is to avoid the problems of latency, jitter, packet loss, etc.

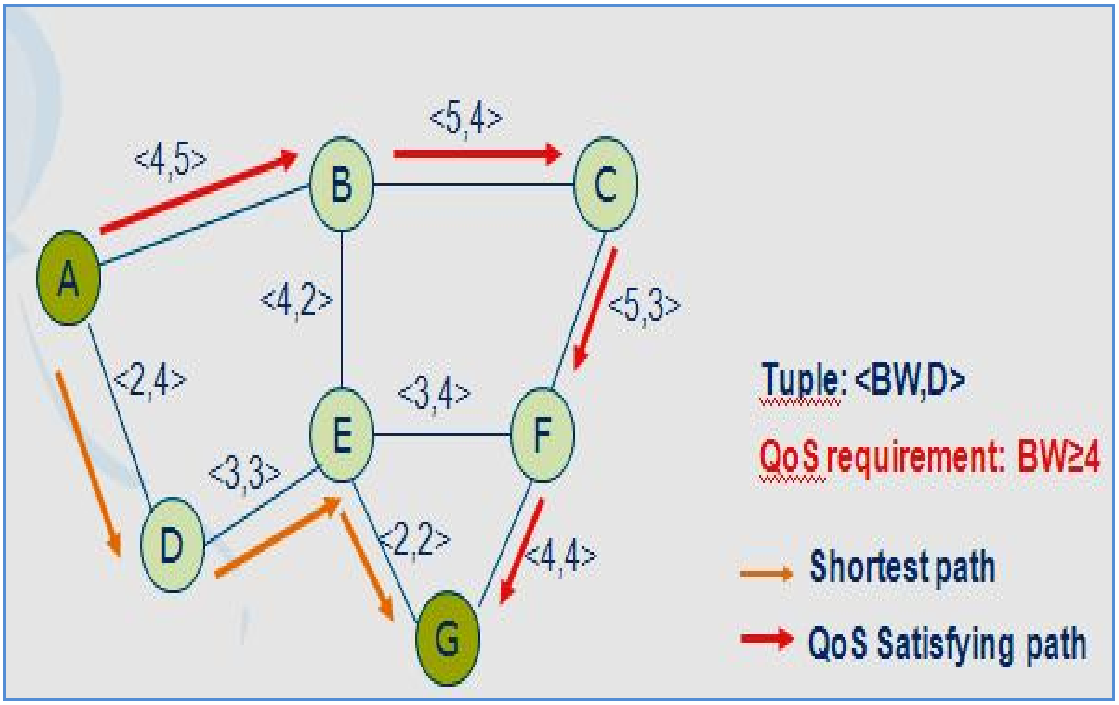


Figure 3.1 Comparison of QoS route and non QoS route.

3.2.1. QoS in Proactive Vs Reactive Routing Protocols

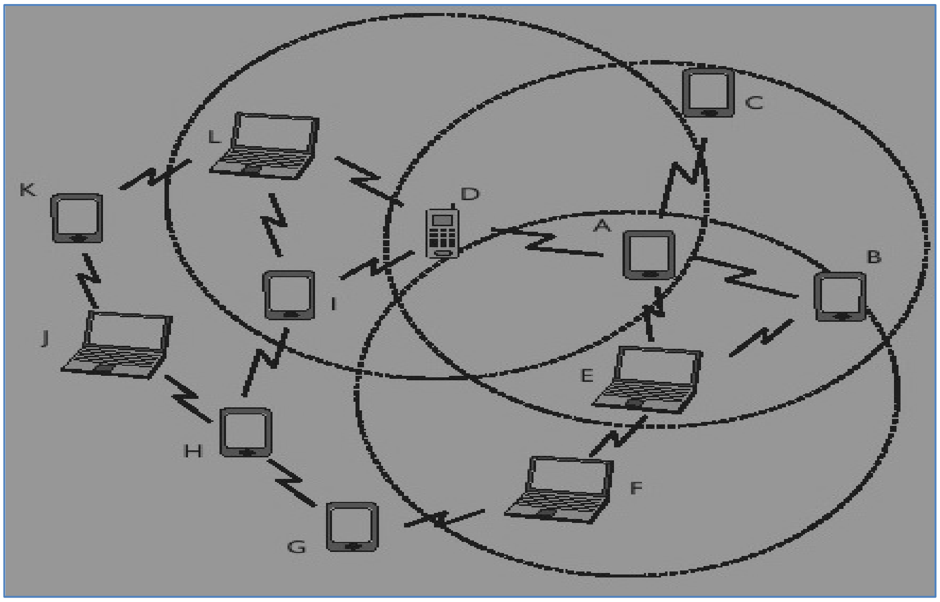
Basically, in proactive protocols, nodes store route information even before it is needed by keeping track of routes for all destinations in the network. But reactive protocols; obtain routing information when needed, by calculating route/paths only before data transmissions takes place as shown in Figure 3.2. [11, 12].

Most of the works on routing protocols is being performed in the framework of IETF MANETs Work Group where the following routing protocols are under active development. These are AODV, DSR, OLSR, TBRPW, DSDV e.t.c.

The unpredictable nature of ad-hoc networks coupled with the requirement of quick reaction to QoS routing demands make the idea of a proactive protocol more suitable. That is proactive routing protocols provide better quality of service than on demand protocols. Because routing information is constantly updated in the protocols, routes to every destination are always available and up-to-date and hence end to end delay can be minimized. For on demand protocols, the source node has to wait for the routes to be discovered before communication can happen. This latency in route discovery might be intolerable for real time communication [13, 14].

Proactive protocols may have lower latency since routes are maintained at all times where as reactive protocols may have higher latency because a route from source to destination will be found only when a sender attempts to send to a receiver. In addition, reactive protocols may have lower overhead since routes are determined only if needed. But, proactive protocols can (but not necessarily) result in higher overhead due to continuous route updating. Proactive routing protocols use different techniques to minimize their control overhead and achieve higher throughput.

Figure 3.2 shows how node A communicates with node B, F and J in proactive, reactive and hybrid mode. In proactive mode, node A has routing knowledge of all node in the network whereas, A has only route to B,F and J in reactive case. And in Hybrid case, A has route to B,C, D, E, F, I, and L proactively and route to J reactively.



Routing Type	Routing knowledge of node A when it communicates with nodes B,F and J	Protocols
Proactive	A has source to B, C, D, E, F, G, H, I, J, K and L (all nodes)	OLSR,DSDV, TBRFB
Reactive	A has only route to B,F and J	AODV,DSR, TORA
Hybrid	A has route to B,C, D, E, F, I, and L proactively and route to J reactively	ZRP

Figure 3.2 Types of Routing Protocols

3.2.2. QoS Routing on well known Routing Protocols

In the following section, we present highlights on three standardized best effort routing protocols DSDV & OLSR from proactive and AODV from the reactive routing protocols for selection of candidate protocols for extension of QoS. The MANET working group and other researchers define some desirable qualitative properties of ad hoc routing protocols. They are useful when assessing performance or suitability of an ad hoc routing protocol. Some of these are data forwarding type, loop freedom, scalability, and security [14].

According to Table 3.1. comparison of the proactive protocols reveals that OLSR better fulfills the desirable characteristic. OLSR protocol [24, 25, 26] is well suited for applications that do not require long delays in the transmission of the data packets. The best working environment for the OLSR protocol is a dense network, where the most communication is concentrated between a large number of nodes. It is also suitable for ad hoc network with the rapid changes of the source and destinations pairs.

Table 3.1. Comparison of routing protocols based on suitability for QoS

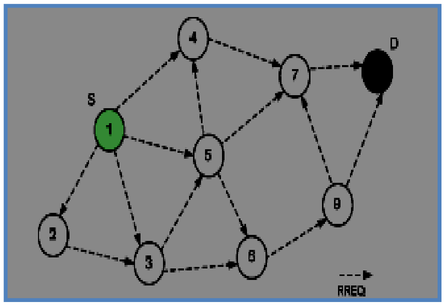
Metrics	DSDV	OLSR	AODV
Data forwarding type	Hop to hop	Hop to hop	Hop to hop
Loop Free	Yes	Yes	Yes
Update transmitted to	Neighbors	To nodes selected as MPR node	Neighbors
Frequency of updates	Periodical as needed	Periodical as Needed	Periodical
Supports asymmetric	No	Yes	Yes
Support security	No	No	No
Use of sequence No.	Yes	Yes	Yes
Scalability	No	Partial	No

3.2.2.1. QoS Routing in MANETs Using Ad'hoc on Demand Distance Vector.

Ad'hoc on demand distance vector (AODV)[21, 22, 29] is reactive distance vector protocol that uses a route discovery process to dynamically build new routes on need basis. When a route to a destination is unknown, AODV creates a route request packet and broadcasts it to its neighbors. Route request messages contain the source ID, destination ID, source sequence numbers, destination sequence numbers, hop count and broadcast ID. The source sequence number and broadcast ID increment each time a new route request is generated. The destination sequence number is the source sequence number of the destination node as last recorded by the source node.

Each intermediate node receiving a route request caches the previous hop for the particular node originating the request; this helps to create a return path for the reply packets. AODV uses the destination sequence number to maintain freshness of routes. The destination node or any intermediate node can reply to a route request. Once a route is formed, AODV uses the current route until the route expires or any topology changes occur.

Figure 3.3 depicts a network where node 1 desires to communicate to node 8. The AODV modules running on node 1 flood the network with route request (RREQ) messages. Each node receiving a RREQ message stores the previous hop and distance to source for the originating RREQ and forwards the RREQ to its neighbors.



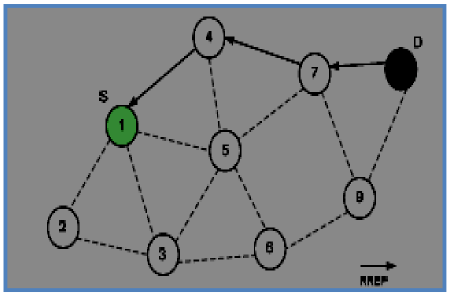


Figure 3.3a: Route request flooding Figure 3.3b: Route replay propagation

Advantages of AODV:

- Minimal space complexity: The algorithm makes sure that the nodes that are not in the active path do not maintain information about this route.
- Maximum utilization of the bandwidth: As the protocol does not require periodic global advertisements, the demand on the available bandwidth is less.
- Most effective routing info: After propagating an RREP, if a node finds receives an RREP with smaller hop-count, it updates its routing info with this better path and propagates it.
- Most current routing info: The route info is obtained on demand.
- Loop-free routes
- Highly Scalable: The algorithm is highly scalable because of the minimum space complexity and broadcasts avoided when it is compared with DSDV.

Disadvantages of AODV:

- Requirement on broadcast medium: The algorithm expects/requires that the nodes in the broadcast medium can detect each others' broadcasts.
- Overhead on the bandwidth.
- No reuse of routing info: AODV lacks an efficient route maintenance technique. The routing info is always obtained on demand, including for common traffic.
- It is vulnerable to misuse: The messages can be misused for insider attacks including route disruption, route invasion, node isolation, and resource consumption.
- AODV lacks support for high throughput routing metrics: AODV is designed to support the shortest hop count metric. This metric favors long, low-bandwidth links over short, high-bandwidth links.
- High route discovery latency: This route discovery latency result can be high in large-scale mesh networks.

When QoS extensions are added to the AODV routing protocol, different items are added to each routing table [21, 22, 25]. These are session ID, maximum delay and minimum available data rate. Comparing with AODV, in QoS based ADOV, we have RREQ, including the QoS requirement, and only the node satisfying this request could broadcast the RREQ further. In addition, the intermediate node cannot give the RREP even if it knows how to get to the destination, since data rate should be tested at each hop until to the destination. Moreover, the network should have periodic mechanisms for checking the available data rate at each node as a result of the mobility of the node. If the available data rate of a node becomes smaller than zero, it means that the node cannot afford the current traffic any more. Source of the traffic going through this node should be noticed.

In [20], the author presents an AODV-based QoS routing protocol. It is designed to function in the network layer. The protocol establishes QoS routes with reserved bandwidth on a per flow basis in a TDMA network. It incorporates an algorithm for calculating end-to-end bandwidth on a path. This algorithm is included in the path discovery mechanism of AODV to establish QoS routes. The protocol in protects active routes with soft-state, i.e., a timer is associated with an active route at a node and is refreshed every time the route is used. If the route is not used within a certain amount of time and the timer expires, the corresponding entry in the routing table is deleted. The protocol defines the five possible states of a QoS route, which indicate whether the route exists, and if so, if it is processed but not established, set up and used to forward packets, broken at upstream of the node and is being repaired, or broken at downstream of the node and is being repaired. Transitions among these states are done by either receiving or transmitting a packet, or expiration of the timer associated with the state. The paper defines eleven conditions and operations associated with transitions among these states. The QoS routing protocol builds different QoS routes for individual flows even between the same source and destination. The protocol is also capable of restoring a route when it breaks due to some topological change, which allows it to cope more robustly with some degree of node mobility. The simulation in the paper shows that the protocol produces higher throughput and lower delay than the best-effort AODV protocol.

It performs best in smaller networks with low node mobility. QoS-AODV protocol with delay constraints has low performance at this point by having a low packet delivery fraction (50-70% for 0.1 seconds delay bound). This is due to the lack of routing paths satisfying the required delay bound especially at high mobility rate and low delay bound, so in this way more packets are being dropped because the routes available for them do not satisfy the QoS requirements.

It is found that, the QoS aware reactive routing protocol named the QAODV routing protocol could improve the QoS of transmissions in terms of end to end delay at the expense of sending more routing packets in the network. This QAODV routing protocol is more significant to be sent especially when the traffic on the network is high (corresponding to a situation where the data rate of the traffic flow is high in the simulations), since that improves the performance of the network remarkably.

QoS-AODV aware routing protocols, only data rate metric is considered in the simulations. End to end delay metric could be an additional metric during the route discovery and maintenance in the routing protocol. Thus, end to end delay can be added to the AODV routing protocol.

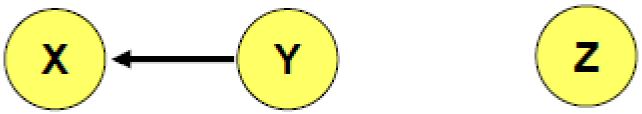
3.2.2.2. QoS Routing in MANETs Using Destination Sequenced Distance Vector

The destination sequenced distance vector routing (DSDV) protocol [18, 19 and 20] is a proactive routing protocol which is a modification of conventional Bellman-Ford routing algorithm. This protocol adds a new attribute, sequence number, to each route table entry at each node. Routing table is maintained at each node and with this table; node transmits the packets to other nodes in the network and also for the connectivity to different stations in the network. These stations list for all the available destinations, and the number of hops required to reach each destination in the routing table. It is designed 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. [16, 17]
The DSDV protocol requires that each mobile station in the network must constantly; advertise to each of its neighbors, its own routing table. Since, the entries in the table may change very quickly, the advertisement should be made frequently to ensure that every node can locate its neighbors in the network. This agreement is placed, to ensure the shortest number of hops for a route to a destination; in this way the node can exchange its data even if there is no direct communication link.

The data broadcast by each node will contain its new sequence number destination address, the number of hops required to reach the destination and the new sequence number, originally stamped by the destination.

The working principle of this protocol is stated as follow:

Assume that node X receives routing information from Y about a route to node Z



Let S(X) and S(Y) denote the destination sequence number for node Z as stored at node X, and as sent by node Y with its routing table to node X, respectively.

Node X takes the following steps:

1. If S(X) > S(Y), then X ignores the routing information received from Y
2. If S(X) = S(Y), and cost of going through Y is smaller than the route known to X, then X sets Y as the next hop to Z
3. If S(X) < S(Y), then X sets Y as the next hop to Z, and S(X) is updated to e S(Y).

The Advantage of DSDV:

- DSDV protocol guarantees loop free paths.
- Count to infinity problem is reduced in DSDV.
- We can avoid extra traffic with incremental updates instead of full dump updates.
- Path Selection: DSDV maintains only the best path instead of maintaining multiple paths to every destination. With this, the amount of space in routing table is reduced.

The limitation of DSDV:

- Route fluctuation due to sequence number is always required to be updated,
- It assumes all wireless networks are bidirectional. But unidirectional can present in ad hoc network. This result in, sink node knows the existence of the source. But not reverse case. In addition in unidirectional case, the sink node is unable to update its existence which lead s to sink unreachably
- The performance of DSDV highly degraded as the number of nodes and increase in mobility as it requires to maintain two tables for each node
- It is not stable and scalable.

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 [17]. There are QoS routing algorithms, which are the QoS extensions of existing best -efforts routing algorithms. Work in [18] proposes an algorithm that uses local bandwidth information to construct a path that satisfies the session bandwidth request.

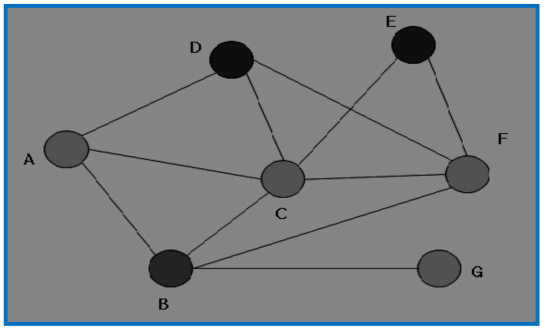
A MAC layer protocol named Real-time MAC (RT-MAC) for MANETs is proposed, which provides a bandwidth reservation mechanism. The protocol is designed to work in an asynchronous environment. The protocol relies on the flexibility of placement of reservation slots (of variable start and finish times) in the super-frame. The protocol makes use of holes (short free slots in the super-frame which otherwise cannot be utilized). The simulation which compares the protocol performance with the MACA/PR protocol, show that RTMAC outperforms MACA/PR in call blocking ratio, average end-to-end delay, packet delivery ratio, and provides less effect of the presence of best-effort traffic on real time traffic. RTMAC is an extension of DSDV [30]. It is responsible for finding an end-to-end path that satisfies the QoS bandwidth requirements. Bandwidth reservation for Constant Bit Rate (CBR) traffic is provided by dividing the transmission time into successive super-frames. This scheme can also be extended to support Variable Bit Rate (VBR) traffic as well.

Simulation results in [17, 18, 19] 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. In addition, 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.

The main limitation of DSDV in QoS routing 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, scalability.

3.2.2.3. QoS Routing MANETs in Optimized Link State Routing

Optimized Link State Routing (OLSR) is an optimization of pure link state algorithm in ad hoc network [22-26]. The routes are always immediately available when needed due to its proactive nature. Hop by hop routing is used in forwarding packets. The use of Multipoint Relay selectors (MPR) in OLSR is the distinctive feature over other classical link state protocols. In OLSR, only nodes selected as MPRs forward control traffic, reducing the size of control message. MPRs advertise link state information for their MPR selectors periodically in their control messages. MPRs are also used to form a route from a given node to any destination in route calculation. Every node periodically broadcasts a list of its MPR selectors instead of the whole list of neighbors. In order to exchange the topological information, the Topology Control (TC) message is broadcasted throughout the network. Each node maintains the routing table in which routes for all available destination nodes are kept.Let's see how MPR selection works on OLSR protocol in Figure 3.4:



Source	1 hop neighbor(B)	2 hop neighbor(B)	MPR(B)
B	A,C, F, G	D, E	C

Figure 3.4.Original OLSR MPR selection

The Advantage of DSDV:

- More efficient in networks with high density and highly sporadic traffic.
- Flat proactive protocol that does not need central administrative system
- It guarantees loop free paths.

Disadvantages of OLSR:

- Overhead on the bandwidth as each host periodically updates.
- It works on best effort basis which have grantee to deliver QoS service.

The MPRs selection principle is that the node with higher idle time will have larger possibility to be selected as MPRs. The MPR set is calculated to contain a subset of the 1-hop neighbours which provides maximum data rate and minimum delay to each 2-hop neighbors.

There are a few schemes of selection of MPRs which aim at finding the route with optimal data rate route in the network [25-27]. They are the revised versions based on the MPR selection method used in OLSR protocol.

The first approach is almost the same as MPR selection in OLSR protocol. A small change is that when there are more than one 1-hop neighbours covering the same number of uncovered 2-hop neighbours, then the one with largest data rate will be chosen as MPR of the node.

In the second aproach, the neighbours with best data rate are selected as MPRs until all the neighbours are covered. That is, the link with highest data rate will be selected first no matter how many 2-hop neighbours it connects to. Thus, more MPRs might be selected for one node in QOLSR than in OLSR, because in OLSR, the 1-hop neighbour who reaches maximum number of 2-hop neighbours will be selected first.

In addition, there has been an internet-draft version for QOLSR that has not been standardized and published by IETF MANET working group at the time of writing [26].

3.2.3. Summary

Many efforts were made to extend QoS features on original routing protocols. But none of them satisfy the required QoS. DSDV performs low especially with high node density and mobility while AODV suffers from delay and throughput. OLSR, on the other hand, is found to have potential for optimization and to incorporate QoS features. In subsequent sections, we will investigate these algorithms through experiment.

3.3.Experimental Analysis of well known Routing Protocols

3.3.1. Simulation Tools

NS 2 is discrete, event driven, open source network simulation software for researching a wide variety of net operations and services at a packet level. It uses TCL (tool command language) for configuring and controlling simulation scenarios set up and C++ for detailed implementation for taking the advantage of efficiency. NS2 interprets the simulation scripts written in TCL and C++ to produce trace files which then processed by other tools such as network animator and xgraph. When the TCL program is compiled, a tracefile and namfile are created which define the movement pattern of the nodes and keeps track of the number of packets sent, number of hops between 2 nodes, connection type etc at each instance of time. In addition to these, a scenario file defining the destination of mobile nodes along with their speeds and a connection pattern file(CBR file) defining the connection pattern, topology and packet type are also used to create the trace files and nam files which are then used by the simulator to simulate the network. 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 NS2 links the various agents (called plumbing in ns -2) to create a complete network [31-33].

3.3.2. QoS Parameters

Packet delivery fraction

It describes the loss rate and maximum throughput that the network can support. For all our simulations we have kept the number of data packets sent out as constant, so that the number of packets successfully received at their destinations will give us a comparison as to how efficient the underlying routing algorithm is under similar traffic load. A high value of PDF indicates that most of the packets are being delivered to the higher layers and is a positive sign of performance.

PDF= No. of Received data packets/ No. of generated data packets

Average End to End Delay

It shows how big data is transferred within a short possible period of time in that particular protocol. The lower the end-to-end delay the better the application performance.

AEED= Time data packet (received by destination – generated by the source)

Routing Overhead

It is the number of routing packets transmitted per data packet delivered at the destination to determine the scalability of a given protocol. A lower control packet overhead is desired.

3.3.3. Simulation Scenario Set up

The setup consists of a test bed up to 50 nodes confined in a 500mX 500m in rectangular area as shown in Figure 3.5.Maximum range of each node is assumed to be 250m.We generate 3 speed movement scenarios (1 m/s, 5m/s and 10m/s) using random way point model which is expected to represent the average speed of human walking(low), bicycle (medium) and Car(high) mobility real world scenarios respectively. In addition, traffic is generated by constant bit rate (CBR). The size of each packet is 512bytes with traffic rate of 4 packet/sec. The network size and the number of nodes are kept constant while varying the number of source-destination pairs within the network for each scenario. In effect, this model attempts to observe the relationship between traffic-density, mobility and system performance.

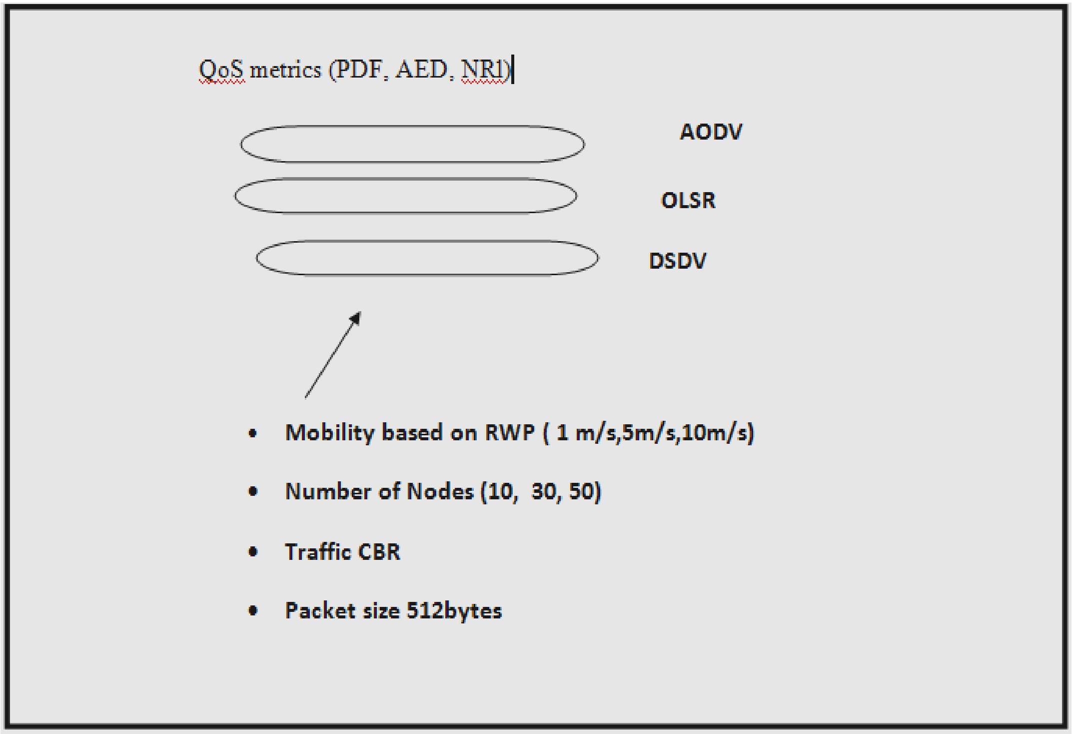


Figure 3.5. MANET Scenario Set up

Various modules in NS 2:

Ns 2 has different modules and specifications that can be configured and set according to the scenario in need. Some of these are:

1. Mobile node:
2. Ad hoc routing
3. Mac 802.11
4. Radio propagation model
5. Channel
6. LL: ARP to resolve MAC 2 IP
7. Agent: for packet generation
8. Reception (…..CBR,UDP,TCP)
9. IFQ: interface Que…

General Parameters:

In each scenario, we vary the number of flows (Source-to- destination Connections.) and evaluate the three well known routing protocols (AODV, OLSR and DSDV) as follow on Table 3.2.

Table 3.2. Parameters for simulation

Parameter	Values	Remarks
Routing protocol	OLSR, AODV, DSDV	The type of protocol being simulated
Transmission range	250 m	The maximum allowable radio range between nodes
Simulation Time	110s	The time for simulation
Topology Size	500X500m	The area in which nodes covers
No. of Node	10, 20,30,40,50	The number of nodes participating in different scenario
Traffic Type	CBR	Constant Bit Rate
Packet rate	5 packet/s	The speed of packets
Packet Size	512 bytes	The size of packet
Speed	1m/s,5m/s, 10m/s	The average speed at which nodes move

General Procedures to write a MANETs Scenario

To create a scenario using TCL, one has to set in the following way.

i. Define options as follows:

ii. Initialize Global Variables in the main program:

iii. Create simulator instance

iv. Setup topography object

v. Create trace object for ns and nam

vi. Define topology:

vii. Configure node how it can be accessed

viii. Create nodes and attach to channel

ix. Define node movement model

x. Define traffic model

3.3.4. Result of the Experiment

The AODV protocol will perform better in the networks with static traffic, with the number of source and destination pairs is relatively small for each host. It uses fewer resources than OLSR, and DSDV because the control messages size is kept small requiring less bandwidth for maintaining the routes and the route table is kept small reducing the computational power. The AODV protocol can be used in resource critical environments.

The OLSR protocol is more efficient in networks with high density and highly sporadic traffic. But the best situation is when there are a large number of hosts. OLSR requires that it continuously has some bandwidth in order to receive the topology update messages. All protocols scalability is restricted due to their proactive or reactive characteristic. In the AODV protocol it is the flooding overhead in the high mobility networks. In the OLSR protocol it is the size of the routing table and topological updates messages and their performance depends a lot on the network environment. Table 3.3. gives summary of comparison among the three Protocols under three different metrices namely Packet delivery fraction, Average End To End Delay and Routing Overhead.

Table 3.3. Summary of Comparison among Protocols:

Routing Protocol	AODV	DSDV	OLSR
Packet delivery fraction	Poor	Good	Good
Average End To End Delay	Poor	Very good	Very good
Routing Overhead	Good	Poor	Poor

3.4.OLSR as a candidate for QoS improvement

There is no single protocol as a solution for all MANET routing needs. Because of the dynamic nature of wireless networks require certain approaches based on the expected mobility scenario and/or works differently when the size of nodes varies.

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 and suitable to incorporate QoS for DSDV.OLSR lives up to its protocol specifications because it performs well in a highly dense network even under varying load conditions. It gives a high throughput under most conditions, but at the cost of an increased overhead.

AODV, the only reactive protocol assessed suffers from delay and throughput. AODV performs well in static scenarios under low traffic loads, but with even small node movements it fails to maintain good throughput.

The results of the assessment of the three protocols made from related work section (3.2) and experimental analysis section (3.3) indicate that there is scope for improvement in proactive protocols, particularly OLSR. The observations from simulation results have revealed that OLSR performs well in large dense networks, but requires increased overhead. OLSR’s overhead can be reduced by using differential schemes similar, especially for HELLO messages and link state updates. 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” on OLSR proactive protocol more suitable.

The approach followed in this thesis work is to re-compute the best route in a way optimal and more effective than other approaches, based on the QoS constraint among all the possible routes which finally come up with QoS aware OLSR routing protocol. That is finding the approach that takes into consideration band width utilization and control overhead at the best case.

3.5.More on OLSR Proactive Routing Protocol

OLSR is a well-known routing protocol for ad hoc networks. It is best effort traffic protocol adapted and optimized from the classic wired link state routing protocol by reducing the control packet overhead and creating efficient flooding which is now published as RFC 3626 [24]. It has been broadly examined [23- 27], implemented and deployed.

OLSR periodically advertises the links building the network, however, OLSR optimizes the topology information flooding mechanism, by reducing the amount of links that are advertised and by restraining the number of nodes forwarding each topology message to the MPR set only. Each message advertising topology information is called Topology Control (TC) message and it is broadcasted into the network. TC messages are only originated at the nodes that have been selected as Multipoint Relays (MPRs) by some other node in the network. MPRs are selected in such a way that a minimum amount of MPRs, located one-hop away from the node doing the selection (called MPR Selector), are enough to reach every single neighbor located two-hops away from the MPR selector. By applying this selection mechanism only a reduced amount of nodes (depending on the network topology) will be selected as MPRs. Every node in the network is aware of its one-hop and two-hop neighbours by periodically exchanging HELLO messages containing the list of its one-hop neighbours. On the other hand, TC messages will only advertise the links between the MPRs and their selectors, then, only a partial amount of the network links (the topology) will be advertised, also MPRs are the only nodes allowed to forward TC messages and only if the messages come from a MPR Selector node. These forwarding constrains considerable decrease the amount of flooding retransmissions.

3.5.1. Basic Principles and Elements in OLSR

Conceptually, OLSR contains different elements: a mechanism for neighbor sensing, a mechanism for efficient flooding of control traffic, and a specification of how to select and diffuse sufficient topological information in the network to provide optimal routes. Let see the basic concepts one by one.

i. *Multipoint relays (MPRs) nodes*: A node which is selected by its 1-hop neighbor, node X, to "re-transmit" all the broadcast messages that it receives from X, provided that the message is not a duplicate.

ii. *Selective flooding*: Periodically advertises the links building the network, but, optimized topology information flooding mechanism using MPRs as shown Figure 3.6a and 3.6b.

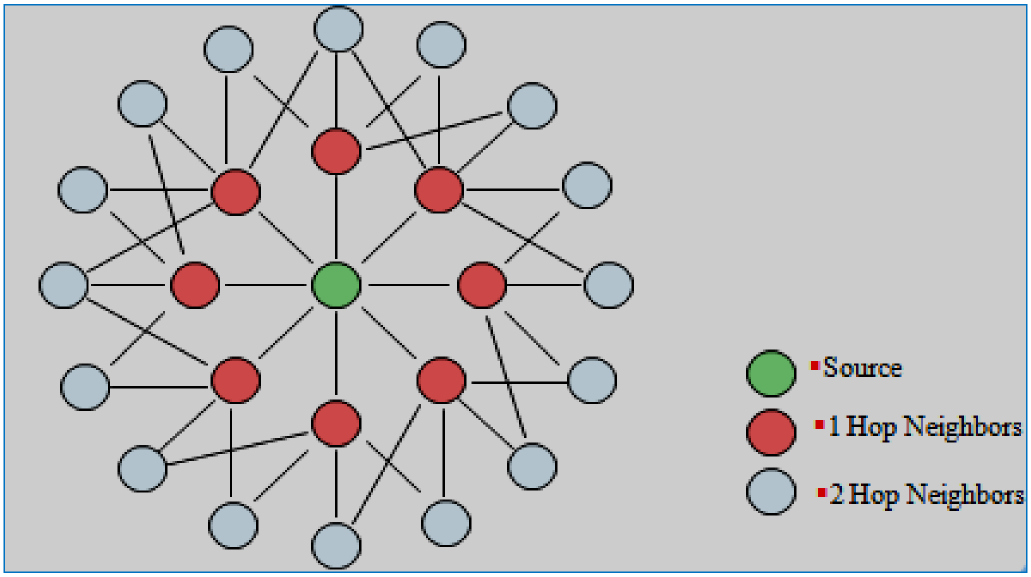


Figure 3.6a. 1 and 2- hop neighbors in selective flooding

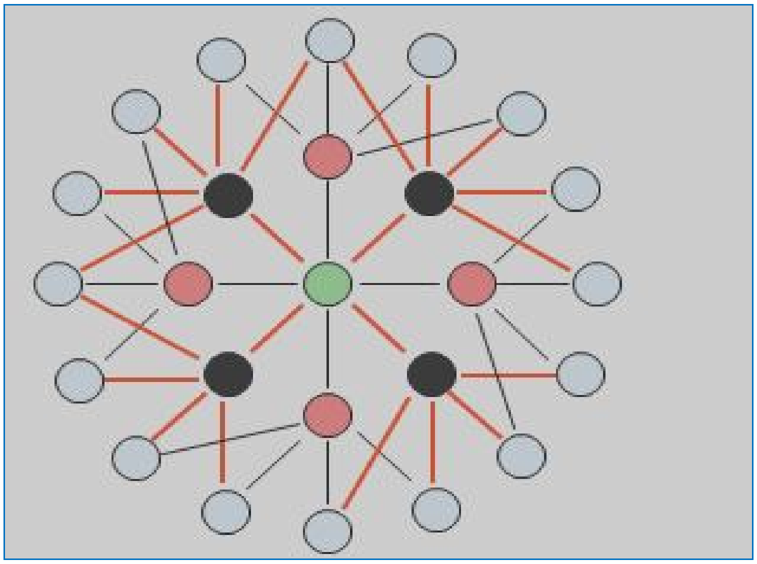


Figure 3.6b. Selective flooding using MPR

iii. *MPR Selector Set: A node which has selected its 1-hop neighbor, node X, as its multipoint relay, will be called a multipoint relay selector of node X.*

iv. *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 and sent only one hop away.

v. *Topology Control messages:* Used for broadcasting information about own advertised neighbors which include at least the MPR Selector list. The TC messages are broadcasted periodically and only the MPR hosts can forward the TC messages.

vi. *Neighbor node:* A node X is a neighbor node of node Y if node Y can hear node X (i.e., a link exists between an OLSR interface on node X and an OLSR interface on node Y).

vii. *2-hop neighbor:* A node heard by a neighbor.

viii. *MPR Selection Algorithm:* It finds the optimal bandwidth path with minimum possible number of MPR to have a lower overhead. The algorithm constructs the MPR set which includes minimum number of the one hop symmetric neighbors from which it is possible to reach all the symmetrical strict two hop neighbors.

OLSR MPR Selection Algorithm:

The original Algorithm for selecting MPR set [23]:

1. Take all the symmetric 1 hop neighbors which are willing to act as MPR.
2. Calculate for every neighbor host a degree, which is a number of the symmetric neighbors, that are two hops away from the calculating source and does not include the source or its one hop neighbors.
3. Add the neighbor symmetric host to the MPR set. If it is the only neighbor from which it is possible to get to the specific two hop neighbors, then remove the chosen host neighbors from the two hop neighbor set.
4. If there are still some hosts in the two hop neighbor set, then calculate reachability of each one hop neighbor, meaning the number of the two hop neighbors, 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 reachable two hop neighbour from the two hop neighbor set.
5. Repeat previous step until the two hop neighbors set is empty.
6. For the optimization, If one host is taken away and all the two hop neighbors, covered by at least one host and the willingness of the host are smaller than WILL_ALWAYS, then the host may be removed.

OLSR Protocol Operation using example:

Consider the following simple MANET Network in Figure 3.7:

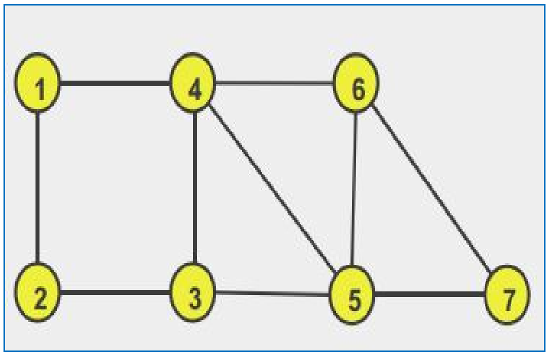


Figure 3.7a: simple MANET

First the possible MPR Selection among many alternatives:

MPR(1)={4}, MPR(2)={3}, MPR(3)={4,5}, MPR(4)={3,5}, MPR(5) = {3, 4}, MPR (6) = {4}, MPR (7) = {5}

For node 3:

1. Node 3 generates a TC message advertising nodes in MS(3) = {2, 4, 5} as Figure 3.7b.
2. It sends it to the nodes in MS (3) and to its MPR (namely, node 4).
3. Node 4 forwards Node 3’s TC message to all the nodes in MS(4) , (namely, 1, 3 and 6) as well as to its MPR (3 and 5)
4. Node 5 receives the first copy either from 3 (in which case it forwards to 4 and 7) or from 4 (in which case it forwards only to 7).

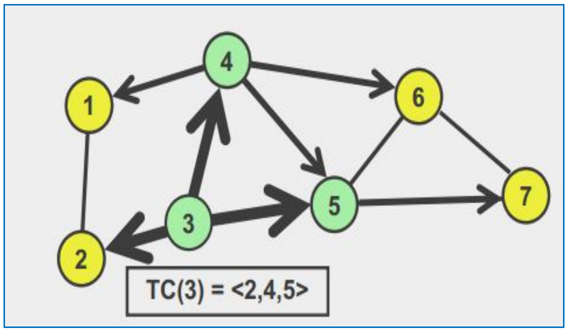


Figure 3.7b: simple MANET,node 3 selective flooding.

For Node 4:

1. Node 4 generates a TC message advertising nodes in MS(4) = {1, 3, and 6} as in Figure 3.7c
2. It sends it to 1, 3, 6 and 5
3. Node 3 forwards to 2 and 5
4. Node 5 forwards to 7

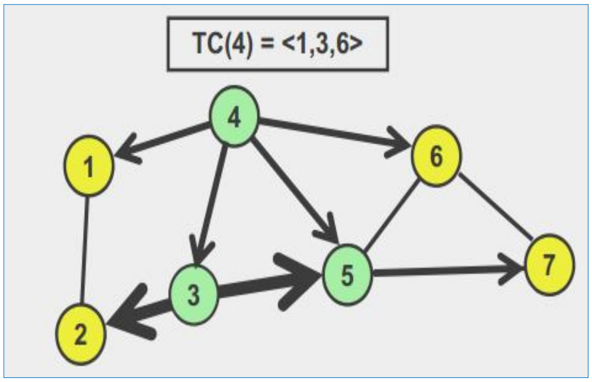
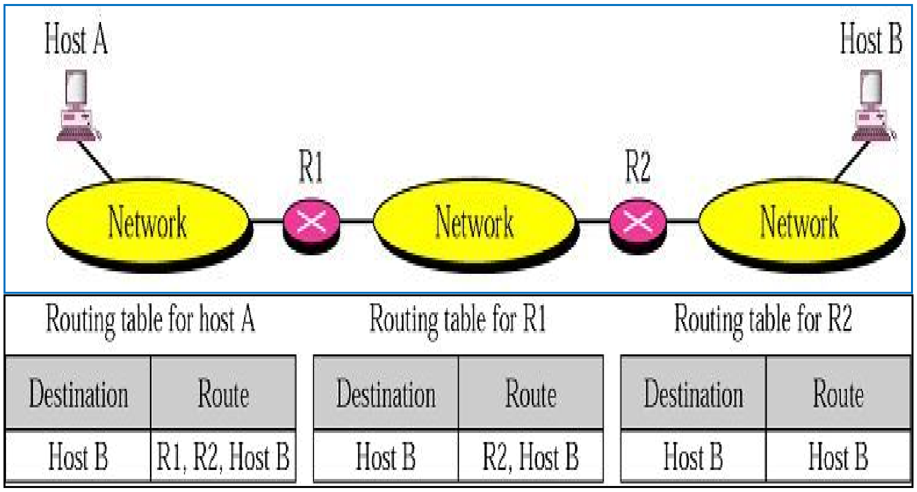


Figure 3.7c: Simple MANET,node 4 selective flooding

ix. *Shortest-widest path algorithm*: Computes the best bandwidth paths from a source to any reachable destinations with minimum hop count.

x. *Routing Table Calculations:* The routing table which contains information like destination, next address (next hop), number of hops to the destination and local interface address which is obtained from hello and TC message when a change of any as shown in Figure 3.8. for host A, R1, R2 and host B.



Routing table for host A

Destination	Route
Host B	R1, R2, Host B

Routing table for R1

Destination	Route
Host B	R2, Host B

Routing table for R2

Destination	Route
Host B	Host B

Figure 3.8. Route table calculation

3.5.2. Open issues of OLSR

As mentioned, OLSR is a routing protocol for best-effort traffic [26, 27], with emphasis on how to reduce the overhead, and at the same time, provide a minimum hop route. MPR selection is the key point in OLSR. The MPR set is selected such that it covers all nodes that are two hops away. This means that the union of the neighbor sets of the MPRs contains the entire 2-hop neighbor set of a node. Each node selects its MPRs independently. The smaller the MPR set, the less overhead the protocol introduces. Understanding this trade-off will allow a network operator to set the protocol parameters based on their primary goals (reducing control message overhead vs. increased routing choices).

QoS enhancement on OLSR is primarily done by modifying the MPR selection method to attain maximum band width and optimal number of MPR. In its MPR selection, the node selects the neighbor that covers the most unreached 2-hop neighbors. However, in QoS routing, by such MPR selection mechanism, the “good quality” links may be “hidden” to other nodes in the network. i.e. in selecting the MPRs, a “good bandwidth” link should not be omitted.

3.5.3. Methods for selecting MPR

Up on the optimization of link state protocols using selective flooding scheme which relay on MPR, variant approaches are introduced. However, some of them have problem of overhead and others miss in selecting quality links. Now let us see some of these using the following MANET scenario Figure 3.9. with A, B, C, D, E, F, G nodes with the corresponding link sizes and source A.

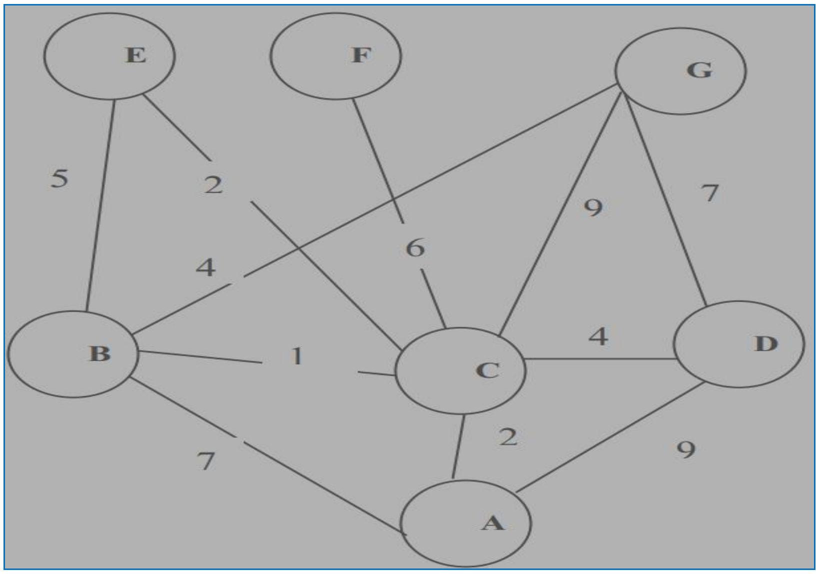


Figure 3.9. MANET Scenario Network

i. *Approach I*: This is similar to the original OLSR selection on the basis of larger 1-hop neighbor covering 2-hop neighbors. 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 [22, 23]. Therefore, network in Figure 3.9 would select MPRs for node A, as Table 3.4a:

Table 3.4a: MPR selection using approach I

Source	1 hop neighbor	2 hop neighbor	MPR
A	B, C, D	E, F, G	C
…	…	…	…

C is selected as A's MPR because it is the only node covering all the 2 hop unreached nodes and has the largest bandwidth. But this approach is quite inefficient in terms of QoS because basically it works under the principle of pure OLSR. It is subject to 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.

ii. *Approach II:* The idea behind MPR selection approach 2 is to select the best bandwidth neighbors as MPRs until all the 2-hop neighbors are covered. Therefore, from table 3.4b, node A's MPR(s) would be D, B, C.

Table 3.4b: MPR selection using approach II

Source	1 hop neighbor	2 hop neighbor	MPR
A	B, C, D	E, F, G	D, B, C
…	…	…	…

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 optionless 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 larger 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 overhead of the network and deteriorate the data transfer metrics. Hence, it redesigned the MPR selection algorithm of the QoS versions of the OLSR so far developed in way of basically looking into the larger bandwidth link. But, controlling the number of MPR not to grow and has adverse effect on basic bandwidth management QoS metrics and routing overhead.

CHAPTER FOUR

THE PROPOSED QoS AWARE OLSR

4.1.Overview

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 Aware 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 band width related QoS Metrics such as Packet Delivery Fraction, Normalized routing overhead. More over the effect of average end to end delay is also considered. Thus, QoS Aware OLSR we proposed here is based on optimization of the two constraints namely selection of path with higher bandwidth and less control overhead. In subsequent sections, we present design and implementation of the proposed approach.

4.2.Design of QoS Aware OLSR Algorithm

In the related work, we have seen that the existing variant OLSR algorithms are limited to providing only best effort QoS delivery mechanism. In approach 1, it lacks to select a wider bandwidth and in approach 2, it selects more nodes as MPR which result in overhead on the network. Both approaches fail to provide optimal methods. Therefore, there is a need to come up with a new alternative MPR selection mechanism that fulfills QoS constraints better.

The idea behind algorithm for our new approach, QoS Aware OLSR is to select the highest bandwidth neighbors with optimal number of MPR. It takes into consideration bandwidth and the number of MPRs at optimal level. Figure 4.1. shows the flow chart of the proposed algorithm for QoS Aware OLSR where a MANETs with n nodes, with source node S, 1 hop neighbor set N, and 2 hop neighbor set N2, MPR set.

Algorithm:

Given simple MANETs with n nodes, with source node S, 1 hop neighbor set N, and 2 hop neighbor set N2, MPR set, the QoS Aware OLSR Algorithm selects MPR set as follows:

Rule 1. Begin

Rule 2. Set the MPR set to be Empty: MPR set={ }

Rule 3. Read the Next Uncovered N2 set element starting from the first.

Rule 4. Set MPR candidate lists, and the maximum bandwidth and maximum Number of N2 covered to be zero

1.1. Read the next MPR candidate list iteratively

1.2. Check if it is the only Candidate that is if it is the only one , take it as MPR,

1.3. Otherwise, compare its bandwidth with the maximum BW first and then with maximum N2 covered respectively. If it returns true, swap the values:

TempMPR ← MPRcandidate
MaxBW← BW MPRcandidate
MaxN2← N2 covered
And return the current MPRcandidate as MPR

1.4. Otherwise, check all MPR candidate list

Rule 5. Go through until all N2 covered

Rule 6. Finish

Figure 4.1. Flow Chart QoS Aware OLSR

QoS Aware OLSR Algorithm using Scenario

Let us see the new algorithm with the following simple MANET scenario in Figure 4.2:

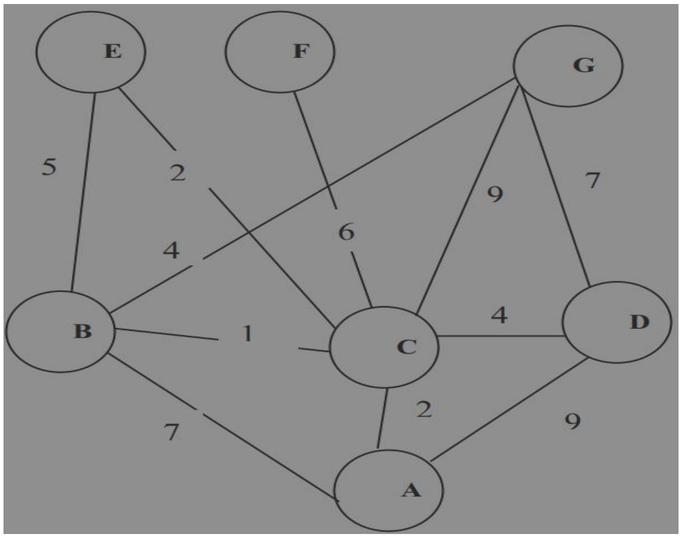


Figure 4.2: MANET Scenario

For example, using this algorithm, based on Figure 4.2, node A.s MPR(s) would be as shown on table 4.1.

Table 4.1: MPR selection using QoS Aware approach:

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

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 is covered. Similarly, C is selected as MPR and F is covered, so all 2-hop neighbors are covered and the algorithm terminates.

4.3.Implementation

Idle time propagation

The QoS Aware 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 [17].

Hello message and TC 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 aware MPR selection algorithm.

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. 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.

Available link band width calculation

QoS Aware OLSR [17,26] uses idle time of the media 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: 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 *2Mbps = 600 kbps. These randomly generated idle times effect the traffic condition in the network snapshot because the consumed bandwidth over each link reflects the traffic flows over that link.

MPR Selection

The QoS aware OLSR promises to find the optimal bandwidth path with minimum possible number of MPR to have a Lower overhead compared with other MPR selection types as described in section 4.2.

Routing table Calculation

The Extended Bellman Ford (BF) algorithm [26] is used to compute the routing table, as it not only finds shortest path but the best bandwidth path, as well. It computes the best bandwidth paths from a source to any reachable destinations with minimum hop count (shortest-widest path). The BF algorithm has a property that, at its h^{th} iteration, it identifies the optimal cost path between the source and each destination, among paths of at most h hops. In the "Extended BF" algorithm, the cost is the bottleneck bandwidth along the path. When the algorithm terminates, the maximum bottleneck bandwidth paths with the smallest number of hops are found.

CHAPTER FIVE

EVALUATION OF QoS AWARE OLSR PROTOCOL

4.1. Overview

In this scenario the behavior of both algorithms Best effort OLSR and QoS Aware OLSR is compared and contrasted in a typical MANET environment of 500 X 500 meters with 50 nodes by varying node density under different speed scenarios as Figure 5.1. The metrics to be analyzed are Packet Delivery Fraction (PDF), Normalized Routing Load (NRL), and Average End to End Delay (AEED). The size of nodes to be taken is 10, 30, and 50 that represents sparse, medium and dense networks respectively. The observation is categorized under three speed scenarios 1m/s, 5m/s, 10m/s to study the nature of the algorithms in different node density and node mobility. The radio range spans up to 250m.

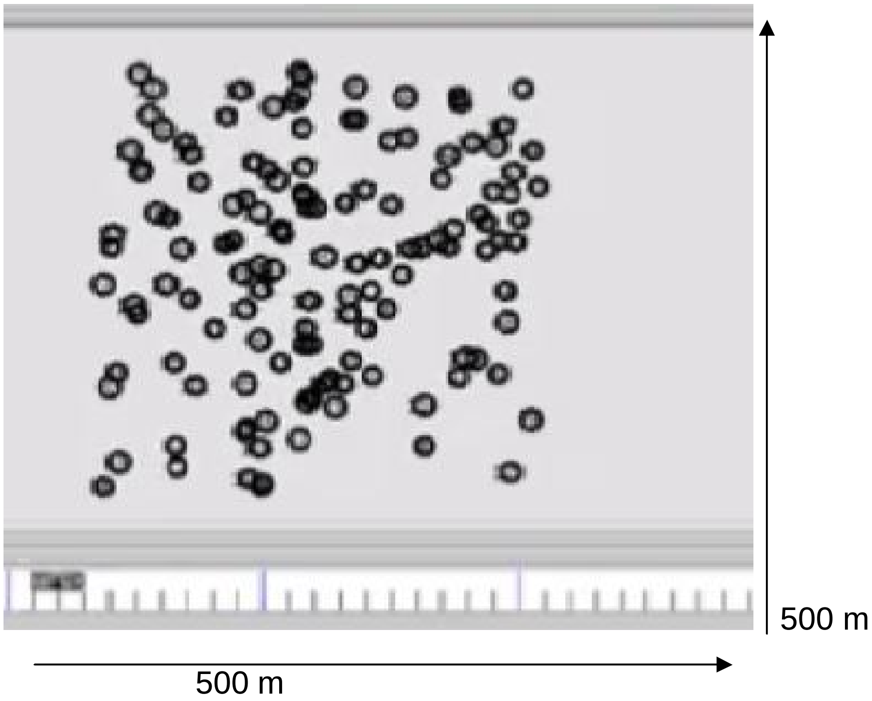


Figure 5.1. 500x500 MANETs Scenario

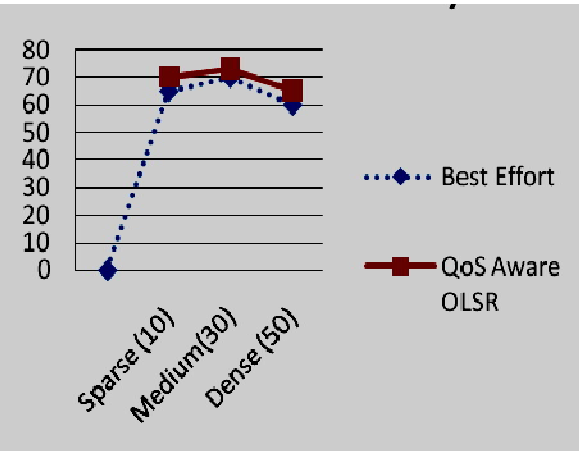
4.2. QoS Aware OLSR in low Mobility Scenario

In scenario1, the parameters are set in a way that the speed is at 1m/s, and the network size is varied to 10, 30 and 50 at different instances to see the effect on delay, overhead and packet delivery fraction.

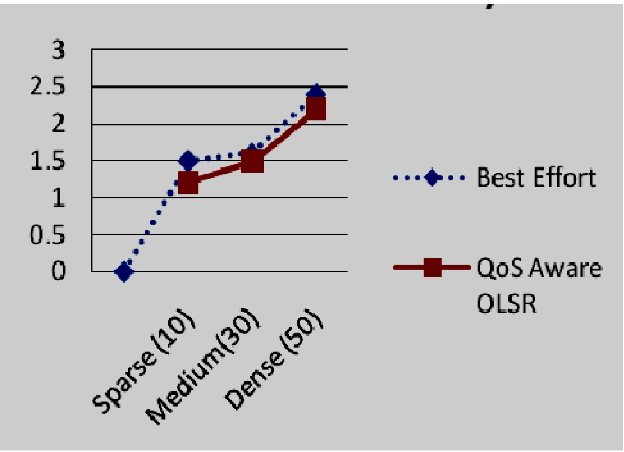
Table 5.1. Comparison protocols under varying node at 1m/s

(Man Walking: A Low Speed Scenario)

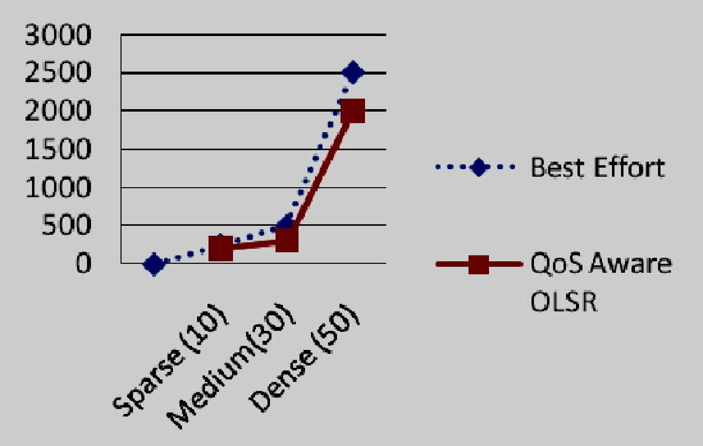
Version	Network size (No.)	PDF (%)	AEED (ms)	NRL
Best Effort OLSR	Sparse (10)	65	250	1.5
	Medium(30)	70	500	1.6
	Dense (50)	60	2500	2.4
QoS Aware OLSR	Sparse(10)	70	200	1.2
	Medium(30)	73	300	1.5
	Dense (50)	65	2000	2.2



a) PDF and Network Density



b) NRL and Network Density



c) AEED and Network Density

Figure 5.2: Comparison of OLSR and QoS Aware OLSR at speed of 1m/s

In this scenario, the behavior of orginal OLSR and QoS ware OLSR is compared and contrasted under varying node density of 10, 30 and 50 at speed of 1m/s using PDF, AEED, and NRL metrics.

From Figure 5.2 it is shown that, the NTR and AEED in QoS OLSR is less than in all the three networks which indicate a performance improvement over that of original OLSR. That is the broken line labeled is above the dash line in all cases. Similarly, PDF of QoS aware OLSR is above in all cases which indicate a performance improvement compared to the original OLSR.

Therefore, a comparative decrement on routing overhead results in a scalable protocol, while decrement in delay makes it suitable for time bounded application such as playback applications, voice over IP use. Similarly, the increment in Packet delivery fraction shows a wider bandwidth path to pass payloads without any problem.

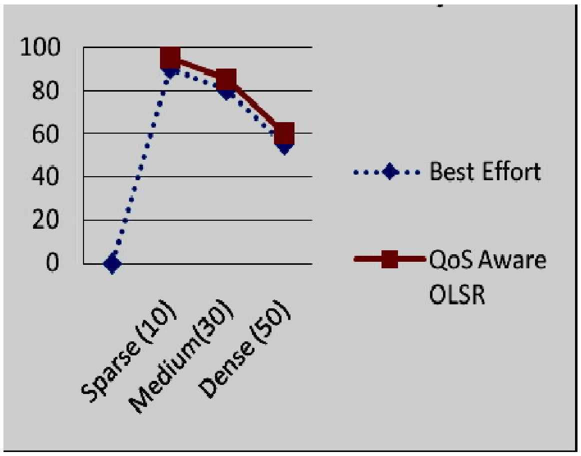
4.3. QoS Aware OLSR in Medium Mobility Scenario

In this scenario, the parameters are set in a way that the speed is at 5m/s, and the network size is varied to 10, 30 and 50 at different instances to see the effect on delay, overhead and packet delivery fraction as in Table 5.2 .

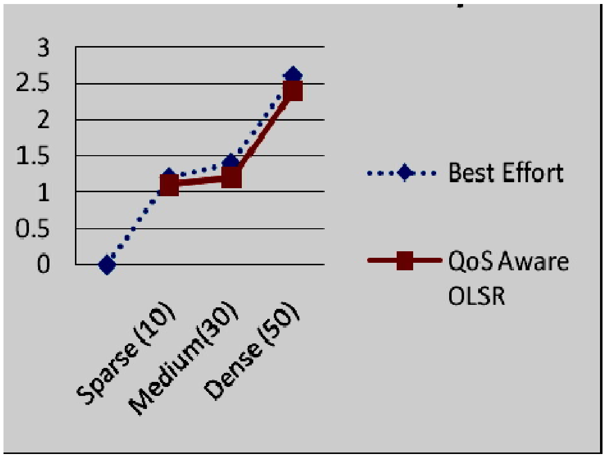
Table 5.2 Comparison of protocols under varying node at 5m/s

(Bicycle: A Moderate Speed Scenario)

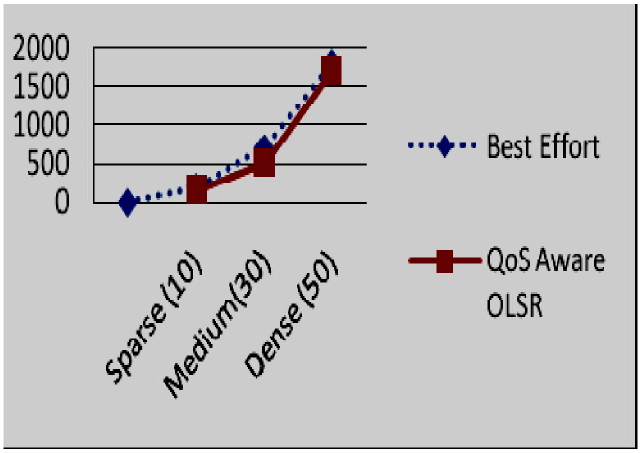
Version	Network size (No. of nodes)	PDF (%)	AEED (ms)	NRL
Best Effort OLSR	Sparse (10)	95	150	1.2
	Medium(30)	90	500	1.3
	Dense (50)	70	1500	2.8
QoS Aware OLSR	Sparse(10)	100	135	1.1
	Medium(30)	95	400	1.2
	Dense (50)	75	1200	2.4



a) PDF and Network Density



b) NTR and Network Density



c) AEED and Network Density

Figure 5.3: Comparison of OLSR and QoS Aware OLSR at speed of 5m/s

In this scenario, the speed is set to 5m/s while the node density is varies from the sparse which contains 10 nodes to 30 and 50 nodes. This is to show the performance of the protocols under different density.

In this particular Scenario, both NTR and AEED matrices shows on Figure 5.3 a sequential increment which indicates its scalability and delay tolerances. In QoS OLSR, PDF is coming above from the original OLSR to indicate its performance increment.

These are good indications that for object moving at 5m/s, all QoS matrices return positive response in Qos OLSR than original OLSR to satisfy QoS requirements in time sensitive applications. In short, QoS OLSR outsmart best effort OLSR even the object at moving with speed of 5m/s.

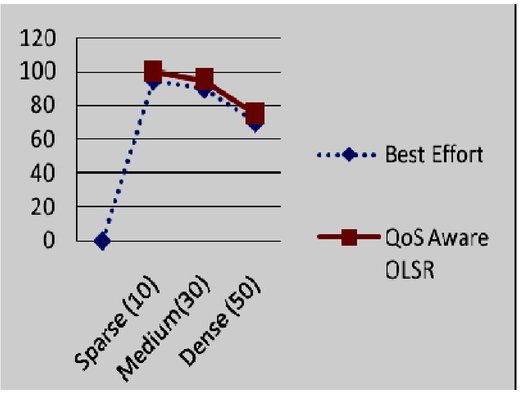
4.4. QoS Aware OLSR in High Mobility Scenario

In this scenario, the parameters are set in a way that the speed is at 10m/s, and the network size is varied to 10, 30 and 50 at different instances to see the effect on delay, overhead and packet delivery fraction as Table 5.3.

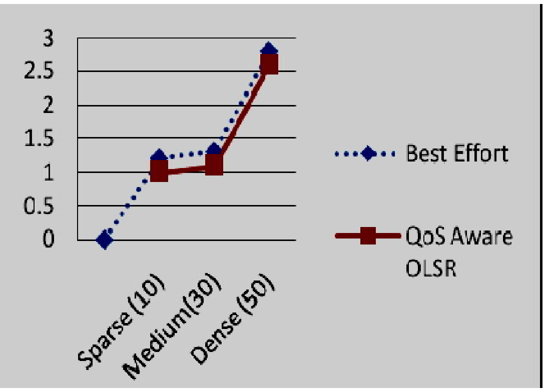
Table 5.3. Comparison protocols under varying node at 10m/s

(Car: A High Speed Movement Scenario)

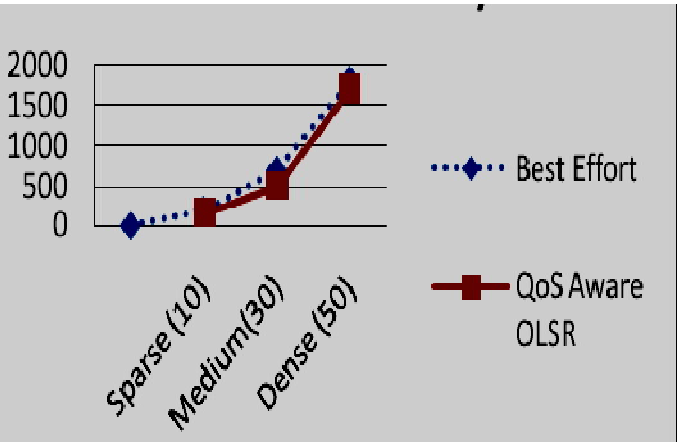
Version	Network size (No. of nodes)	PDF (%)	AEED (ms)	NRL
Best Effort OLSR	Sparse (10)	100	200	3
	Medium(30)	95	700	2
	Dense (50)	75	1800	1.8
QoS Aware OLSR	Sparse(10)	105	150	2
	Medium(30)	95	500	1.5
	Dense (50)	80	1700	1.2



a) PDF and Network Density



b) NTR and Network Density



c) AEED and Network Density

Figure 5.3: Comparison of OLSR and QoS Aware OLSR at speed of 10m/s

The last case is conducted when the object is moving at a speed of 10m/s which is equivalent to a car speed scenario. But keeping the same all other parameters.

The experiment shows a comparative decrement in both NTR and AEED in comparison to the original protocol while a better PDF from best effort OLSR as depicted in Figure 5.3.

These results show that even though the mobility is at high speed, the QoS OLSR by any means outsmarts the best effort OLSR. That is all QoS metrices outputs positive which makes QoS OLSR candidate and first choice protocol for deploying massively in real time communications including online game, VoIP, online conferencing.

4.5. Summary

In summary, for all the three scenarios, the value of delay and traffic overhead increment is less in QoS Aware OLSR than its corresponding Best effort OLSR version while increasing the network density and the speed. Similarly, packet delivery fraction of QoS Aware OLSR is better than the original OLSR while network density and speed increased. This confirms that QoS Aware OLSR is better for QoS than best effort OLSR.

CHAPTER SIX

CONCLUSION AND FUTURE WORKS

6.1.Conclusion

In this thesis work, the principles of mobile ad hoc networks focusing on how to enhance QoS in MANETs routing protocols and hence make them QoS aware is discussed. Specifically, we have seen how to add to best effort OLSR a QoS aware feature using conceptual and experimental analysis on three routing protocols namely AODV, DSDV and OLSR to select the best protocol for QoS extension. Using three metrics OLSR in QoS is better than AODV and DSDV and has open spaces for QoS improvement.

The reengineering of the best effort OLSR based on new MPR selection approach found a better version which is relatively suitable in delay bounded applications using the packet delivery fraction, average end to end delay and normalized overhead, QoS aware OLSR is found better than best effort OLSR.

In conclusion, the new QoS aware OLSR designed in a way that outsmart the best effort OLSR and hence fulfilling the basic QoS constraints such as delay which makes meaningless in real time communication , throughput which gives a wider and optimal path, and routing overhead which consumes more bandwidth for traffic controlling.

6.2.Future Works

These are some of the future works.

- Reengineering of the OLSR protocol using multi metrices and setting different scenarios and parameters to come up better version.
- Using other heuristic MPR selection mechanism to have a better QoS Aware OLSR
- Using Other enabling technologies
- Redesign of other the pro-active QoS routing protocols to compare their performance and further investigate which kind of the QoS routing protocol is more suitable.

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Appendixes:

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_ h alt"
$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
```

Declaration

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

Declared by:

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Date: ________________________

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Name: Dejene Ejigu (PhD)

Signature: __________________

Date: ______________________

Place and date of submission:

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