Challenging Ad hoc Networks Under Reliable & Unreliable Transport With Variable Node Density.

Research Thesis

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Islamabad
2007

Adhoc network - management

Ad hoc network - Access control

A dissertation submitted to the
Faculty of Basic & Applied Sciences
International Islamic University Islamabad.
As partial fulfillment of the
Requirements for the award of degree of
MS in Computer Science (Networks).

Project Title:

Challenging Adhoc Networks under Reliable & Unreliable Transport with varible Node Density

Organization:

Department of Computer Science
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296-FAS/MSCS/F06

Languages :

C ++, and OTCL

Simulation Tools used:

Network Simulator NS-2 (Version 2.31)

Operating Systems:

Linux (Kubuntu), Windows Vista

System Used:

Pentium 4, RAM 1 GB

Date started:

1st July 2007

Date completed:

7 December 2007

ABSTRACT

The main motivation of the research project is to analyze different performance parameters of three well known Ad-hoc network routing protocols (AODV, DSR, DSDV and OLSR) with varying node density and velocity. As in real world the movements of nodes are almost always random, therefore we selected the random way point mobility model.

Ad hoc network is an active research area now-a-days. Plenty of literature is available in this field. The researcher has developed many Routing Algorithms for effective routing in MANETs. Similarly researchers also have analyzed these protocols in different scenarios.

The Research area which needs more work & is still demanding the researcher attention is to work out efficiency of such networks in reliable (suitable for delay tolerant and error sensitive data) & unreliable (for delay sensitive and error tolerant information such voice and video streaming) transport layer protocols. In this project we study the behavior of different Ad –hoc network routing protocols (AODV, DSR, DSDV and OLSR) under reliable TCP and unreliable UDP transport layer protocols with variable node density and velocity. From simulation results we observed that each protocol perform in a different way with different node density and velocity.

ACKNOWLEGEMENT

At first, I bestow all praises, acclamation and appreciation to all mighty Allah, the most merciful, gracious and beneficial, Whose bounteous blessing enable me to pursue and perceive higher ideals of life, All praises for his Holy prophet Muhammad (S.A.W) who enable me to recognize our lord and creator and brought to us a real source of knowledge from Allah, the Quran, A role model for us in every aspect of life.

Secondly I must mention that it was mainly due my parents' moral and financial support during our entire academic career that enabled me to complete our work dedicatedly. I would like to thanks to our teacher's and especially consider it a proud of privileged to express our gratitude and sense of obligation to Prof Dr M Sikandar Hayat Khiyal, Dr Muhammad Sher, Qaisar javaid, Khalid Iqbal, Mata-ur-Rehman,M.Adeel, Nadir shah, Hilal, and Hafiz Faiz-ul-Wahab for their dexterous guidance and kind behavior during the project. I would also like to admit the efforts of our truly friends who cooperate me in completion of this project.

I would once again owe all my Achievements to my loving parents, Brothers & sisters, and M. Anwar Khattak for their Prayers and support for completion of this research project.

Dedication

I Dedicate This Research Project to
All Mighty ALLAH his
Prophet Hazrat Muhammad (P.B.U.H),
My beloved Parents, Family Members,
Respected Teachers, Sincere Friends
And My Future Advisor and Guide
M. Anwar Khattak
(PhD Scholar).

DECLARATION

I, here by declared that this research work has not been copied from any source. It is further declared that I have developed this research entirely based on my personal efforts under supervision of Prof. Dr. M Sikandar Hayat Khiyal.
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TABLE OF CONTENTS

Chapter. NO **Page. No**

Chapter 1

INTRODUCTION

1. Introduction

This segment of our thesis covers the areas related to our research project.

1.1 Background

1.1.1 Transport Layer:

This layer lies on fourth position of OSI Model. Segmentation is an important process done here. This layer segments data from the sending host's system and reassembles the data segments on receiving system. The transport layer attempts to provide a data transport service that shields the upper layers from transport implementation details. Specifically, such issues as how reliable transport between the two hosts is accomplished, is the concern of this layer. It is providing reliable service, transport error detection-and-recovery, and information flow control. TCP and UDP are common layer 4 protocols.

a) Transmission control protocol (TCP)

TCP is typically used by applications that require guaranteed delivery. It is a sliding window protocol that provides handling for both timeouts and retransmissions.
TCP establishes a full duplex virtual connection between two endpoints. Each endpoint is defined by an IP address and a TCP port number and is implemented as a finite state machine.
The byte stream is transfered in segments. The window size determines the number of bytes of data that can be sent before an acknowledgement from the receiver is necessary.

b) User Datagram protocol (UDP)

The User Datagram Protocol (UDP) is a transport layer protocol defined for use with the IP network layer protocol. It is defined by RFC 768 written by John Postel. It provides a best-effort datagram service to an End System (IP host).
The service provided by UDP is an unreliable service that provides no guarantees for delivery and no protection from duplication (e.g. if this arises due to software errors

within an Intermediate System (IS)). The simplicity of UDP reduces the overhead from using the protocol and the services may be adequate in many cases.

A computer may send UDP packets without first establishing a connection to the recipient. The computer completes the appropriate fields in the UDP header (PCI) and forwards the data together with the header for transmission by the IP network layer.

1.2 General Concepts - An Overview

In previous section, we discussed background to data and computer communication. In this section, we are going to review general concepts related to our project.

1.2.1. Wireless

Wireless is a term used to describe telecommunications in which electromagnetic waves (rather than some form of wire) carry the signal over part or the entire communication path. Some monitoring devices, such as intrusion alarms, employ acoustic waves at frequencies above the range of human hearing; these are also sometimes classified as wireless. The first wireless transmitters went on the air in the early 20th century using radio telegraphy (Morse code). Later, as modulation made it possible to transmit voices and music via wireless, the medium came to be called "radio." With the advent of television, fax, data communication, and the effective use of a larger portion of the spectrum, the term "wireless" has been resurrected. Wireless technology is rapidly evolving, and is playing an increasing role in the lives of people throughout the world. In addition, ever-larger numbers of people are relying on the technology directly or indirectly. (It has been suggested that wireless is overused in some situations, creating a social nuisance.) More specialized and exotic examples of wireless communications and control include

- Global System for Mobile Communication (GSM): A digital mobile telephone system used in west and other parts of the world. The de facto wireless telephone standard in West.
- General Packet Radio Service (GPRS): A packet-based wireless communication service that provides continuous connection to the Internet for mobile phone and computer users.
- Universal Mobile Telecommunications System (UMTS): A broadband, packet-based system offering a consistent set of services to mobile computer and phone users no matter where they are located in the world

1.2.2. Ad-Hoc Network:

With the advancement in radio technologies like Bluetooth, IEEE 802.11 or Hiperlan, a new concept of networking has emerged. This is known as ad hoc networking where potential mobile users arrive within the common perimeter of radio link and participate in setting up the network topology for communication. Nodes within ad hoc are mobile and they communicate with each other within radio range through direct wireless links or multihop routing [4].

An Ad-hoc network is a local area network or other small network, especially one with wireless or temporary plug-in connections, in which some of the network devices are part of the network only for the duration of a communications session or, in the case of mobile or portable devices, while in some close proximity to the rest of the network. In Latin, *ad hoc* literally means "for this," further meaning "for this purpose only," and thus usually temporary. For example, In Bluetooth technology where handheld devices like mobile phones etc communicate with each other using wireless transmission and having no fixed or predefined infrastructures. In computer networking, an ad hoc network refers to a network connection established for a single session and does not require a router or a wireless base station.

An Ad-hoc network technology that allows people to come to a conference room and, using infrared transmission or radio frequency (RF) wireless signals, join their notebook computers with other conferees to a local network with shared data and printing resources. Each user has a unique network address that is immediately recognized as part of the network.

A **wireless Ad-hoc network** is a computer network in which the communication links are wireless. The network is ad-hoc because each node is willing to forward data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity. This is in contrast to wired network technologies in which some designated nodes, usually with custom hardware and variously known as routers, switches, hubs, and firewalls, perform the task of forwarding the data. It is also in contrast to managed wireless networks, in which a special node known as an access point manages communication among other nodes.

We can say that An Ad-hoc wireless network is a collection of two or more devices equipped with wireless communications and networking capability. Such devices can communicate with another node that is immediately within their radio range (peer-to-peer communication) or one that is outside their radio range (remote-to-remote communication) using intermediate node(s) to relay or forward the packet from the source (sender) toward the destination (receiver).

An Ad-hoc wireless network is self-organizing and adaptive. This means that a formed network can be de-formed on-the-fly without the need for any system administration .The Ad-hoc network can be heterogeneous, i.e., the nodes can be of different types (palmtop, laptop, mobile phone...) with different computation, storage and communication capabilities.

As an ad-hoc wireless network does not rely on any fixed network entities, the network itself is essentially infrastructureless.

Since ad-hoc networks rely on forwarding data packets sent by other nodes, power consumption are critical issue still now.

Basically, an Ad-hoc network is a temporary network connection created for a specific purpose (such as transferring data from one computer to another). If the network is set up for a longer period of time, it is just a plain old local area network (LAN).

An Ad-hoc (or "spontaneous") network is a local area network or other small network, especially one with wireless or temporary plug-in connections, in which some of the network devices are part of the network only for the duration of a communications session or, in the case of mobile or portable devices, while in some close proximity to the rest of the network. The term Ad-hoc has been applied to future office or home networks in which new devices can be quickly added, using, for example, the proposed Bluetooth technology in which devices communicate with the computer and perhaps other devices using wireless transmission.

Minimal configuration and quick deployment make ad-hoc networks suitable for emergency situations like natural disasters or military conflicts. The decentralized nature of most wireless ad hoc networks makes them suitable for a variety of applications where central nodes cannot be relied on, and may improve the scalability of wireless ad-hoc networks compared to wireless managed networks, though theoretical and practical limits to the overall capacity of such networks have been identified.

1.2.3.Types of Adhoc Network:

There are two important types of Ad-hoc network,

Vehicular Ad-hoc Network

Mobile Ad-hoc Network

1.2.3.1. Vehicular Ad-hoc Network (VANET)

VANET is a form of ad-hoc network, to provide communications among nearby vehicles and between vehicles and nearby fixed equipment, usually described as roadside equipment. The main goal of VANET is providing safety and comfort for passengers. To this end a special electronic device will be placed inside each vehicle which will provide

Ad-Hoc Network connectivity for the passengers. This network tends to operate without any infra-structure or legacy client and server communication. Each vehicle equipped with VANET device will be a node in the Ad-Hoc network and can receive and relay others messages through the wireless network.

Collision warning, road sign alarms and in-place traffic view will give the driver essential tools to decide the best path along the way. There are also multimedia and internet connectivity facilities for passengers, all provided within the wireless coverage of each car. Automatic payment for parking lots and toll collection are other examples of possibilities inside VANET. Most of the concerns of interest to MANET,s are of interest in VANET,s, but the details differ. Rather than moving at random, vehicles tend to move in an organized fashion. The interactions with roadside equipment can likewise be characterized fairly accurately. And finally, most vehicles are restricted in their range of motion.

Vehicular Ad-hoc Networks (VANETs) can be considered as a subset of Mobile Ad hoc Networks (MANETs) with unique characteristics. A typical VANET consists of vehicles and access points along the road. Vehicles move on the roads sharing information between themselves and with the Internet through the access points.

Vehicles Mobility:

Vehicles often move at high speed but their mobility is rather regular and Predictable.

Network Topology:

High speed movement creates scenarios characterized by a very dynamic network topology.

No significant power constraint:

Vehicles can always rely on recharging batteries

Localization:

An accurate estimate of vehicles position can be made available through GPS systems or on-board sensors

Routing Protocols for VANETs

a) Proactive algorithms (Table-Driven)

Better performance in terms of delay but they need a considerable amount of control traffic (e.g., DSDV, OLSR)

b) Reactive algorithms (on-demand)

Minimize the number of broadcast packets by creating routes only on demand (e.g., AODV, DSR)

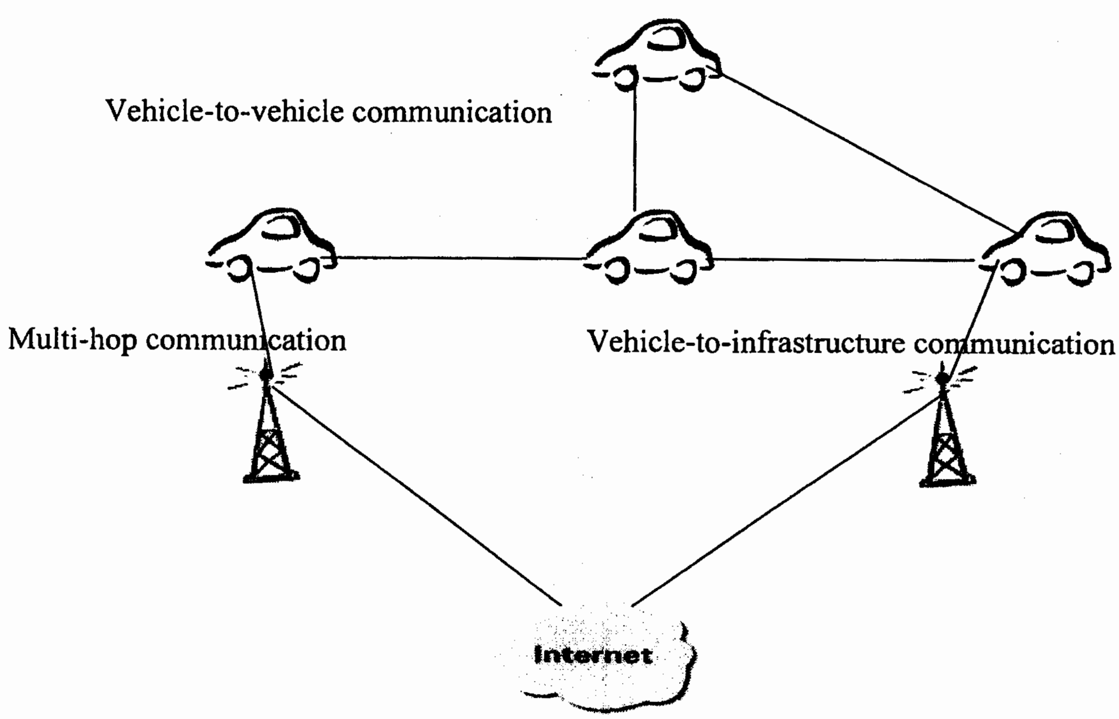
I) Position-based unicast routing (geographical forwarding)

These routing protocols exploit the availability of accurate location information. More suited to dense networks and to frequent network disconnections (e.g., GPSR)

II) Geocast routing

A kind of multicast routing where the destination nodes are characterized by their geographical coordinates in VANETs nodes interested in notifications of traffic congestions or warnings are located in the same place.

Figure 1.1: Vehicles communication



Majority of applications for VANETs rely on broadcast dissemination of information in the applications area.

a) Blind flooding is the first approach to achieve broadcasting since it does not require local or global topology information.

b) Broadcasting has a strong influence on network performance.

c) Serious redundancy, contention and collision problems can occur as a result of flooding.

d) An efficient broadcast protocol should minimize the total number of packet retransmissions, while at the same time preserving network connectivity.

1.2.3.2. Mobile Adhoc Networks

Mobile Ad-hoc networks (MANETs) are networks where the nodes are mobile, communicating via wireless links, operating without fixed infrastructure. MANET is also known as infrastructure-less network as it doesn't require any pre-established infrastructure like access points in case of WLAN and BTSs in cellular wireless networks. The nodes in an Adhoc network can be a laptop, PDA, or any other device capable of transmitting and receiving information. Nodes act both as a Host (transmitting and receiving data) and as a Router (forwarding the data in transit) resulting in multi-hop routing. Network is temporary as nodes are generally mobile and may go out of range of other nodes in the network.

Mobile ad-hoc networks became a popular subject for research as laptops and wi-Fi wireless networking became widespread in the mid-to-late 1990s. Many of the research papers evaluate protocols and abilities assuming varying degrees of mobility, usually with all nodes within a few hops of each other, and usually with nodes sending data at a constant rate. Different protocols are then evaluated based on the

- Packet delivery ratio
- End-to-End Delay
- Packet Overload etc.

I) Operating Principles of MANETs:

In order to understand the working principles of MANETs we are going to present an example of multi-hop sample ad hoc network. Here, mobile node A communicates directly (single-hop) with another such node B whenever a radio channel with adequate propagation characteristics is available between them. Otherwise, multi-hop communication is necessary where one or more intermediate nodes must act as a relay (router) between the communicating nodes. For example, there is no direct radio channel (shown by the lines) between A and C or between A and E as shown in figure 1.2. Nodes B and D must serve as intermediate routers for communication between A and C, and between A and E, respectively. Thus, a distinguishing feature of ad hoc networks is that all nodes must be able to function as routers on demand along with acting as source and destination for packets. To prevent packets from traversing infinitely long paths, an obvious essential requirement for choosing a path is that it must be loop-free. And this loop-free path between a pair of nodes is called a route.

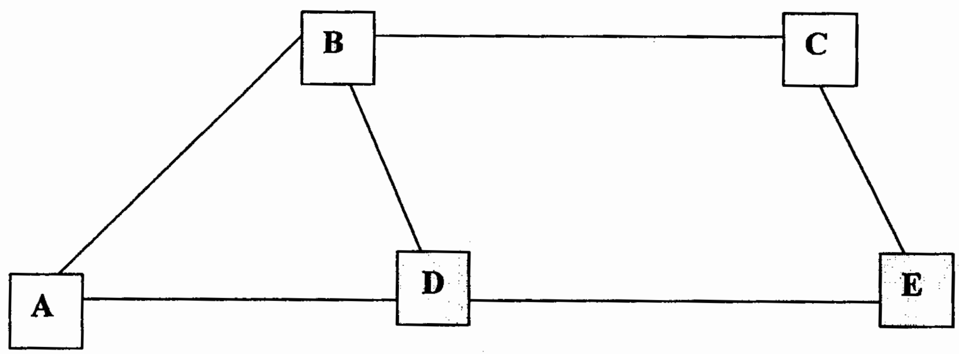


Figure1.2: Example of an ad hoc network

An Ad-hoc network begins with at least two nodes, broadcasting their presence (beaconing) with their respective address information. If node A is able to establish direct communication with node B as in figure 1.2, verified by exchanging suitable control messages between them, they both update their routing tables. When a third node C joins the network with its beacon signal, two scenarios are possible. The first is where both A and B determine that single-hop communication with C is feasible. The second is where only one of the nodes, say B, recognizes the beacon signal from C and establishes direct communication with C. The distinct topology updates, consisting of both address and route updates, are made available in all three nodes immediately afterwards. In the first case, all routes are direct. For the other, the route update first happens between B and C, then between B and A, and then again between B and C, confirming the mutual reachability between A and C via B.

As the node moves, it may cause the reachability relations to change in time, requiring route updates. Assume that, for some reason, the link between B and C is no longer available as shown in figure 1.3. Nodes A and C are still reachable from each other, although this time only via nodes D and E. Equivalently, the original loop-free route (A<->B<->C) is now replaced by the new loop-free route (A<->D<->E<->C). All five nodes in the network are required to update their routing tables appropriately to reflect this topology change, which will be first detected by nodes B and C, then communicated to A, E, and D.

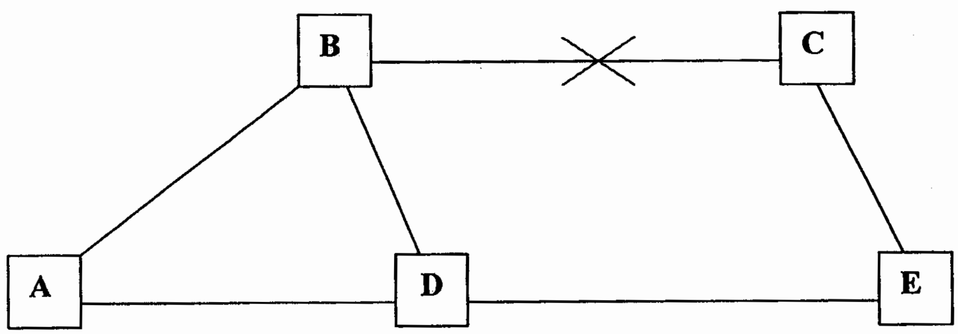


Figure 1.3: Topology update due to a link failure

This reachability relation among the nodes may also change for various reasons. For example, a node may wander too far out of range, its battery may be depleted, or it may just suffer from software or hardware failure. As more nodes join the network, or some of the existing nodes leave, the topology updates become more numerous, complex, and usually, more frequent, thus diminishing the network resources available for exchanging user information (i.e., data).

Finding a loop-free path between a source-destination pair may therefore become impossible if the changes in network topology occur too frequently. Too frequently here means that there may not be enough time to propagate to all the pertinent nodes the changes arising from the last change in network topology. Thus the ability to communicate degrades with increasing mobility and as a result the knowledge of the network topology becomes increasingly inconsistent. A network is combinatorially stable if, and only if, the topology changes occur slow enough to allow successful propagation of all topology updates as necessary or if the routing algorithm is efficient enough to propagate the changes in the network before the next change occurs. Clearly, combinatorial stability is determined not only by the connectivity properties of the networks, but also by the efficiency of the routing protocol in use and the instantaneous computational capacity of the nodes, among others. Combinatorial stability thus forms an essential consideration for attaining efficient routing objectives in an ad hoc network.

II). Characteristics of MANET

MANETs have some special features which make them different from other wired and wireless networks. Few of them are listed below:

⇒ The topology of ad hoc network is highly dynamic; nodes come in and go out of the network due to the movement of nodes outside the transmission range, nodes power off and battery failure of the mobile node during communication.

⇒ The mobile nodes have limited capabilities as most of them are:

- ➢ battery powered,
- ➢ having less CPU processing power,
- ➢ and low transmission and reception range.

⇒ MANETS are more exposed to errors than other networks.

⇒ In case when transmission power of one node is higher than the other. First may be able to communicate while the other may not, thus resulting in unidirectional link.

III). Applications of MANET

There are numerous scenarios that do not have an available network infrastructure which could benefit from the creation of an ad hoc network:

⇒ **Rescue/Emergency Operations:** rapid installation of a communication infrastructure during a natural/environmental disaster that has destroyed the previous communication infrastructure.

⇒ **Military Missions:** rapid installation of a communication infrastructure in a hostile/unknown territory.

⇒ **Commercial projects:** simple installation of a communication infrastructure for commercial gatherings such as conferences.

⇒ **Educational classrooms:** simple installation of a communication infrastructure to create an interactive classroom on demand.

1.3. Routing protocols In Ad-hoc Network

In this chapter we will discuss few topics that are closely related to our research topic that is routing in Ad-hoc Network and different routing protocols.

1.3.1. Routing

Routing in Ad-hoc Network is relatively different from other conventional wired and wireless networks. There are many reasons summarizing, why routing in Ad-hoc network is different from other networks?

- Host Mobility

  As host in MANETs are mobile, due to this mobility the link failure/repair will happen most often. Therefore the routing protocol must have capability to work with such type of environment.
- When mobile nodes move fast, that is, changing their speed and direction rapidly, the Rate of link failure/repair will be increased accordingly.
- New performance criteria may be used
  - Route Stability Despite Mobility
  - Energy Consumption

1.3.2. Protocols

For data packets to travel from a source to a destination on a network, it is important that all the devices on the network speak the same language, or protocol. Thus we can say that "A communication protocol is the set of rules, or an agreement, that determines the format and transmission of data".

Protocols are broadly classified into two main categories:

Routed Protocols

Routing Protocols

1.3.2.1. Routed Protocols

"Any network protocol that provides enough information in its network layer address to allow packets to be forwarded from host to host based on the addressing scheme". Routed protocols define the format and use of the fields within a packet. Packets are generally conveyed from end system to end system.

Most popular example of routed protocols is Internet Protocol (IP). It is a network layer protocol; as a result it can be routed over an internetwork, network of networks. It is also called as routable protocols.

1.3.2.2. Routing Protocols

Most often the networks are multi-hop; the packet has to travel through more than one hop before reaching to destination. Thus we need a mechanism to find out the correct route for each send/receive pair. For this purpose we use routing protocols both in conventional and MANET networks. Before jumping into MANET routing protocols directly, we should have a fair understanding of conventional routing protocols.

1.4. Properties of an Efficient Routing Algorithm

Many routing protocols for Ad-hoc networks have been proposed so far, each one offering some advantage over the previous approach. But in general, there are some common desirable properties that any routing protocol for an ad hoc network should possess as mentioned in [28].

⇒ **Loop free:** Presence of loops in the path from the source to the destination result in inefficient routing. In the worst-case situation, the packets may keep traversing the loop indefinitely and never reach their destination, thus resulting in the consumption of bandwidth which is scarce resource especially in the case of wireless communication.

⇒ **Distributed Control:** The Ad-hoc network routing protocols should be distributed in nature and shouldn't be dependent on central controlling node (Router) as happens in other networks. This is because nodes in Adhoc networks come in and go out very rapidly.

⇒ **Fast Routing:** The quicker the routing decisions are made, the sooner the packets can be routed towards the destination, as the probability that the packets take the chosen route before it gets disrupted because of node mobility is quite high.

⇒ **Topological changes:** Topological changes in one part of the network should lead to minimal changes in routing strategy in other distant parts of the network. This will keep the routing update overheads in check and make the algorithm scalable.

⇒ **Multiplicity of Routes:** Even if node mobility results in disruption of some routes, other routes should be available for packet delivery.

⇒ **Power Efficient:** A routing protocol should be power efficient. That is the protocol should distribute the load; otherwise shut-off nodes may cause partitioned topologies that may result in inaccessible routes.

⇒ **Secure:** A routing protocol should be secure. We need authentication for communicating nodes, non-repudiation and encryption for private networking to avoid routing deceptions.

⇒ **QoS Aware:** A routing protocol should also be aware of Quality of Service. It should know about the delay and throughput for a source-destination pair, and must be able to verify its longevity so that a real-time application may rely on it.

1.5. Classification of Routing Protocols

To achieve the required results the researchers have paid much attention to this area. As a result numbers of routing protocols have been suggested based on variety of algorithms (link-state, distance-vector). Before going into the details of these protocols we should classify them to make their discussion easier. Therefore we classify the Ad-hoc Network routing protocols as follow:

1.5.1. Reactive vs. Proactive

This is the first and very important classification of Ad-hoc routing protocols.

1.5.1.1. Proactive Routing Protocols

These are routing protocols which try to maintain always up-to-date entries in routing table for every possible source and destination. The advantage of these protocols is that when data packets are generated, they are transmitted according to routing tables' entries. That is, transmission occurs without delay, due to maintainability of up-to-date routing table entries. These protocols are suitable for wired networks and ad hoc networks where mobility is low.

But its disadvantage is that if mobility is high then a lot of traffic will be generated to maintain up-to-date routing table entries due to frequent topology changes. So it does not suit to networks where mobility is high.

Some of proactive routing protocols are given

- Destination Sequence Distance Vector (DSDV) routing protocol [20],
- Optimized Link State Routing (OLSR) [29]

1.5.1.2. Reactive Routing Protocol

In these routing protocols, routes are determined on-demand. That is when a node wants to transmit the data packets; it initiates the route discovery process to the destination. In this way it reduces control traffic. Therefore it is best suited for network with high mobility. However its data transmission rate is more than that of proactive routing protocol due to route discovery for data packet on-demand. Some of reactive routing protocols are:

- Ad-hoc On-demand Distance Vector (AODV) [30],
- Dynamic Source Routing (DSR) [18]

There are also hybrid protocols, like Zone Routing Protocol (ZRP) by combining both reactive and proactive protocol.

1.5.1.3. Centralized vs. Distributed

In centralized algorithm all route determination and maintenance is performed at centralize nodes. For example in wired networks RIP or other routing algorithms are applied at centralized routers.

In case distributed routing the process of calculating routes is shared among the network nodes participating in the network. Ad hoc network routing protocols like DSR and AODV perform in distributed fashion.

1.6. MANET Routing protocols

Ad-hoc Network attracted researchers because of its unique application. Therefore, lots of routing Protocols have been suggested. A list of well-known routing protocols is given below.

⇒ Dynamic Source Routing (DSR)

⇒ Ad Hoc On-Demand Distance Vector (AODV)

⇒ Destination Sequenced Distance Vector (DSDV)

⇒ Zone Routing Protocol (ZRP)

⇒ Clusterhead Gateway Switch Routing Protocol (CGSR)

⇒ Location Aided Routing (LAR)

⇒ Global State Routing (GSR)

⇒ Hierarchical State Routing (HSR)

As our research is focused on DSR, DSDV, and AODV, therefore, in this section we will discuss these protocols in detail.

1.6.1. Ad-hoc On Demand Distance Vector (AODV)

Ad hoc on-demand distance vector (AODV) routing protocol is also reactive routing protocol that is routes are determined in on-demand fashion. AODV also uses broad cast route discovery mechanism as used in DSR. AODV routing protocol does not use source routing mechanism but instead of that it relies on dynamically establishing routing tables at intermediate nodes. It uses destination sequence number, as used in destination sequenced distanced vector (DSDV) routing protocol, to maintain most recent routing information between nodes. However the maintenance of this sequence number is different from DSDV. In AODV each node maintain monotonically increasing sequence number counter. When a node has to send a packet to the destination and does not have valid route to that destination then it initiates route discovery process by broadcasting the route request. Each intermediate node forwarding the route request records in its routing table the address of neighbor from which it has received the first broadcast copy that is establishing reverse path along which the route reply will come. Additional copies of same route request received by that node are discarded. When route request reaches destination or the intermediate node having fresh enough route to the targeted destination then it sends the route reply message back to the neighbor from which it has received the first route request copy that is along the reverse path. When route reply message is forwarding along the reverse path then each node maintain forward route entries in their routing tables which represents active forward route. There is a timer associated with each route entries. On expiration of timer the entry is deleted. When an intermediate node detects link failure, may cause by moving of the node along the active path, it notifies its upstream neighbor nodes. These upstream neighbor nodes notify of the link failure its upstream neighbors until link failure notification reaches to the source node (originator node). The source node then may reinitiate the route discovery process if it desires. It is also possible that source node itself moves and active path is disturbed. In this case the source node may reinitiate the route discovery process.

To maintain local connectivity a node may locally broadcasts periodic Hello messages. It is also possible that a node listen to the retransmission of data packet to insure that next node is within range [14] [16].

Route Discovery mechanism in AODV Protocol

Each mobile host in the network acts as a specialized router and routes are obtained as needed, thus making the network self-starting. Each node in the network maintains a routing table with the routing information entries to its neighbouring nodes, and two separate counters: a node sequence number and a broadcast-id. When a node (say, source node 'S') has to communicate with another (say, destination node 'D'), it increments its broadcast-id and initiates path discovery by broadcasting a route request packet RREQ to its neighbors. The RREQ contains the following fields:

– Source-Address

– Source-Sequence# -to maintain freshness info about the route to the source.

– Destination-Address

– Destination-sequence# - specifies how fresh a route to the destination must be before it is accepted by the source.

– Hop –Count

The (source-adders, broadcast-id) pair is used to identify the RREQ uniquely. Then the dynamic route table entry establishment begins at all the nodes in the network that are on the path from S to D.

As RREQ travels from node to node, it automatically sets up the reverse path from all these nodes back to the source. Each node that receives this packet records the address of the node from which it was received. This is called Reverse Path Setup. The nodes maintain this info for enough time for the RREQ to traverse the network and produce a reply to the sender and time depends on network size.

If an intermediate node has a route entry for the desired destination in its routing table, it compares the destination sequence number in its routing table with that in the RREQ. If the destination sequence number in its routing table is less than that in the RREQ, it rebroadcasts the RREQ to its neighbors. Otherwise, it unicasts a route reply packet to its neighbor from which it was received the RREQ if the same request was not processed previously (this is identified using the broadcast-id and source-addr). Once the RREP is generated, it travels back to the source, based on the reverse path that it has set in it until traveled to this node. As the RREP travels back to source, each node along this path sets a forward pointer to the node from where it is receiving the RREP and records the latest destination sequence number to the request destination. This is called Forward Path Setup.

If an intermediate node receives another RREP after propagating the first RREP towards source it checks for destination sequence number of new RREP. The intermediate node updates routing information and propagates new RREP only,

– If the Destination sequence number is greater, OR

– If the new sequence number is same and hop count is small, OR

Otherwise, it just skips the new RREP. This ensures that algorithm is loop-free and only the most effective route is used [26].

The below figure 7.1 is an example, which shows how the route to the destination is found by AODV routing protocol.

Step by step explanation of figure 1 is as follows:

1. Source 'S' has to send data to destination.
2. S sends RREQ to its neighbors A, B, C.
3. B finds the path in its routing table (with destn seq-number s1 and hop count c1) and sends RREP to S.
4. C sets up reverse path.
5. C forwards RREQ to its neighbors D and E.
6. E sets up reverse path.
7. E forwards RREQ to its neighbors F and G.
8. E deletes the reverse path after a time out period as it does not receive any RREPs from F and G.
9. D finds the path (with dest seq-number s2 which is greater than s1 and hop count c1) in its routing table and sends RREP to C.
10. C receives RREP from D and sets up forward path and forwards RREP to S.[27]

11. A sets reverse path; forwards RREQ to its neighbors; receives RREP (with path of hop count c2 which is greater than c1); sets forward path; and forwards this RREP to S.

12. S receives a path info from C (with destn seq-number s2 and hop count c1), another path info from B (with destn seq-number s1 and hop count c1), and another path info from A (with destn seq-number x which is less than s1 and s2 and hop count
c2 which is less than c1).

13. S chooses path info from C (which was originated from D), giving first priority to the path with greatest destination sequence number and then second priority to the path with smallest hop count. Though path given by A is of smallest hop count, it is ignored because the destination sequence number is greater than the path from C.[27]

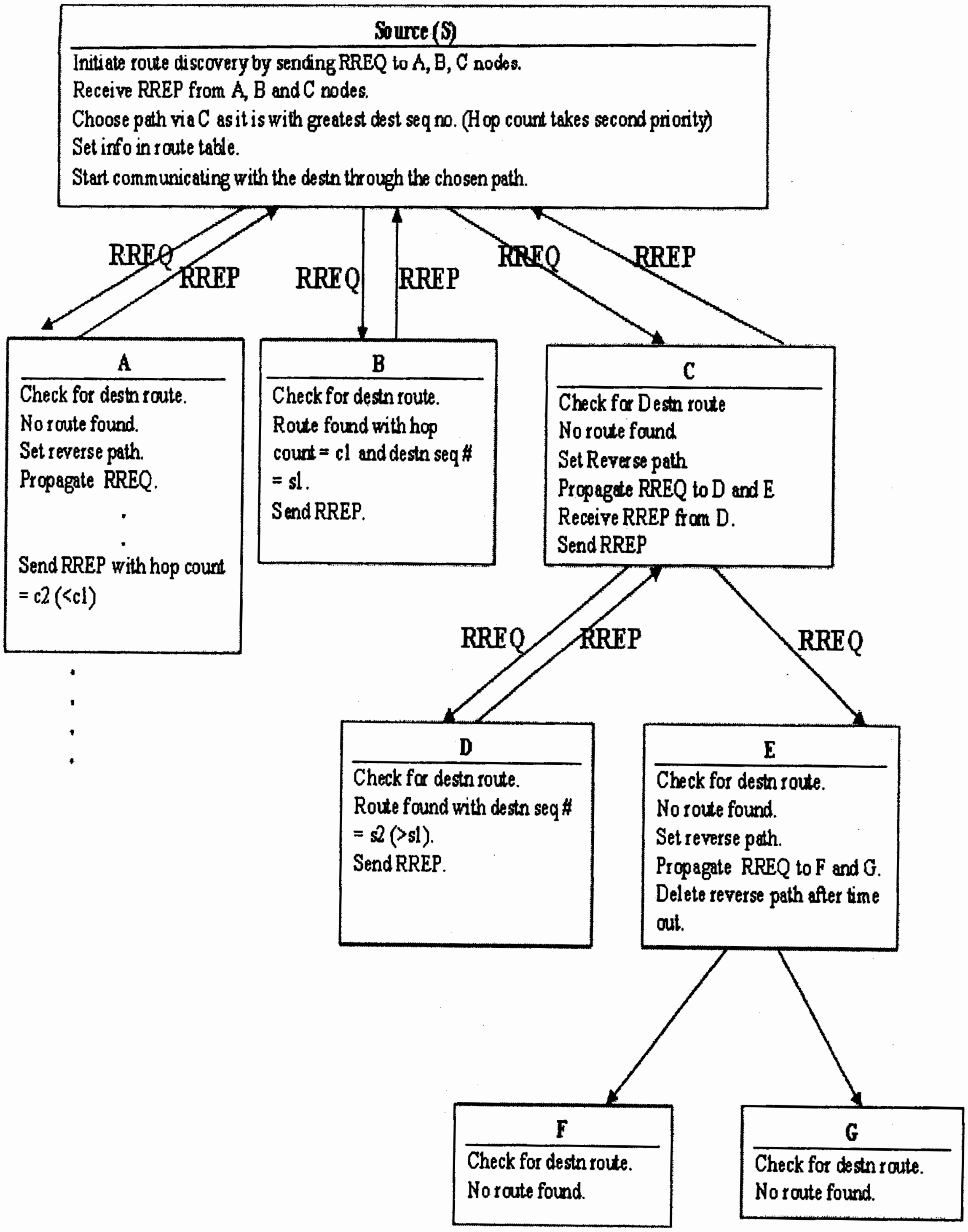


Figure 2: Route finding process in AODV Routing Protocol.

1.6.2. Dynamic Source Routing (DSR)

DSR is reactive routing protocol. Therefore route is determined in on-demand fashion that is there are no periodic route advertisements. It has two important phases, route discovery and route maintenance. When a node wants to send a packet and does not know the route to the destination, it initiates route discovery process. In this phase the node broadcast the route request, having the initiator, target destination, list of intermediate node through which it has been forwarded (initially this list is empty). Each forwarding node adds itself to the list in route request. A node receiving same route request again discard it. If the receiving node is destination or having route to destination then it sends the route reply to the initiator on the route contained in route request. Route reply has the complete list of hops (intermediate nodes) specifying the route from the initiator to the destination. When the initiator receives route reply, it stores this route in its cache so that it can be used for subsequent transmission. DSR is source routing that is the route, complete sequence of hops through which the packet should be forwarded, to the destination is specified in the packet by source. In route maintenance the host monitors that the source route is operating correctly. Each forwarding node makes sure that packet forwarded to the next hop is received correctly; this is done by acknowledgement. If next hop have not received the packet, that is the route is broken, then the node initiate route error toward the initiator (source). The initiator finds the route through route discovery mechanism again. Several optimizations for DSR routing protocol have been proposed. For example, when a node is forwarding a packet it updates its route cashes using the route present in forwarding packet. Due to source routing in DSR, the routing loop, either short-lived or long-lived, cannot be formed as they can be detected and removed immediately [14] [15] [18]

1.6.3. Destination Sequenced Distance Vector (DSDV)

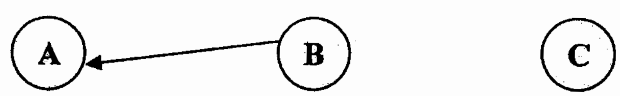
Destination sequence distance vector (DSDV) [31] is one of proactive routing protocol proposed for mobile ad hoc networks. Each node in DSDV maintains routing table, having all available destination with number of hopes to each. Each node in DSDV routing protocol advertise its routing information to neighbor nodes periodically or incrementally, according to topology condition. DSDV uses destination sequence number to avoid routing loop and count-to-infinity problem [14] [5] [21].

Loop Avoidance in DSDV

As DSDV is a distance vector routing protocol, formation of both short and long lived routing loops is a natural part of such algorithm. In case of conventional routing we use different techniques, like split horizon, maximum hop count etc to get rid of such loops. DSDV has built in feature of sequence no. for avoidance of such loops. In case of DSDV, each node periodically forwards routing table to neighbors. Each node increments and appends its sequence number when sending its local routing table. Each route is tagged with a sequence number; routes with greater sequence numbers are preferred. Each node advertises a monotonically increasing even sequence number for itself. When a node decides that a route is broken, it increments the sequence number of the route and advertises it with infinite metric. Destination advertises new sequence number.

Example

Let's consider an example, showing the working of DSDV routing algorithm. Here we consider three nodes, say A, B, and C.



Node A is receiving information from B about node C:

Let destination sequence no. at A for C is S(A). Node B sends an update S(B).

If S(A) < S(B), then A ignores the routing information received from B

If S(A) > S(B), and cost of going through B is smaller than the route known to A, then A sets B as the next hop to C.

If S(A) = S(B), then A sets B as the next hop to C, and S(A) is updated to equal S(B).

Route Discovery mechanism in DSDV Protocol

In DSDV protocol each node in the network maintains routing table for the transmission of the packets 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. The routing entry is tagged with a sequence number which is originated by the destination station. In order to maintain the consistency, each station transmits and updates its routing table periodically. The packets being broadcasted between stations indicate which stations are accessible and how many hops are required to reach that particular station. The packets may be transmitted containing the layer 2 or layer 3 address [3].

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 my 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 and the following information for each new route:

– The destination address

– The number of hops required to reach the destination and

– The new sequence number, originally stamped by the destination

The transmitted routing tables will also contain the hardware address, network address of the mobile host transmitting them. The routing tables will contain the sequence number created by the transmitter and hence the most new destination sequence number is preferred as the basis for making forwarding decisions. This new sequence number is also updated to all the hosts in the network which may decide on how to maintain the routing entry for that originating mobile host.

The mobile host cause broken links as they move form place to place within the network. The broken link may be detected by the layer2 protocol, which may be described as infinity. The broadcasting of the information in the DSDV protocol is of two types namely: Full dump and incremental dump. Full dump broadcasting will carry all the routing information while the incremental dump will carry only information that has changed since last full dump.

When an information packet is received from another node, it compares the sequence number with the available sequence number for that entry. If the sequence number is larger, then it will update the routing information with the new sequence number else if the information arrives with the same Sequence number it looks for the metric entry and if the number of hops is less than the previous entry the new information is updated (if information is same or metric is more then it will discard the information). While the nodes information is being updated the metric is increased by 1 and the sequence number is also increased by 2. Similarly, if a new node enters the network, it will announce itself in the network and the nodes in the network update their routing information with a new entry for the new node.

Example for DSDV operation

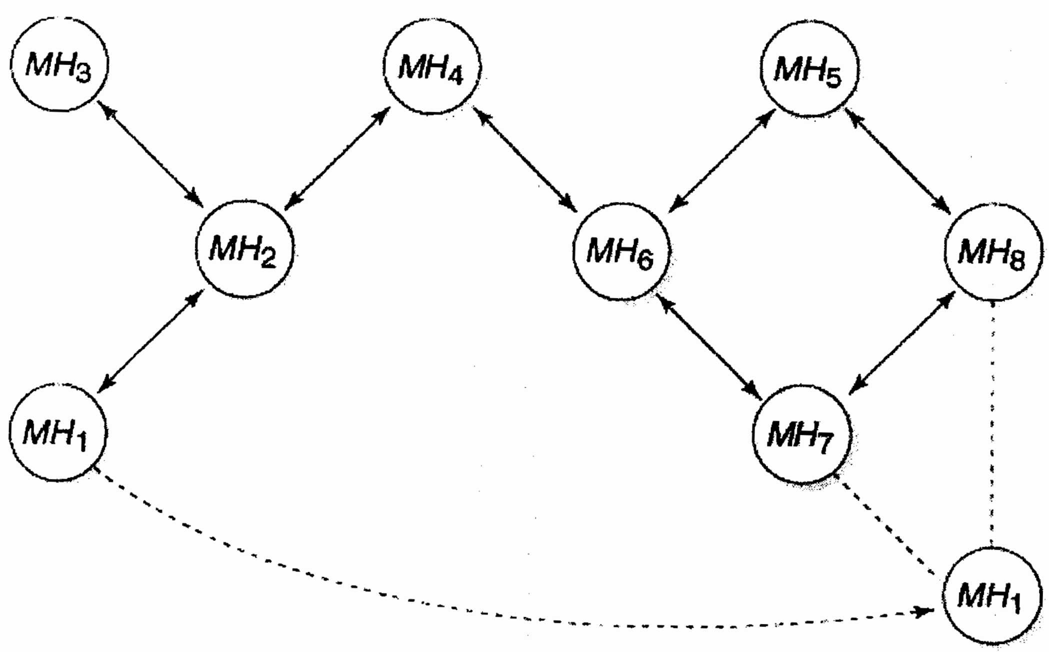


Figure 2: Movement of Mobile host in Adhoc Networks[32].

Consider the above fig. 2 which has 8 hosts in the network. We will have a look at the changes to the MH4 routing table with reference to the movements of MH1. Initially, all the nodes advertise their routing information to all the nodes in the network and hence the routing table at MH4 initially looks like

Table 1: Routing table of MH4[32]

Destination	Next Hop	Metric	Sequence Number
MH1	MH2	2	S406 _MH1
MH2	MH2	1	S128 _MH2
MH3	MH2	2	S564 _MH3
MH4	MH4	0	S710 _MH4
MH5	MH6	2	S392 _MH5
MH6	MH6	1	S076 _MH6
MH7	MH6	2	S128 _MH7
MH8	MH6	3	S050 _MH8

And the forwarding table at the MH4 would look like this

Table 2: Forwarding table at MH4[32]

Destination	Metric	Sequence Number
MH1	2	S406 MH1
MH2	1	S128 MH2
MH3	2	S564 MH3
MH4	0	S710 MH4
MH5	2	S392 MH5
MH6	1	S076 MH6
MH7	2	S128 MH7
MH8	3	S050 MH8

But, when the host MH1 moves its location as shown in the figure 2 nearer to MH7 and MH8 then, the link between MH2 and MH1 will be broken resulting in the assignment of infinity metric at MH2 for MH1 and the sequence number will be changed to odd number in the routing table at MH2. MH2 will update this information to its neighbor hosts. Since, there is a new neighbor host for MH7 and MH8; they update their information in the routing tables and they broadcast. Now, MH4 will receive its updated information from MH6 where MH6 will receive two information packets from different neighbors to reach MH1 with same sequence number, but different metric. The selection of the route will depend on less hop count when the sequence number is the same. Now the routing table will look like

Table .3: Routing table after MH1 movement [32]

Destination	Next Hop	Metric	Sequence Number
MH1	MH6	3	S516 _MH1
MH2	MH2	1	S238 _MH2
MH3	MH2	2	S674 _MH3
MH4	MH4	0	S820 _MH4
MH5	MH6	2	S502 _MH5
MH6	MH6	1	S186 _MH6
MH7	MH6	2	S238 _MH7
MH8	MH6	3	S160 _MH8

And the forwarding table will look like

Table 4: Forwarding table at MH4 after Movement of MH1 [32]

Destination	Metric	Sequence Number
MH1	3	S516 _MH1
MH2	1	S238 _MH2
MH3	2	S674 _MH3
MH4	0	S820 _MH4
MH5	2	S502 _MH5
MH6	1	S186 _MH6
MH7	2	S238 _MH7
MH8	3	S160 _MH8

Optimized Link State Routing Protocol

Optimized Link State Protocol (OLSR) is a proactive routing protocol, so the routes are always immediately available when needed. OLSR is an optimization version of a pure Link state protocol. So the topological changes cause the flooding of the topological information to all available hosts in the network. To reduce the possible overhead in the network protocol uses Multipoint Relays (MPR). The idea of MPR is to reduce flooding of broadcasts by reducing the same broadcast in some regions in the network, more details about MPR can be found later in this chapter. Another reduce is to provide the shortest path. The reducing the time interval for the control messages transmission can bring more reactivity to the topological changes. [33] OLSR uses two kinds of the control messages:

Hello and Topology Control (TC). Hello messages are used for finding the information about the link status and the host's neighbors. TC messages are used for broadcasting information about own advertised neighbors which includes at least the MPR Selector list. The proactive characteristic of the protocol provides that the protocol has all the routing information to all participated hosts in the network. However, as a drawback OLSR protocol requires each host periodically to send the updated topology information throughout the entire network. This increases the protocols bandwidth usage. But the flooding is minimized by the MPRs, which are only allowed to forward the topological messages.

1.7. Mobility Models

There are numerous mobility models, but since we have taken one mobility model for our research that is Random way point Mobility Model, so I am going to explain them. They are:

1.7.1. Random Waypoint Mobility Model

Another one of the most commonly used mobility model is Random Way Point [16, 27]. It is also implemented in ns-2[18]. In Random Way Point Mobility model each node selects uniformly at random a destination point, called waypoint, in the simulation area.

The node move toward this destination with velocity selected uniformly at random [Speedmin, Speedmax]. When node reaches its destination, it pauses for some predefined time, called pause time. After pause time, the same process is repeated by the node.

If pause time in Random Waypoint mobility model is equal to 0 then this model behave similar to random walk mobility model [16].

Figure 2.2 shows the traveling pattern of mobile nodes in Random Waypoint mobility model.

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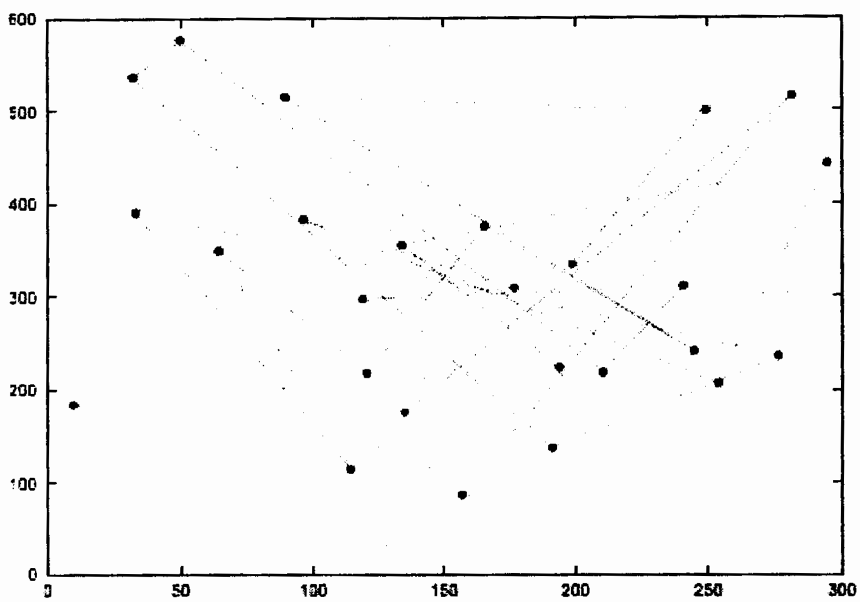

Figure 2.1 - Traveling pattern of an MN using the Random Waypoint Mobility Model

1.7.2. Random Walk Mobility Model

One of the most widely used mobility model is Random Walk Mobility Model [17]. The movement of many entities in nature is unpredictable, like the movement of molecules of air [17]. In this mobility model a node moves from one location to another location by choosing randomly direction and speed according to predefined range between [0, 2π] and [Speedmin, Speedmax] respectively. Each movement in Random Walk Mobility model occurs in either constant interval time t or constant distance traveled d, at the end of which new direction and speed are calculated. There are various derivatives of this mobility model including 1-D, 2-D, 3-D and d-D developed [17]. In Random Walk

Mobility model the entity movement is around its starting point, without worry of the entity wandering away never to return. Figure 2.1 shows traveling pattern of a node in Random Walk mobility model.

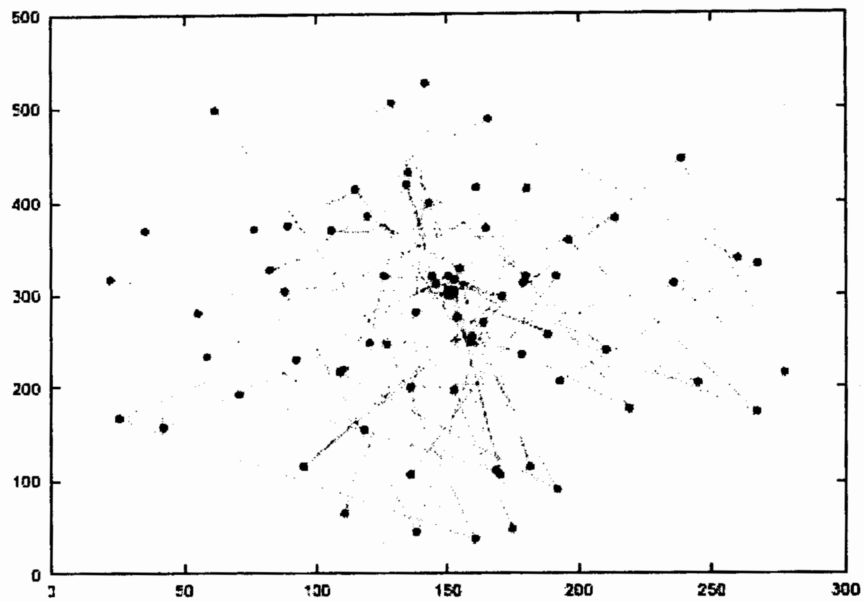

Figure 2.2 – Traveling pattern of an MN using the 2-D Random Walk Mobility Model

1.7.3. Random Direction Mobility Model

It was observed that Random Way Point Mobility model results to a situation called density waves [26]. In this situation the nodes converge at the centre of simulation area, and then disperse, and then converge again. The nodes select the new destinations that are either in the middle of simulation area or which require traveling through the centre of the simulation area. To handle such a situation, [26] developed Random Direction Mobility model.

In Random Direction Mobility model the nodes first choose a direction, and then find the destination on the boundary of simulation area in this line of direction and then select a speed. Initially the direction selected by each node is between 0 to 359 degree. Then start motion toward the destination. When reached to the destination node pauses for some predefined time. Then it selects direction between 0 to 180 degree and continues the same above process. A variant form of Random Direction Mobility model has also been developed called Modified Random Direction Mobility model. In this mobility model, the nodes select the direction similarly as in Random Direction Mobility model but they are not forced to select destination on the simulation boundary. That is they can select the destination any where along that direction. Similarly they pause when reached to the destination for some predefined time.

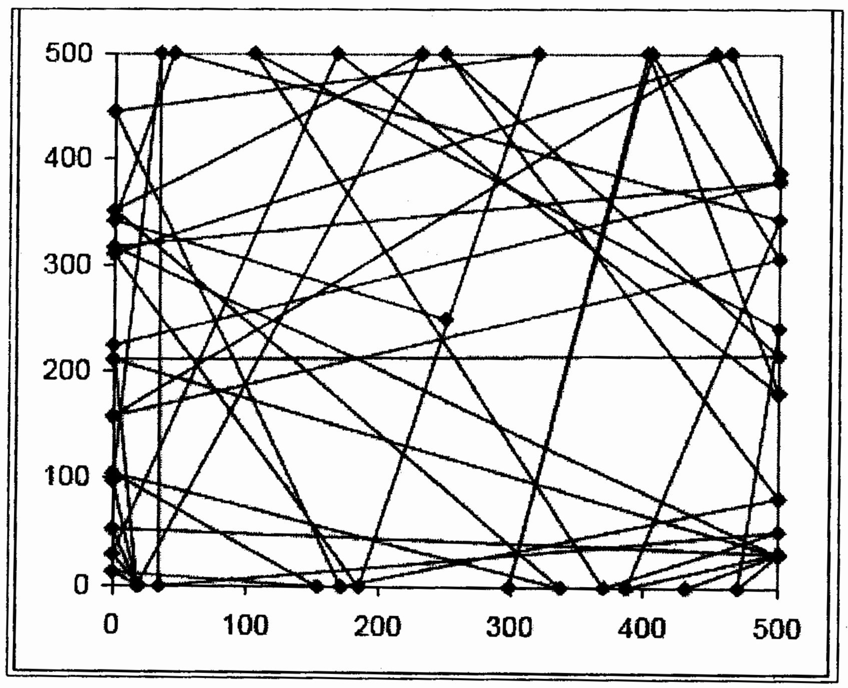

Figure 2.3 - Traveling pattern of an MN using the Random Direction Mobility Model.

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Chapter 2

Literature Review

2. Literature Review

This chapter provides an overview of the related work to our research project.
There are many research papers with the performance evaluation of Adhoc network protocols but they use different metrics to evaluate there results instead of nodes mobility and nodes velocity some of them. In this section an overview of some papers is covered.

3.1. Research Work of Performance and Quantitative Analysis

In this paper [1], the authors ***Md. Abdullah-Al-Mamun, M. Mahbubur Rahman*** investigate the performance of TCP of various (single-hop and multi-hop) routing protocols for mobile ad hoc networks. Using *ns*-2, here the Authors evaluate the TCP window size, throughput and packet delay over a single TCP connection. And there results shows that the various performance metrics are tightly related, and that TCP performance is tightly coupled with the stability and length of the routing path of each routing protocol.

A variety of routing protocols have been proposed for Mobile Ad-Hoc Networks. However, little attention has been paid to study the performance of TCP traffic over these protocols. Therefore the authors investigate the performance of TCP over multi hop routing protocols using simulations in *ns*-2 for a range of node mobility with a single traffic source. The performance metrics that they considered include TCP window size , throughput and packet delay. Based on numerical results, they show that TCP performance is tightly coupled with the stability and length of routing paths. Therefore they plan to investigate TCP performance of routing protocols with multiple traffic sources.

In this paper[2] the Authors ***H. M. El-Sayed O. Bazan,U. Qureshi, M. Jaseemuddin*** shows that the Ad-hoc networks offer challenges to TCP's congestion control mechanism related to its inability of distinguishing between losses induced by congestion and others types of losses. There are numerous articles to deal with this issue that can be broadly categorized to either end-system based or network-assisted. In this paper the author present a summary of those articles with emphasis on their distinguishing characteristics. The author of the paper also present the performance study of an end-system based mechanism that performs precise detection of network states by measuring appropriate metrics. They evaluate its performance under variety of network conditions running different class of routing protocols DSR (reactive) and DSDV [5] (proactive). Their performance study shows the effect of different factors in isolation and in combination with each other on the TCP performance, and the impact of routing protocol design approaches in the TCP stability.

They simulated TCP session in mobile ad-hoc network running two different classes of routing protocols – DSR representing on-demand and DSDV representing link state protocol, under a variety of network conditions. Their conclusions are as follows:

(1) Congestion exhibits more dynamic behaviour due to node mobility. Congestion duration varies depending upon the path intersection whereas congestion level varies due to session intersections.

(2)Channel error causes packet losses and packets out of order delivery because of routing changes.

(3) Asymmetric routes result in RTT variations.

(4) Combined effects of channel error, congestion and mobility result in increasing congestion level, packets out of order ratio and packet loss ratio.

Furthermore, the main source of throughput degradation in DSR seems to be POOR whereas in DSDV it seems to be PLR. [6]

In this paper [8], the authors **Jerome Haerri, Fethi Filali and Christian Bonnet** evaluate AODV and OLSR performance in realistic urban scenarios. They studied those protocols under varying metrics such as node mobility and vehicle density, and with varying traffic rates and show that clustering effects created by cars aggregating at intersections have remarkable impacts on evaluation and performance metrics. They provide a qualitative assessment of the applicability of the protocols in different vehicular scenarios. In this paper, they evaluated the performance of AODV and OLSR for vehicular ad hoc networks in urban environments. The traffic regulations and the vehicles characteristics handled by the vehicular mobility model (VMM).They create a clustering effect at intersection. This effect has remarkable properties on standard performance evaluations of ad hoc protocols. The first one is that neither the initial nor the maximum velocity has any influence on routing protocols in urban environments. Indeed, due to the interaction with the spatial environment and also other neighbouring cars, vehicles experience non negligible speed decay independent of the network velocity. Then, a second property is local increase of nodes density, which clearly has a consequence on both tested ad hoc routing protocols. The Authors tested OLSR and AODV against node density and data traffic rate. They found that OLSR outperforms AODV in VANETs. For most of the metrics used in this paper, OLSR has better performance that AODV. Indeed, OLSR has smaller routing overhead, end-to-end delay and route lengths. And for the PDR, where OLSR may be outperformed by AODV after a certain threshold, the performance loss is limited to 10%. Accordingly, unlike a previous study for MANET ([7]), which suggested that neither OLSR nor AODV could outperform each others, OLSR, a proactive protocol, is more fitted to VANET than reactive ones. They showed that the average velocity was not a valid parameter to evaluate routing protocols in VANET under realistic motion patterns. Accordingly, for future realistic performance evaluation, one should rather evaluate ad hoc protocols against new metrics, such as acceleration/ deceleration capabilities of the drivers, or the length of street segments instead of simple average mobility. They deliberately parameterized the network to be fully connected, to avoid biased results from disconnected graphs. However, as stated in the paper, network disconnections are also a major property of VANETs and we will perform similar tests with shorter transmission range. They evaluate the effect of heterogeneous vehicles in urban environments on routing protocols for VANETs. Finally, they plan to include geographical forwarding protocols in future performance evaluation as they are more suited to dense networks or to frequent network disconnections.

In This paper [7] the Authors **REN Wei, YEUNG D.Y, JIN Hail** presents evaluation and comparison of the TCP performance in different mobile scenarios generated by Random Waypoint (RW) (the Random Waypoint (RW) mobility model to generate the node moving scenarios so that other mobility models were ignored) and Social Network (SN) mobility models. In this paper the authors discussed the impact of AODV and DSDV routing protocols on the TCP through put, delay and drop rate performance. Their Extensive simulation results and analysis showed that TCP has better performance over AODV than over DSDV and has more stable performance in SN mobility than in RW mobility. Therefore they suggest using more mobility models, in particular, such as SN, in the evaluations of the transport layer or routing layer protocols because the mobility patterns have impacts on the protocol performance. In this work, they evaluate the TCP performance including the good put, delay and drop rate over AODV or DSDV routing protocol in Random Waypoint mobility model and in Social Network mobility model. Extensive simulation results and analysis showed that the TCP performance is better over AODV than over DSDV because of its higher good put, lower drop rate and is more stable in different mobile host speed scenarios, in the scenarios generated by both Social Network mobility model and Random Waypoint mobility model.

TCP performance is more stable in the mobile patterns of Social Network mobility model than in the mobile patterns of Random Waypoint mobility model. Therefore they suggest using more mobility models, in particular, such as SN, in evaluating the performances of the transport layer protocols because the mobility patterns have impacts on the protocol performance.

The host speeds also should be considered especially if the mobility model is Random Waypoint.For TCP over AODV and RW, the maximized host speed with intermediate (10 m/s) value has the best good put and drop rate performance. For TCP over AODV and SN, the hosts with lower speed have better goodput and drop rate performance.[7]

In this paper [9] the Authors **K.Kathiravan, Dr. S. Thamarai Selvi, A.Selvam** evaluate TCP optimization in mobile ad hoc networks MANETs is a challenging issue because of

NS-2 is used as the simulation tool. The simulation environment contains 50 nodes and the simulation time is 200 seconds.

All protocols are provided with identical traffic load and mobility patterns, while considered TCP and UDP as transport protocols and FTP as a traffic generator. The simulation results show that DSDV being a pro-active protocol, in most cases, offer low average delay while DSR introduces significant delay before transferring the packet. AODV produces low delay than DSR and TORA.

DSDV performance is best considering its ability to maintain connection by periodic exchange of information which is required for TCP based traffic. But for highly mobile multihop networks, UDP is preferred as a transport protocol. The authors are of the view that for such traffic, a reactive routing protocol like DSR is better than proactive routing protocol.

Pillai Unnikrishnan, in the paper "Introduction and analysis of DSR protocol" [15] have presented analysis of DSR, an important reactive MANET routing protocol.

First Mr. Pillai has presented DSR protocol design overview and it properties in detail. Route Discovery and Route Maintenance are important steps in DSR working mechanism. DSR also provide support for heterogeneous networks. Next DSR protocol is compared with AODV.

Finally the behavior of DSR protocol has been simulated with the NS-2 network simulator. The simulations were run in ad hoc networks of 50 mobile nodes. It was seen that the DSR protocol worked well in scenarios with relatively small amounts of DSR nodes. DSR does not need any periodic link status sensing or routing advertisements because of the fact that DSR embeds control information in the data packets, which is sent to the network. It can be seen that the protocol worked quite well with very little overhead when the functionalities were up to specifications. Routing instability may be a cause of concern in DSR when the protocol relies on every source to know the best path to the destination. If the path is no longer valid and the other network elements know that the source would still insist that the path is correct. Since DSR supports unidirectional links as well as bi-directional, there arises no problem in the directionality of a link in an ad hoc network.

Link failures in DSR are mild and causes of route discovery are less. Since there is a large amount of cached routes in each node in DSR, route discovery is delayed until all the cached routes fail. Caches getting stale are quite high when with high mobility and with low mobility link failures are low. DSR performed better in less stressful conditions because of the aggressive caching features in use. Finally DSR requires that every node in the network should trust each other.

Vahid Garousi, in the paper "*Analysis of Network Traffic in Ad-Hoc Networks based on DSDV Protocol with Emphasis on Mobility and Communication Patterns*" [21] has presented DSDV analysis with emphasis on mobility and communication pattern. First of all he has carried out detailed description of DSDV protocol design and working. DSDV is a hop-by-hop vector routing protocol requiring each node to periodically broadcast routing updates. One key advantage of DSDV over traditional vector protocols is that it guarantees loop-freedom. Each DSDV node maintains a routing table for the "next hop" to reach a destination node. DSDV tags each route with a sequence number and considers a route R more favorable than $\underline{R}$ if R has a greater sequence number than, or if the two routes R and $\underline{R}$ have equal sequence numbers but R has a lower metric (such as transmission cost).

Finally author has carried out some simulations in NS-2. The following parameters are varied to check DSDV performance.

- ⇒ Scene Area Size.
- ⇒ Number of Mobile Nodes.
- ⇒ Pause Time.
- ⇒ Maximum Speed.
- ⇒ Number of Connections.
- ⇒ Transmission Rate.

It can be seen that, the number of forwarded packets increases as the size of the ad-hoc network scene area increases. In the same way, ratio of lost packets decreases with an increase in number of mobile nodes. When nodes make a longer pause between two consecutive moves, ratio of forwarded packets increases. However, when the number of connections in the network is 40, packet overhead (ratio of forwarded packets) does not change considerably with changes in nodes' pause time.

The analysis also point out that when nodes are moving faster, fewer packets are dropped (lost) and the routing overhead is less than the case when the nodes are moving with less speed. Increasing the number of connections among fixed number of nodes enhances the routing overhead and the packet delivery rate. Increasing the transmission rate in an ad-hoc network with fixed size and number of nodes increase the number of transmitted packets in different groups.

Karavetsios, Economides in their paper titled "Performance comparison of distributed routing algorithms in ad hoc mobile networks" [22] have also carried out detailed performance comparison of distributed algorithms (AODV, DSDV) in ad-hoc networks. First of all they have classified routing protocols in MANETs as Table-Driven, Demand-Driven and Hybrid.

Simulation model is developed finally to check the performance of protocols. Most simulations use a file that describes the movement scenario of nodes. The scenario files are edited so that all the different network situations would be extensively simulated. Scene Length, number of Nodes, Pause Time, and Maximum Speed are different parameters for generation of mobility scenarios.

Authors have selected the DSDV routing as the "representative" of the Table-Driven protocols because it maintains a loop-free fewest-hop, which means the creation of fewer forwarded packets, path to every destination in the network. DSDV achieves a low Routing Overhead and low Average Delay. They selected AODV as the second algorithm for their comparisons because it supports unicast and multicast packet transmissions and it achieves the lowest Routing Overhead from other protocols in its category. AODV also contains mechanisms that help to select the least congested route instead of the shortest route.

While it is not clear that any particular class of algorithm is the best for all network conditions, each protocol has definite advantages and disadvantages and has certain situations for which it is well suited. Deductively, AODV algorithm is a more efficient routing protocol than DSDV, when the pause time of nodes' movement is small. When the nodes stay unmoving for a long time, DSDV is preferable.

3.1. Research Work of Mobility Models

Very limited number of papers are available on the mobility models. The following papers describe the mobility models in much detail.

T. Camp, Jeff Boleng and Vanessa Davies in [23] have presented a detailed survey of different mobility models for Adhoc networks. Some are listed below:

- ⇒ Random Walk
- ⇒ Random Waypoint
- ⇒ Random Direction
- ⇒ Gauss-Markov
- ⇒ City Section
- ⇒ A Probabilistic Version of the Random Walk Mobility Model
- ⇒ Group mobility model

After this the authors have explained the importance of mobility models and their effect on the performance of different routing protocols. For this purpose DSR protocol is considered. After simulating different scenarios, different metrics like throughput, end-to-end delay, number of hop counts etc are calculated in above mentioned mobility models to show the effects of mobility models.

It is concluded from the paper that mobility models affect the performance of protocols significantly. Keeping all other parameters same and changing only mobility model in simulation, results dramatic change in the behaviour of DSR protocol performance. In the same way changing a single parameter like pause time within a mobility model considerably alters DSR performance.

The authors are of the view that they should design more mobility models, which closely represent the scenarios in actual life. The important thing is that NS-2 has built-in support for only RandomWay mobility model. But the authors of this paper have coded other mobility models that can be implemented in NS-2.

Fan Bai and Ahmed Helmy's, "*survey of mobility models*" in Wireless Adhoc Networks [24], also presents detailed description of mobility models for Adhoc networks.
Fan and Helmy presented a detailed survey and examination of different mobility models proposed in the recent research literature. Beside the commonly used Random Waypoint model and its variants, models that exhibit the characteristics of temporal dependency, spatial dependency and geographic constraints are also discussed. As they have attempted to provide an overview of the current research status of mobility modeling and analysis.

3.2. Research Work of Routing Protocols

Adhoc networking is an exciting research area nowadays. Therefore, plenty of literature is available related to Adhoc network and especially its different routing algorithms.

Yih-Chun Hu & David B. Johnson in [16] have proposed and analyzed the use of implicit source routing in ad hoc networks, and shown that it preserves the advantages of source routing while avoiding the associated per-packet overhead in most cases. Authors have evaluated this technique through detailed simulations of ad hoc networks based on the Dynamic Source Routing protocol (DSR), an on-demand ad hoc network routing protocol based on source routing.

David B. Johnson & David A. Maltz in their paper "Dynamic Source Routing in Ad Hoc Wireless Networks" [18] have discussed DSR protocol. This paper presents a protocol for routing in Adhoc networks that uses dynamic source routing. The protocol adapts quickly to routing changes when host movement is frequent, yet requires little or no overhead during periods in which hosts move less frequently. Based on results from a packet-level simulation of mobile hosts operating in an ad hoc network, the protocol performs well over a variety of environmental conditions such as host density and movement rates.

Charles E. Perkins and Pravin Bhagwat in [20] have described DSDV protocol for mobile computers. First, they have introduced Adhoc networks and then routing challenges specific to Adhoc networks. DSDV is presented as a routing protocol. Also layer-2 functions are described, which traditionally hasn't been utilized as a protocol level for routing. They have explained the DSDV operations with the help of examples in tables. Different properties for example, guaranteed loop-free path to each destination etc. of DSDV protocol is also discussed. Finally this routing mechanism is compared to other routing algorithms of Ad hoc networks.

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Chapter 3

Research Methodology

3.1. Methodology

The research methodology defines what the activity of research is, how to proceed, how to measure progress, and what constitutes success .Different methodologies defined by distinct schools which wage religious war against each other.

Methods are tools used. Don't let them use you. Don't fall for slogans that falls one above the others: "research needs to be put on firm foundations;" "Philosophers just talk." You have to know what's computed before you ask how. To succeed at research, you have to be good at technical methods and you have to be suspicious of them. For instance, you should be able to prove theorems and you should harbor doubts about whether theorems prove anything.

The method section answers these two main questions:

1. How was the data collected or generated?
2. How was it analyzed?

In other words, it shows your reader how you obtained your results.

But why do you need to explain how you obtained your results?

- We need to know how the data was obtained because the method affects the results. For instance, If you are investigating users, perceptions of the efficiency of public transport in Bangkok, you will obtain different results if you use a multiple choice questionnaire than if you conduct interviews. Knowing how the data was collected helps the reader to evaluate the validity and reliability of your results, and the conclusion you draw for them.
- Often there are different methods used to investigate a research problem. Your methodology should make clear the reasons why you choose a particular method or procedure.
- The reader wants to know that the data was collected or generated in a way that is consistent with accepted practice in all fields of study. For example if you are using a questionnaire, readers need to know that it offered your respondents a reasonable range of answers to choose from (asking if the efficiency of public transport in Bangkok is "a. Excellent, b. Very good or c.

good" would obviously not be acceptable as it doesn't allow respondents to give negative answers).

- The research methods must be appropriate to the objective of studies. If you perform a case study of one commuter in order to investigate users, perceptions of the efficiency of public transport in Bangkok, your method is obviously unsuited to your objectives.
- The methodology should also discuss the problems that were anticipated and explain the steps taken to prevent them from occurring , and the problems that did occur and the ways their impact was minimized.
- In some cases, it is useful for other researcher to adapt or replicate your methodology, so often sufficient information is given to allow others to use the work. This is particularly the case when a new method had been developed, or an innovative adaptation used.

Some work is like science. You look at how people learn arithmetic, how the brain works, how kangaroos hop, and try to figure it out and make a testable theory. Some work is like engineering: you to build a better problem solver or shape from algorithm. Some work is like mathematics: you play with formalisms, try to understand their properties, prove thins about them. Some work is example driven, trying to explain scientific phenomenon. The best work combines all these and more.

3.2. Problem Definition

Ad-hoc network is an active research area now-a-days. Researcher analyzed the ad hoc networks in different scenarios such as.

- Different Researchers have analysed these protocols in different mobility patterns of mobile nodes.
- Some have targeted the transmission power of mobile nodes in these ad-hoc networks.
- Others have evaluated the performance of different routing protocols using different combinations of transmission power, mobility, pause time etc.
- The Research area which needs more work & still demanding the researcher's attention is to work out efficiency of such networks in reliable (suitable for delay tolerant and error sensitive data) & unreliable (for delay sensitive and

error tolerant information such voice and video streaming) transport layer protocols.

- Similarly node density is another area of greater importance. In real life we have ad hoc networks of variable sizes in terms. For example there are only two users involved in case simple Bluetooth connection between two mobiles. In conferences the nodes may vary from few to hundred depending of no. of participants. Similarly in some cases we may have nodes greater than few hundreds as in case of commercial Airlines. Therefore we should have prior knowledge of the behaviour of ad hoc in such type of networks.
- This is why I selected this Area for my MS research to further explore this exciting field of ad hoc networks both in reliable and unreliable transport with varying nodes density.

3.3. Basic Scenario

1. Project Defined Scenario
Project.Tcl

In this module we have created our basic scenario,

a. Pairing of nodes

We change the nodes density in every step for each protocol.First we check AODV with 50 nodes 75, 100, 125 and 150 nodes resectively.we also change the velocity of nodes in each scenario in first scenario the nodes velocity is 5 meter/second and than gradually increases to 10, 15, 20, 25 and 30 m/s. Similarly we also check DSDV and DSR with different Nodes density and velocity. We check the effects on these matrics changes on each protocol.

b. Defining transmission area, transmission range and transmission time, etc. here we us transmission area of 1500 x 1500.our transmission range is 250 meters.

c. Simulation time etc.

2. There are two portions in this step and the difference lies in this step of our project left and right side.

A. Transmission Control Protocol (TCP)

On left side of the Diagram in module 4 we use Transmission control protocol which further use File transfer protocol (FTP) on application layer to deliver the data from sender to receiver.

B. User Datagram protocol (UDP)

On Right Side of the diagram in Module 4 we use user datagram Protocol which uses constant Bit Rate (CBR) to send data packets from source to destination.

3. Protocols:

In this module we apply well known routing protocols to second module. The protocols are mentioned below:

1. Destination Sequenced Distance Routing (DSDV)
2. Dynamic Source Routing (DSR)
3. Ad-hoc On-Demand Distance Vector Protocol (AODV)
4. Optimized Link State Routing Protocol (OLSR)

The details of these protocols are given in Introduction part of this document.

4. Project Reliable/ Unreliable Protocol

In this module, we applied the above mentioned ad hoc network routing protocols (DSDV, OLSR, DSR, and AODV) in both sections that is reliable and unreliable.

5. Network Simulator-2 Run

In this module we run our project on Network Simulator-2 and observe the whole implementation carefully.

6. Trace_Project_Reliable / Unreliable protocol

After simulating our scenarios, we get trace files for each simulation. These files give us information about no. of packets send/received, delay, overload, packet ID, port numbers etc.

7. Analysis & Filtering

The resulted Trace File for each protocol is analyzed in this module. On the basis of both trace files TCP and UDP obtain from all protocols with different node density, velocity we draw 27 graphs with help of which we analyze the behavior of each protocol in that particular environment.

8. Evaluation & Conclusion

In this step we evaluate and conclude the entire graphs and here we are able to decide a protocol to use in our required scenario.

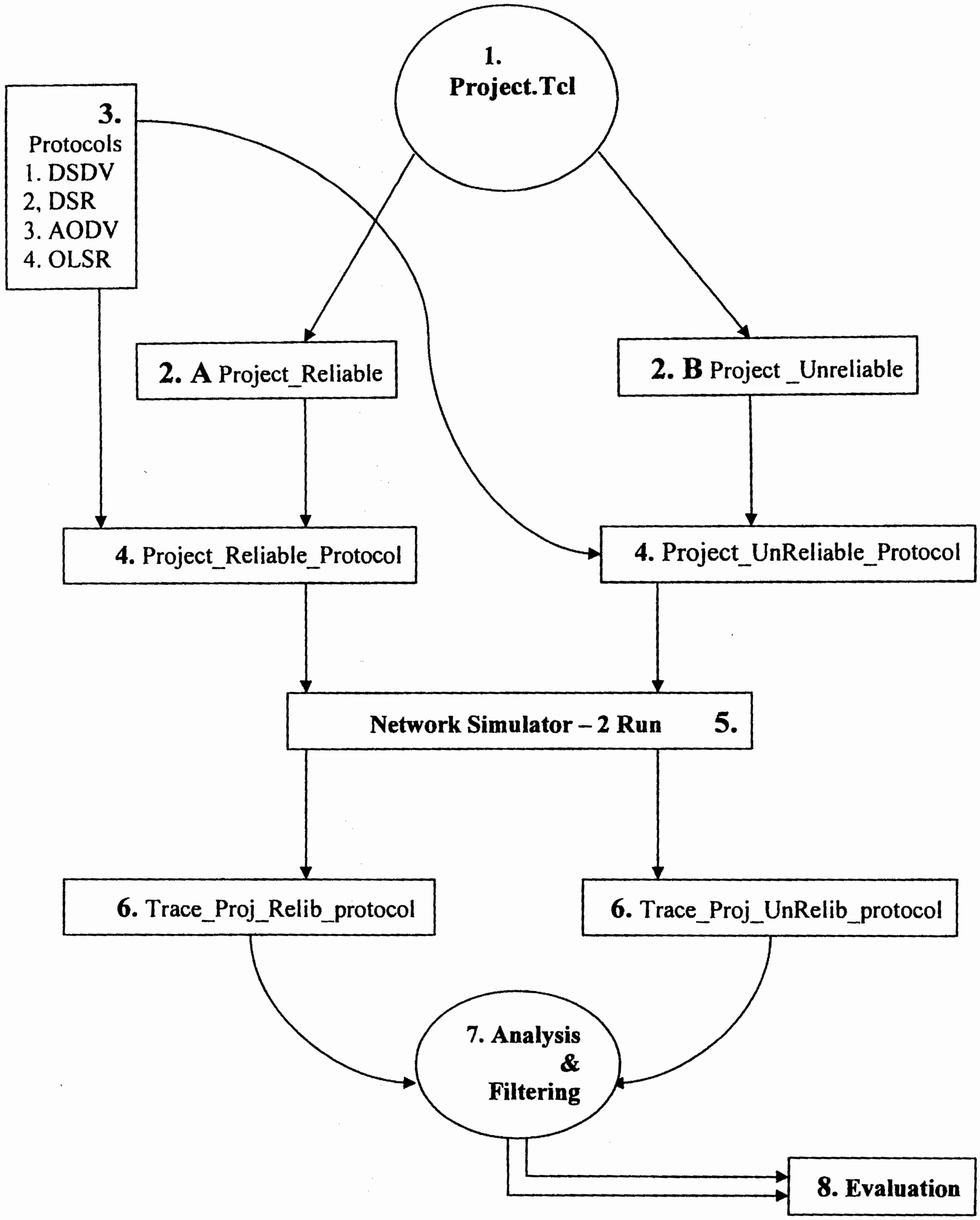

Figure 3.1. An Overview of My Basic Solution Scenario

3.4. Performance Metrics

This is the most important chapter in our thesis, since it deals with the performance evaluation of Ad-Hoc Network routing protocols (AODV, DSDV, DSR) with both TCP and UDP under variable nodes density. The performance metrics we used here are packets received, packets lost, Nodes velocity, Delay and Overload etc

1. Throughput

The amount of data transferred from one place to another or processed in a specified amount of time. Data transfer rates for disk drives and networks are measured in terms of throughput. Typically, throughputs are measured in kbps, Mbps and Gbps.

Percentage throughput = (No. of packet received / No. of packets sent)* 100

2. Packet Received

Packet received is equal to number of packets send form source minus number of packet loss in the path to destination.

No of Packets Received = No of packets send – No of packets Loss

3. Delay

The average time taken by the data packet to reach the intended destinations, here we considered Average End-to-End delay. This include delay occurred due to different reasons like queuing delay, propagation delay, processing delay etc. it is an important parameter for delay sensitive application like multimedia application. It is also very important for application where data is processed online.

$$Mean\ Delay = \frac{\sum_{i=1}^{n} Delay\ Of\ Packet}{n}$$

4. Overhead:

Overhead is the extra information which is needed to deliver the packet to its right destination. It depends on the routing protocol which you are using for communication.

Chapter 4

Implementation & Results

Implementation and Results

In chapter 3 we explain our methodology adopted and now in this chapter we explain its implementation scenarios and results. Our goal is to carry out a systematic performance study of four routing protocols for ad hoc networks namely Ad hoc On Demand Distance Vector (AODV) Routing protocol, Dynamic Source Routing (DSR) protocol, Destination Sequence Distance Vector (DSDV) routing protocol and Optimized Link State Routing (OLSR) protocol.

4.1) Implementation Approach and Scenarios:

Here we are analyzing Adhoc network protocols both proactive protocols (OLSR and DSDV) and reactive protocols (AODV and DSR) under TCP and UDP traffic for various performance parameters such as throughput, overhead and delay. First we created different scenarios with variable node density of 50, 75, 100, 125 and 150 respectively. Than we specify the velocity of these nodes in each particular scenario. The velocity of the nodes is 5 meter per second as lower level 15 meter per second as moderate and 30 meter per second as high level.

We use random way point mobility model for nodes movement. In Random Way Point Mobility model each node selects uniformly at random a destination point, called waypoint, in the simulation area and start movement toward that point. When node reaches its destination, it pauses for some predefined time, called pause time. After pause time, the same process is repeated by the node.

We start from throughput and analyze each protocol throughput with varying node density and velocity. In case of UDP and TCP traffic we observe the affect on each protocol throughput. Than we check overheads and delay for all protocols both in case of UDP and TCP. In the last we analyze the results for throughput, end to end delay and overhead in each protocol with variation of node density and mobility.

4.2) Different Parameters Used in Research Project:

Parameters	Values
Source data rate	8 Kbps
Source Nodes	10
Packet Size	500 Bytes
Initial Energy	1000 Joule
Transmission Power	2.0 J
Reception Power	1.0 J
Idle Power	1.0 J
Sleep Power	0.001
Varying Node Density	50,75,100,125,150
Nodes Mobility	5,15,30 (m/sec)

4.3) NS-2 Simulation Environment

The MANET network simulations are implemented using NS-2 simulator. Nodes in the simulation move according to a model that we call Random Waypoint Mobility model. Each node is then assigned a particular trajectory. The simulation period for each scenario is 200 seconds and the simulated mobility network area is 1500 m x 1500 m rectangle. In each simulation scenario, the nodes are initially located at the center of the simulation region. The nodes start moving after the first 10 seconds of simulated time. The MAC layer protocol IEEE 802.11 is used in all simulations with the data rate 11 Mbps.

4.4) Throughput Vs Node density with TCP traffic

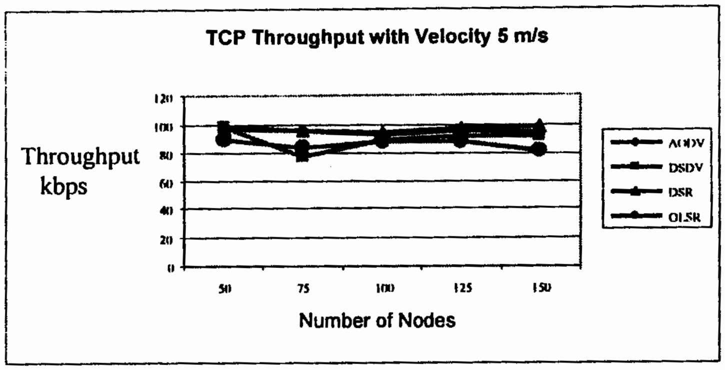

Figure 4.1) TCP Throughput with Velocity 5 m/s

Figure 4.1 shows throughput comparison. Throughput of reactive protocols AODV and DSR is greater than proactive protocols OLSR and DSDV.As the number of nodes increases in the network there is no major change in throughput of these protocols except OLSR approaches to 80%.

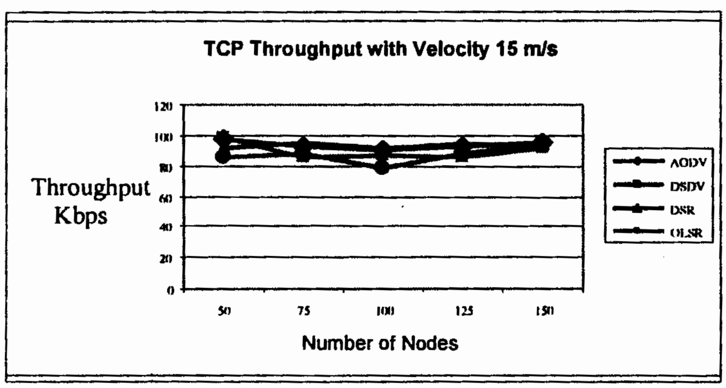

Figure 4.2) TCP Throughput with Velocity 15 m/s

Figure 4.2 shows throughput of four different routing protocols with different node density and velocity (15m/s). Again the throughput of AODV and DSR is consistent but sudden variations in throughput of both DSDV and OLSR as the node density increases.

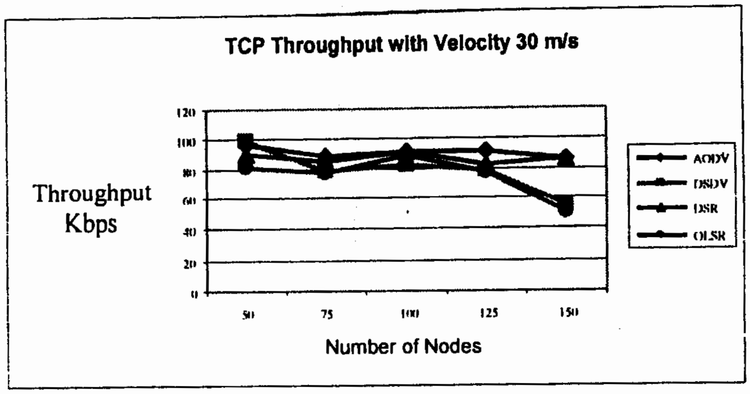

Figure 4.3) TCP Throughput with Velocity 30 m/s

Figure 4.3 shows throughput of proactive and reactive protocols with high nodes velocity 30m/s. By observing the graphs, it is clear that with high mobility as the number of nodes increases, throughput of these protocols also decreases especially in case of OLSR and DSDV.

4.5) Throughput Vs Node density under UDP

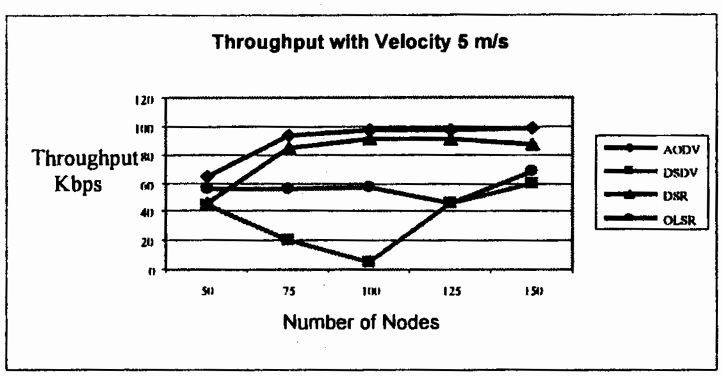

Figure 4.4) UDP Throughput with Velocity 5 m/s

Figure 4.4 shows Throughput of Four routing protocols with UDP traffic. Throughput of the AODV and DSR increasing as the number of nodes increases. While throughput of OLSR and DSDV lies below 60% although it may approaches to 60 and 63% when the node density is high.

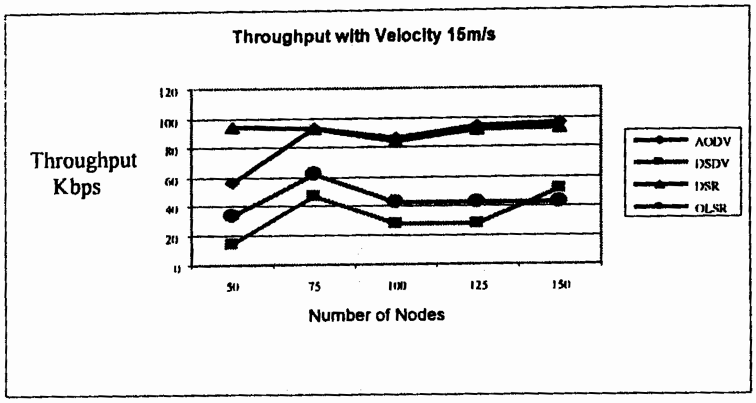

Figure 4.5) UDP Throughput with Velocity 15 m/s

Figure 4.5 shows throughput of the four protocols with UDP traffic and velocity 15m/s, again throughput of both proactive protocols lies below than throughput of reactive protocols. Although throughput of all protocols is lower at low node density and then suddenly increases.

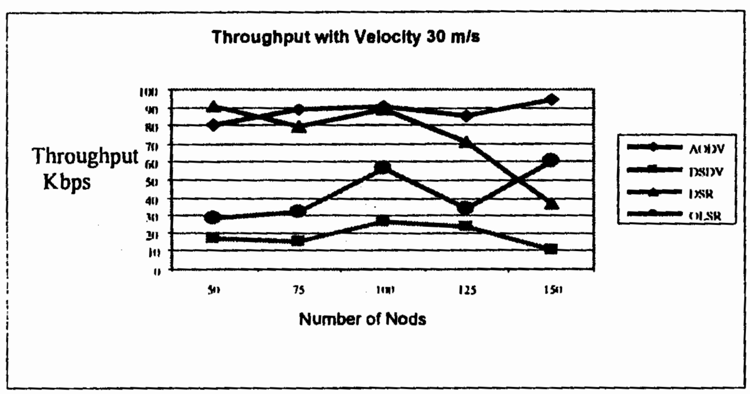

Figure 4.6) UDP Throughput with Velocity 30 m/s

Figure 4.6 shows throughput of the four protocols with UDP traffic and velocity 30m/s. The throughput of DSDV lies at the bottom and less than 30%. Although the throughput of OLSR in middle. Throughput of AODV is above 80% but throughput of DSR decreases as number of nodes increases.

4.6) Average Delay Vs Node density under TCP traffic

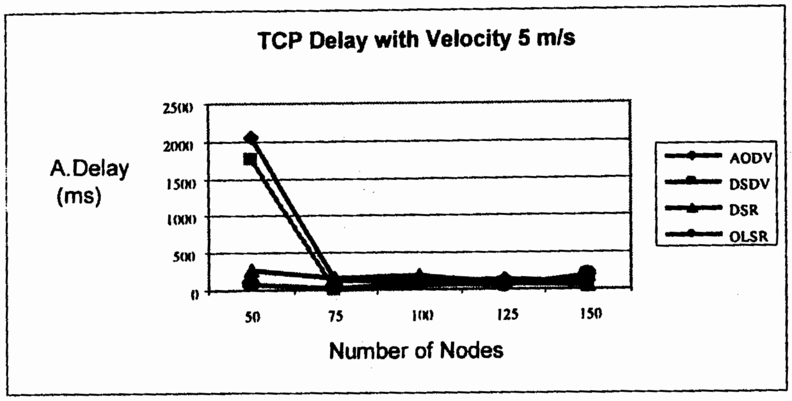

Figure 4.7) TCP Delay with Velocity 5 m/sec

Figure 4.7 shows delay of different protocols with TCP traffic and lower node mobility. In the start delay in AODV and DSDV is higher with lower node density but as the node density increases, delay of these protocols also decreases.

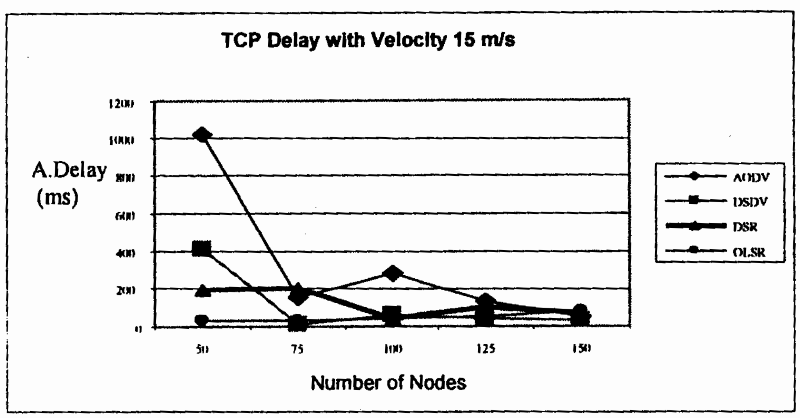

Figure 4.8) TCP Delay with Velocity 15 m/sec

Figure 4.8 shows delay with TCP traffic and node velocity 15m/s. Again at lower node density delay in OLSR, AODV and DSDV is greater and then decreases with increase in node density. While delay due to OLSR protocol is minimum even there is a little bit increase in delay as the network density increases.

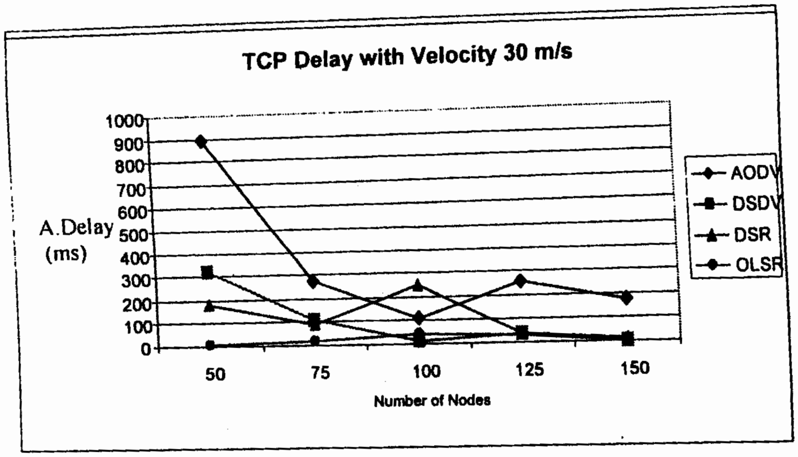

Figure 4.9) TCP Delay with Velocity 30 m/sec

Figure 4.9 shows delay with TCP traffic and node velocity of 30m/s. Again at lower node density delay in OLSR, AODV and DSDV is greater and than decreases with increase in node density. While delay due to OLSR protocols is minimum even there is a little bit increase in delay as the network density increases.

4.7) Average Delay Vs Node density under UDP traffic:

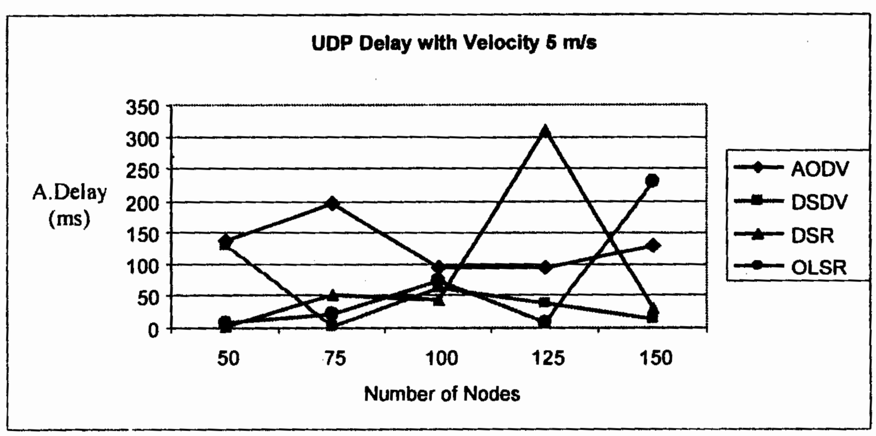

Figure 4.10) UDP Delay with Velocity 5 m/sec

Figure 4.10 shows Delay with UDP traffic and node velocity of 5m/s. Again the same case is here for AODV and DSDV having greater delay at low node density and than gradually decreases with increase in node density. Although delay in OLSR and DSR is less at small node density while increases with increase in node density.

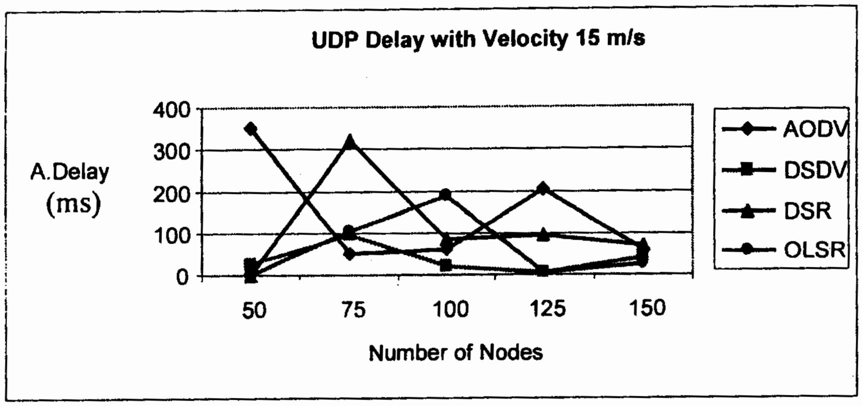

Figure 4.11) UDP Delay with Velocity 15 m/sec

Figure 4.11 shows Delay with UDP traffic and node velocity of 15m/s. Here AODV having greater delay at low node density and than gradually decreases with increase in node density. Although delay in DSDV, OLSR and DSR is less at small node density while increases with increase in node density.

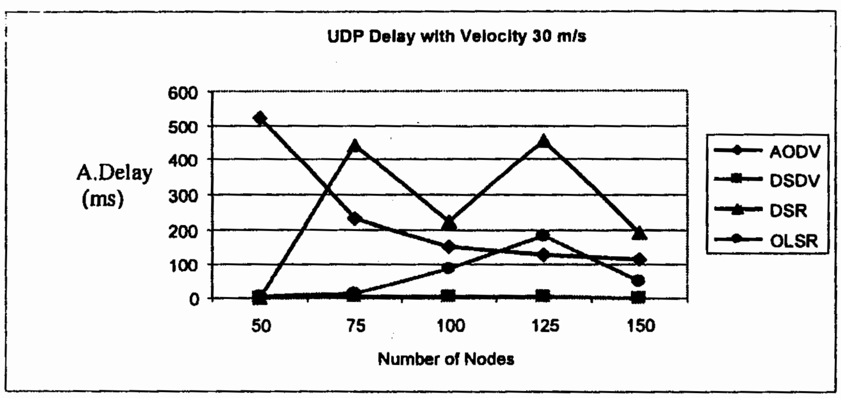

Figure 4.12) UDP Delay with Velocity 30 m/sec

Figure 4.12 shows Delay with UDP traffic and node velocity of 5m/s. Again the same case is here for AODV and DSDV having greater delay at low node density and then gradually decreases with increase in node density. Although delay in OLSR and DSR is less at small node density while increases with increase in node density.

4.8) Overhead Vs Node density under TCP traffic

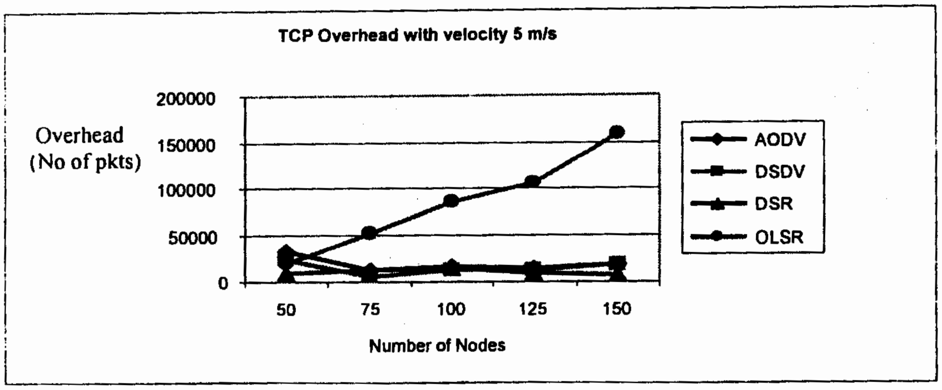

Figure 4.13) TCP Overhead with Velocity 5 m/sec

Figure 4.13 shows Overhead with TCP traffic and node velocity of 5m/s. The Overhead of OLSR is continuously increasing with increase in node density. Although overhead of DSR, AODV and DSDV is much lesser than OLSR except at 50 node density.

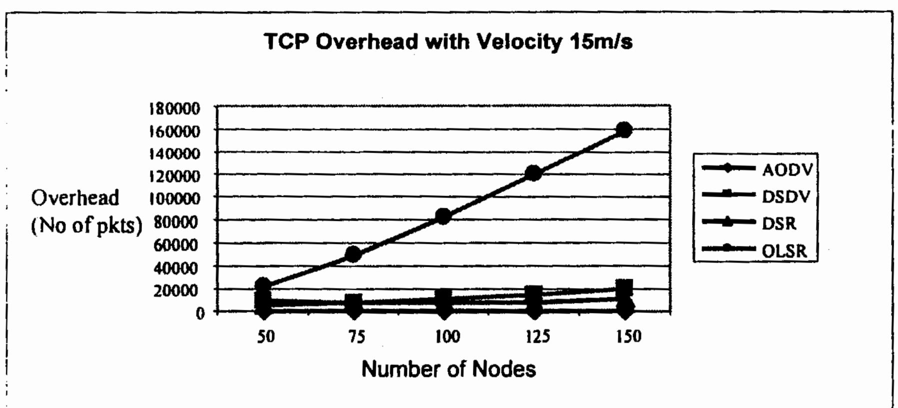

Figure 4.14) TCP Overhead with Velocity 15 m/sec

Figure 4.14 shows Overhead with TCP traffic and node velocity of 15m/s. The Overhead of OLSR is continuously increasing with increase in node density. Although overhead of DSR, AODV and DSDV is much lesser than OLSR at all node density.

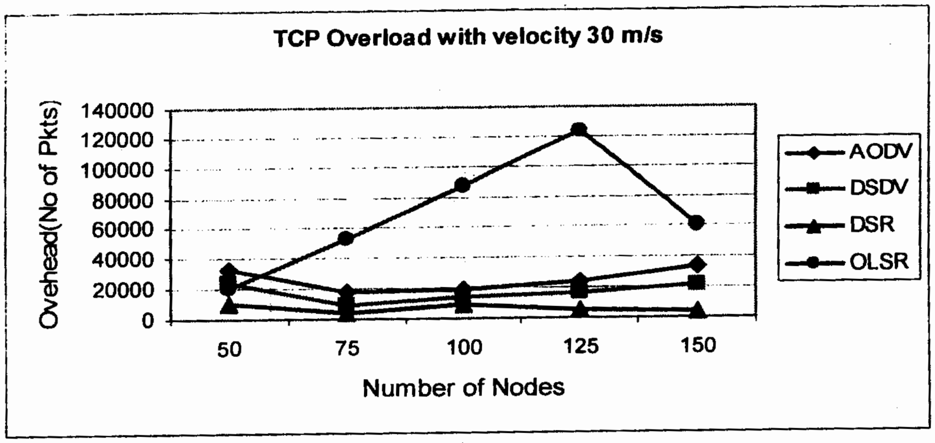

Figure 4.15) TCP Overhead with Velocity 30 m/sec

Figure 4.15 shows Overhead with TCP traffic and node velocity of 30m/s. The Overhead of OLSR is continuously increasing with increase in node density and suddenly decreases with 150 node density. Although overhead of DSR, AODV and DSDV is much lesser than OLSR having a little increase with high node density.

4.9) Overhead Vs Node density under UDP traffic

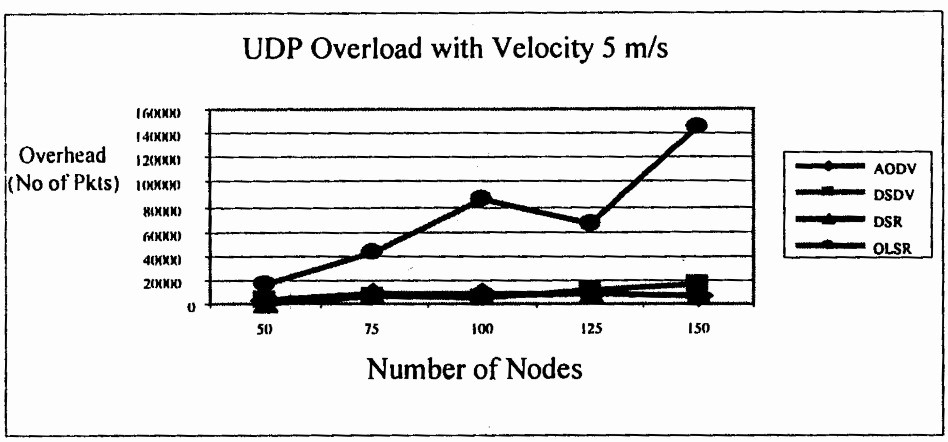

Figure 4.16) UDP Overhead with Velocity 5 m/sec

Figure 4.16 shows Overhead with UDP traffic and node velocity of 5m/s. The Overhead of OLSR is continuously increasing with increase in node density while less at node density of 125. Although overhead of DSR, AODV and DSDV is much lesser than OLSR at all node density.

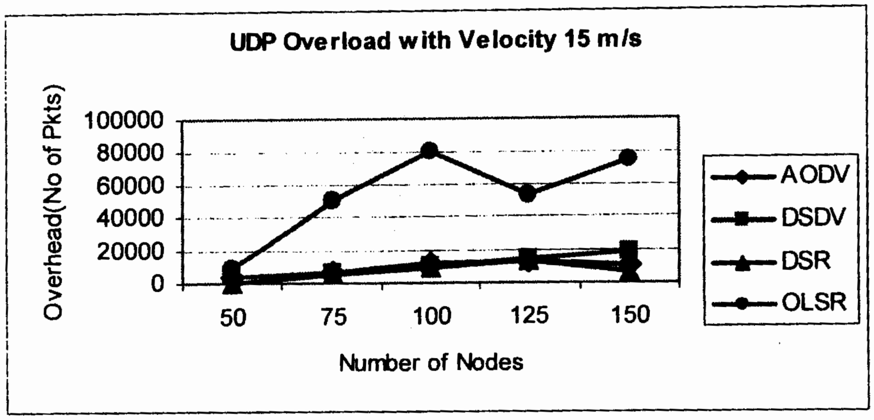

Figure 4.17) UDP Overhead with Velocity 15 m/sec

Figure 4.17 shows Overhead with UDP traffic and node velocity of 15m/s. The Overhead of OLSR is continuously increasing with increase in node density while less at node density of 125. Although overhead of DSR, AODV and DSDV is gradually increases with node density.

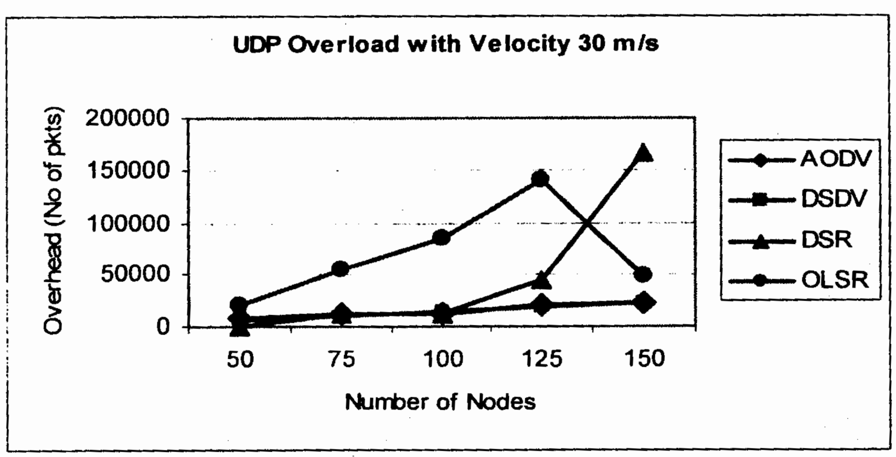

Figure 4.18) UDP Overhead with Velocity 30 m/sec

Figure 4.18 shows Overhead with UDP traffic and node velocity of 30 m/s. The Overhead of OLSR is continuously increasing with increase in node density while less at node density of 150. Although overhead of DSR, AODV and DSDV is gradually increases with node density. But at node density of 125 and 150 overhead of DSR suddenly increases.

4.10) Energy Consumption in Different Scenarios:

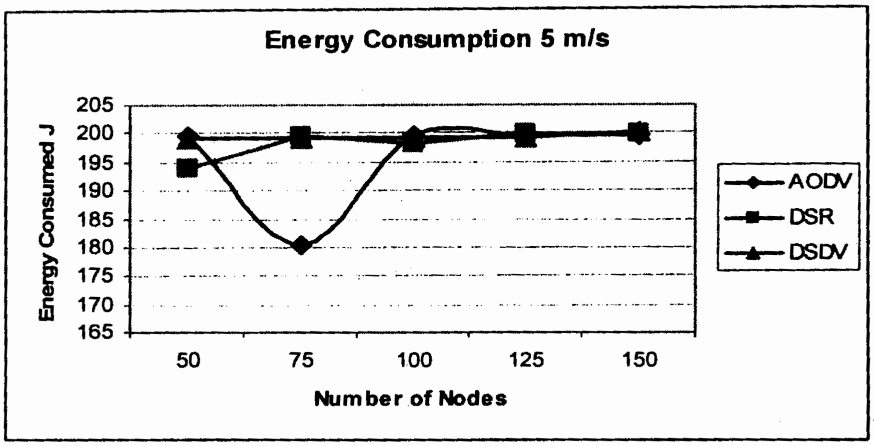

Fig1.19: Energy consumption analysis with 5m/s nodes velocity

The graph in figure 4.19 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 5m/s. In DSDV energy consumption has less effect with varying nodes density. In case of AODV, we find fluctuating curve minimum at 75 then keep on increasing, peak value is obtained at 120 nodes. After this energy consumption remains more or less constant. In case of DSR minimum consumption is recorded at 50 node densities, and then starts going up till the line becomes straight, thus energy consumption is constant.

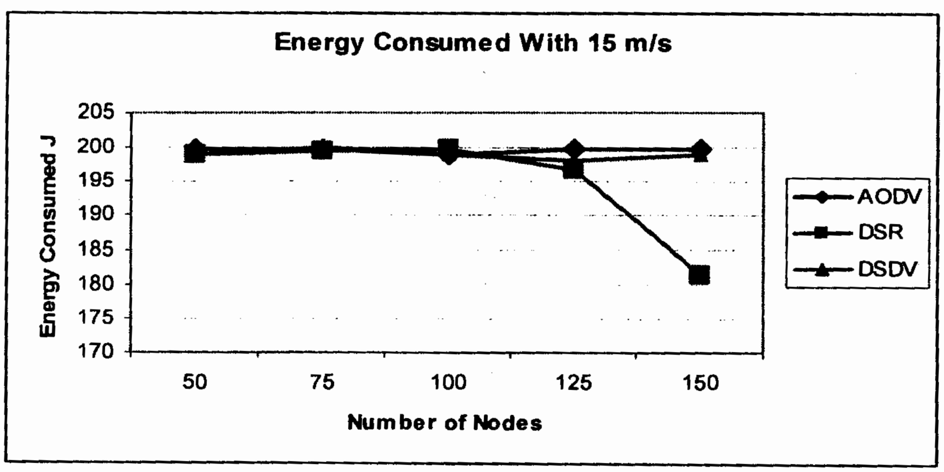

Fig 4.20: Energy consumption analysis with 15m/s nodes velocity

The graph in figure 4.20 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 15m/s. In DSDV energy consumption has less effect with varying nodes density. In case of DSR, we find fluctuation at node density 125 and 150; peak value is obtained at 100 nodes. After this energy consumption remains more or less constant. In case of AODV energy consumption is constant and there is no major change observed.

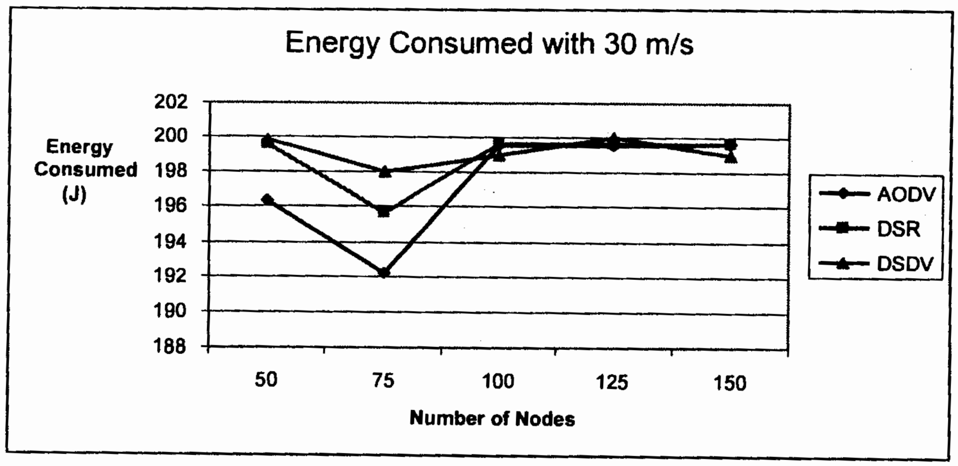

Fig 4.21: Energy consumption analysis with 30 m/s nodes velocity

The graph in figure 4.21 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 30 m/s. In case of all protocols energy consumption decreases at 75 nodes density and than suddenly increases as nodes density increases from 100 to 150.

4.11) Energy Consumed when Nodes are Idle State:

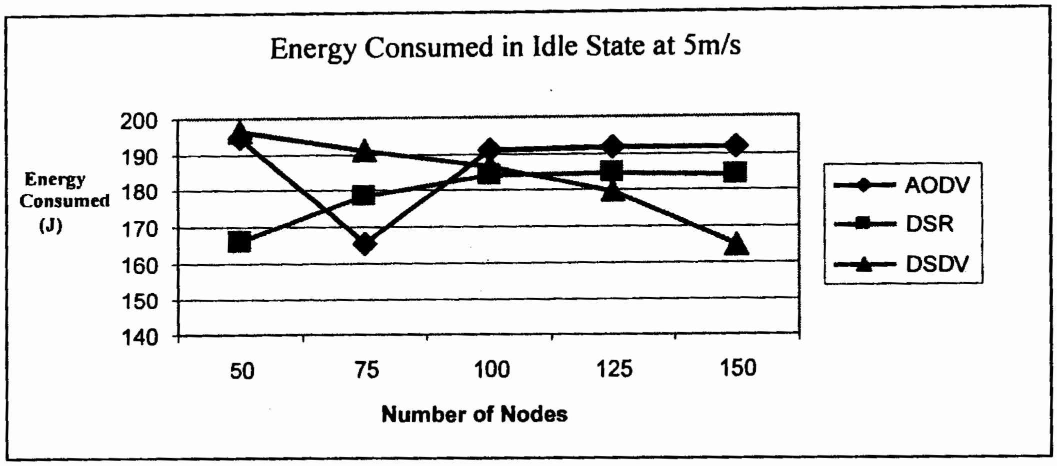

Fig 4.22: Energy consumption analysis with 5m/s in Idle state

The graph in figure 4.22 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 5m/s and nodes are idle. In DSDV energy consumption decreases with increase in nodes density. In case of DSR energy consumption increases with increase in node density, In case of AODV energy consumption is constant and except 75 node density there is no major change observed.

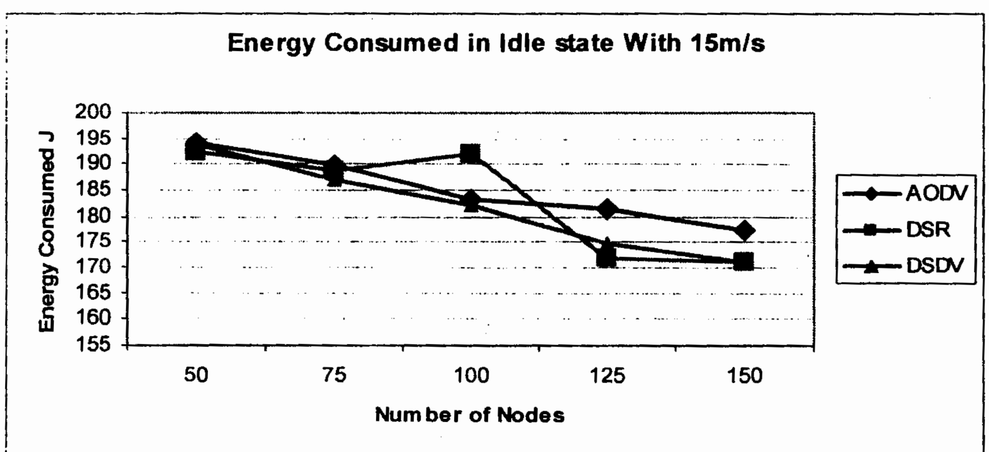

Fig 4.23: Energy consumption analysis with 15m/s in Idle state

The graph in figure 4.23 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 15m/s and nodes are idle. In case of all protocols the energy consumption decreases in idle state as well as nodes density increases.

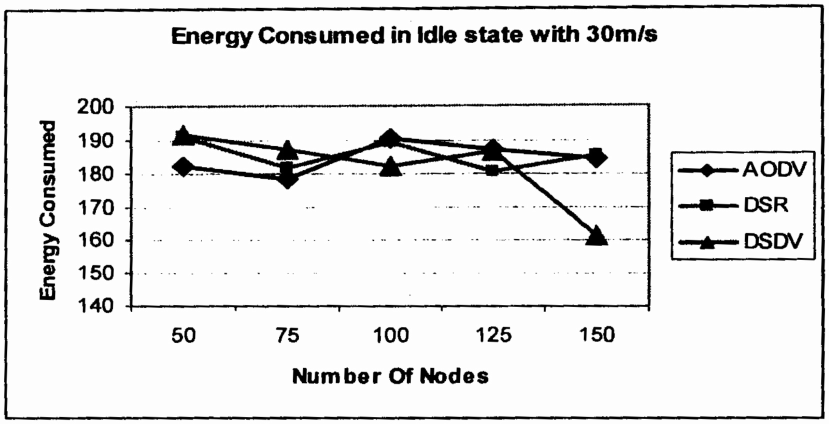

Fig 4.24: Energy consumption analysis with 30m/s in Idle state

The graph in figure 4.24 reflects energy consumption of different nodes when nodes density keep on changing while keeping velocity constant at 30m/s. In DSDV energy consumption decreases with varying nodes density. In case of DSR, we find fluctuation at node density 75 and 125; peak value is obtained at 100 nodes. In case of AODV energy consumption increases at 100 nodes and than gradually decreases.

4.12) Effect of varying Data generators on protocols:

These figures show variation in throughput, overhead and delay with varying numbers of data generators. Here the node density is 100 and also node mobility is 15 m/s.

4.12.1) Throughput with Different numbers of Data generators:

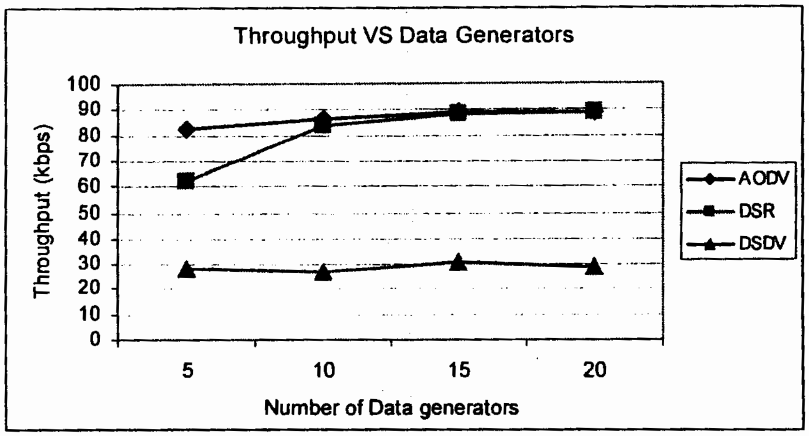

Figure 4.25: Throughput with different number of data generators

Figure 4.25 shows throughput with different numbers of data generators. Throughput of reactive routing protocols AODV and DSR is increasing with increase in number of data generators. Initially when data generators are 5 throughputs of protocols is lower and than increases. In case of DSDV protocol throughput is very low and there is no major change with increase in data generators.

4.12.2) Overhead with Different numbers of Data generators:

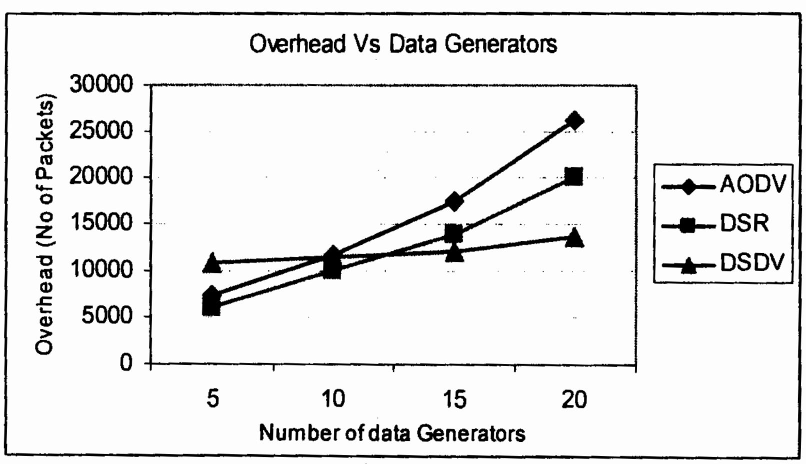

Figure 4.26: Overhead with different number of data generators

Figure 4.26 shows overhead with different numbers of data generators. Overhead of all protocols AODV, DSR, DSDV increasing with increase in number of data generators. Initially when data generators are 5 overhead of protocols is lower and than gradually increases with increase in data generators. In case of DSDV protocol overhead increases very slowly than other protocols.

4.12.3) Delay with Different numbers of Data generators:

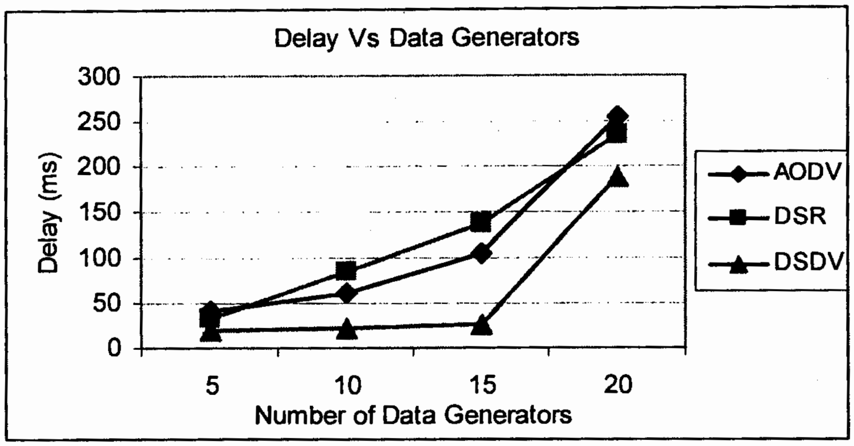

Figure 4.27: Delay with different number of data generators

Graph in figure 4.27 shows delay of different protocols with different numbers of data generators. Delay of all protocols is increasing with increase in number of data generators. Initially when data generators are 5 delay of protocols is lower and than gradually increases with increase in data generators. Delay in AODV and DSR is greater than DSDV protocol.

Chapter 5

Analysis & Conclusion

5.1. Analysis:

In this section we analyzed four different routing protocols like AODV, DSR, DSDV and OLSR. It is shown through simulation results that DSR generates less routing overload than AODV, DSDV and OLSR. AODV suffers from end to end delay while OLSR has very high routing overhead and continuously increases with increase in node density. The DSR performs better because it exploits caching aggressively and maintains multiple routes to the destinations.

Performance comparison of AODV and DSR routing protocols in a constrained situation is done in [7]. The authors claim that the AODV outperforms DSR in normal Situation but in the constrained situation DSR out performs AODV,

The performance of two on demand routing protocols namely DSR and AODV, both use on demand route discovery, they have different routing mechanics. We observe that for application oriented metrics such as delay, throughput DSR outperforms than AODV when the numbers of nodes are smaller. AODV outperforms DSR when the number of nodes is very large. As the velocity of the nodes increases than delay in DSR also increases. It is also observed that DSR consistently generate less routing load than AODV.

In our implementation the protocols are performing in an unpredictable fashion in most of the cases with varying nodes mobility and density.

From figure 4.1 to 4.18, it is clear that node density and mobility plays an important role in the performance of Ad-hoc networks. Keeping all other parameters same and changing only node density effect performance of an ad-hoc network routing protocol.

Figure 4.1 to 4.3 shows routing protocols throughput under reliable transport layer protocol, TCP with different nodes densities of 50, 75, 100, 125 & 150. All the four protocols show mixed response to varying nodes density. Here the Performance of reactive protocols (AODV and DSR) in term of throughput is far better than proactive protocols (OLSR and DSDV).

Graph in figure 4.3 where nodes mobility is 30 meters per seconds shows that with increasing node density the throughput of proactive protocols is decreasing, the main reason is that these protocols send continuously route information to maintain there routes update. With increase in node mobility there are sudden changes in network topology due to which it is very difficult to manage routes to different mobile nodes. For example if node A send its route information to node B and after 5 sec it changes its position then this record of route with node B must be updated and this updating takes time.

Figure 4.4 to 4.6 depicts throughput of four protocols under unreliable transport UDP with varying nodes density 50, 75, 100, 125 & 150. In case of UDP traffic AODV and DSR throughput is better than OLSR and DSDV. With lower node velocity the throughput of these protocols increases as the nodes density increases. But with increase in nodes velocity throughput of DSR protocol gradually decreases although AODV protocol show same behavior so it is clear from figure 4.6 that performance of DSR protocol decreases under UDP traffic with increase in nodes velocity. DSDV show very poor response under UDP traffic in all scenarios.

Comparing results for both UDP and TCP, we conclude that all the protocols perform well under TCP as far as protocols throughput is concerned. This is because in TCP, lost packets are retransmitted, unlike UDP. In UDP no mechanism for lost packets exists therefore packet delivery ratio is lower than UDP.

It has been noted that there is a trend of increase in throughput of different protocols with increase in mobility (velocity) and node density for all protocols. Such trend is observed in case of TCP traffic while only for reactive protocols in case of UDP traffic. At small node density few data packets are delivered due to lack of routes. But with increase in node density routes for connectivity also increases that is why packet delivery ratio increases with increase in node density. Due to faster node movement the link breakage will be more frequent. Even though the effective bandwidth seen at individual nodes suffer due to increased transmission power and collision. The delivery ratio still keeps on increasing compare to node density. It happens so because link breakages are less frequent and routes are maintained for relatively longer period of time. [25]

Figure 4.7 to figure 4.12 show end to end delay of different protocols under TCP traffic. We conclude that there is trend of increasing end to end delay with increasing speed (velocity) and node density. In case of both TCP and UDP traffic

DSDV protocol performs better than other three protocols. All these protocols show mixed performance at each node density and velocity.

When nodes keep on moving more frequently there will be more topology changes and more link breakages. This will cause activation of routes discovery process to find additional links. Thus packets have to wait in buffers until new routes are discovered. This results in larger average delay.

From the figures 4.4 to 4.6 it is clear that throughput of DSDV and OLSR protocols is decreasing rapidly with increase in speed of nodes. We observed DSDV and OLSR as poor protocol for mobile environment. This is because DSDV and OLSR are proactive protocols, dependent on periodic broadcast. Therefore it needs some time to converge before a route can be used. This convergence time can probably be considered negligible in a static wired network, where the topology is not changing so frequently. In an Ad-hoc network on the other hand, where the topology is expected to be very dynamic, this convergence time will probably mean a lot of dropped packets before a valid route is detected.

Overall from this research work we conclude that changing these parameters in an Ad-Hoc network there is certain effects on the throughput of network. But one thing keep in mind that the behavior of each protocol depends on our own scenario which is further explained in Figures.

For example if we have 50 nodes in our scenario and the nodes velocity is constant as 15 meters per seconds and we are using an unreliable transport layer protocol (UDP) than the throughput of DSR protocol is maximum and lies above 90 percent which is greater than throughput of other three protocols (AODV, DSDV and OLSR). But when we increase the nodes density than throughput of AODV also increases because routes increase to destination while DSDV and OLSR remain same with low throughput. Similarly overload and delay is also less in DSR at low node density than other protocols. Therefore here we are able to recommend that in such scenario we should prefer DSR protocol instead of others. But the results are totally unpredictable when we run the same scenario using TCP protocol at transport layer here AODV throughput is better than DSR but with increase in node density the packet delivery ratio of all the four protocols (AODV, DSR, OLSR and DSDV) lies above 80 percent.

We also conclude from figures 4.7 to 4.12 that if we have a delay intolerant traffic than we should prefer Proactive protocols (OLSR and DSDV) because there is very less delay in our network for proactive routing protocols as clear from figures either we are using UDP or TCP at transport layer it does not matter. In case of overload parameter Proactive protocols overload is continuously increasing with increase in node density both cases of transport layer protocols.

In the last we must say that behavior of each protocol is different, in each scenario a protocol may perform better with low node density and velocity but with the increase in node density and velocity give poor performance.

Similarly we should also keep in mind about our scenario parameters both constants and variable. Furthermore after the above proves we are able to say, a protocol needs to be developed which is tolerant to above anomalies.

Energy Consumption graphs shows that all protocols consumed same amount of energy at different nodes density and mobility but when node density is 75 at 30 m/s there is sudden decrease in energy.

In case of idle state AODV and DSDV energy is increases with except 75 node density. While incase of node mobility 15 and 30 m/s energy consumption decreases with increase in node density.

With different traffic rates throughput reactive routing protocols is greater than DSDV and continuously increasing with increase in data generator.

Overhead and delay incase of all protocols is increasing with increase in data generators.

5.2. Conclusion:

At the end of this research work we conclude that

- On demand protocols (DSR and AODV) seemed to perform better than OLSR and DSDV especially when mobility is increases. DSDV may suffer from quite a big packet loss.
- Whereas in reactive protocols, DSR performs better than AODV in less stressful situation. When stress is increased, AODV has generally better performance.

- It has been shown that as the mobility of the node increases, it is desirable to increase the transmission power in order to achieve delivery of data packets to their destination.
- We showed that the average velocity is not a valid parameter to evaluate routing protocols. For future realistic performance evaluation one should rather evaluate Adhoc network protocols under new metrics such as acceleration, deceleration capabilities of nodes.
- Number of data generators has effects on throughput, overload and delay of all protocols and continuously increasing.
- DSDV performance is better in delay intolerant networks due to its ability to maintain connection by periodic updates from neighbors.
- We consider both TCP and UDP as transport layer protocols. We found TCP is performing better than UDP in terms of data throughput. This is because TCP contains algorithm for the recovery of lost/erroneous packets. While UDP lacks such capability and is based on best effort delivery.
- In our simulation result, the on-demand routing protocols well in high mobility and high node density network but the pro-active routing protocols like OLSR shows the worst performance because its periodic route update and hello messages become the severe overhead in high mobile and dense network.
- This study also shows that reactive protocols are superior to pro-active routing protocols. Although DSR is better for networks having low node density and AODV is best for large networks.

5.3. Future Work

Ad hoc wireless is the hot area of research now-a-days. This resulted in the development of large number of protocols for Adhoc networks. Therefore plenty of work is required to be done to evaluate the performance of these protocols in different real world scenarios. Therefore we also have some other parameters such as nodes pause time, transmission range, simulation time and node density which may affect the performance of protocols in term of its throughput, overload, and delay. Therefore my plan of work is to move this Research work forward and change other parameters one by one and observe the performance of each protocol in each particular scenario in term of its packet delivery ratio, delay overload, throughput, Qos and out-of-order delivery etc. The average velocity is not a valid parameter to evaluate routing protocols. For future realistic performance evaluation one should rather evaluate Adhoc network protocols with variable velocity of nodes.

We have observed that different protocol perform differently in different scenario. There is no single protocol that performs well in all scenarios with all perspectives. Therefore there is a need to design such a protocol which performs efficiently in different situations like low and high node density, low and high speed of mobile units and randomness etc.

REFERENCES

8. References

1. *Md. Abdullah-Al-Mamun, M. Mahbubur Rahman"**Performance Evaluation of TCP over routing Protocols for Mobile Adhoc Networks"** Department of Information and Communication Engineering Islamic University Kushtia 2003, Bangladesh.*

2. *H. M. El-Sayed , O.Bazan, U.Qureshi, M.Jaseemuddin "**Performance Evaluation of TCP in Mobile Adhoc Networks** "College of Information Technology, UAE University, UAE) WINCORE Lab, Ryerson University, Toronto, Ont., Canada.2004*

3. *RFC:3626*

4. *Preetida Vinayakray-Jani, Nokia Research Center, Helsinki, Finland" **Security within Ad hoc Networks**" PAMPAS Workshop, Sept. 16/17 2002, London.*

5. *C. E. Perkins and P. Bhagwat, " **Highly Dynamic Destination-Sequenced Distance-Vector Routing** (DSDV) for Mobile Computers", Proceeding of the ACM SIGCOMM Conference on Communications Architectures, Protocols and Applications, London, UK, pages 234-244.1994*

6. *Shree Murthy and J.J. Garcia-Luna-Aceves **"An Efficient Routing Protocol for Wireless Networks"** Computer Engineering, University of California.*

7. *REN Wei, YEUNG D.Y, JIN Hail " **TCP performance evaluation over AODV and DSDV in RW and SN mobility models**" (School of Computer Science and Technology, Huazhong University of Science and Technology, Wuhan 430074, China) (Department of Computer Science, Hong Kong University of Science and Technology, Hong Kong, China).2005*

8. *Jerome Haerri, Fethi Filali, Christian Bonnet, **"Performance Comparison of AODV and OLSR in VANETs Urban Environments under Realistic Mobility Patterns"** Institute Eurecomz Department of Mobile Communications.*

9. *K. Kathiravan , Dr. S. Thamarai Selvi , A.Selvam " **TCP Performance analysis for Mobile Ad-hoc networks using on-demand routing protocols"** Crescent Engineering College Vandalur, Chennai, MIT Chromepet Campus Anna University, Chennai.*

10 *S. Kannan, John E Mellor and D.D.Kouvatsos "**Investigation of Distance Vector Routing for Mobile Ad hoc Networks** " Mobile Computing and Networking Research group Department of Computing University of Bradford.*

11. *Dillip Kumar Puthal and Prof. Bibhudatta Sahoo "**Performance Evaluation of MAC DCF Scheme in WLAN"***

12. *Luiz Albini,Antonio Caruso, Stefano Chessa, Piero Maestrini,* ***"Reliable Routing in Wireless Ad Hoc Networks"*** *Institute di Scienza e Technologies' dell'Informazione,Area della Ricerca, CNR di Pisa-S.Cataldo, 56100 Pisa, Italy.*

13. *Gang Ding, Xiaoxin Wu, and Bharat Bhargava* ***"Performance Evaluation of Multiple-Rate Mobile Ad Hoc Networks"*** *School of Electrical and Computer Engineering, Purdue University, W. Lafayette, Department of Computer Sciences, Purdue University, W. Lafayette, IN 47907.*

14. *P.chenna Reddy, Dr.P.chandrasekhar Reddy,"* ***Performance Analysis of Adhoc Network Routing protocols,"*** *2006*

15. *Pilli Unnikrishann ,"* ***Introduction and Analysis of DSR protocol,"*** *2004*

16. *Yih-Chun Hu & David B. Johnson,* ***"Implicit source Routes for on demand Adhoc Network Routing."*** *Mobi Hoc 2001*

17. *Tracy camp, Jeff Boleng, Venessa Davies,* ***"A Survey of mobility Models Of Adhoc Network"*** *research, Deptt of Math and computer sciences Colorado school of Mines , Golden, CO, 10 September 2002*

18. *David B. Johnson & David A. Maltz,* ***"Dynamic source routing in Adhoc Wireless networks,"*** *computer science Department carnigie Mellon university 5000 Forbes Avenue pittsbergue. 1996.*

19. *Khalid Iqbal & Hilal* ***"performance Analysis of MANET Routing protocols in different Mobility Models"*** *final thesis. 2004-2007*

20. *Charles Perkins and Privan Bhagwat* ***"Highly Dynamic Destination Sequenced Distance vector Routing (DSDV) for mobile computers"*** *ACM SIG COMM,9 proceeding on communication Architecture, protocols and Applications, pages 234-244, 1994*

21. *Vahid Garousi,* ***"Analysis of Network Traffic in Ad-Hoc Networks based on DSDV Protocol with Emphasis on mobility and Communication Pattern,"*** *Department of systems and Computer Engineering Carleton university, Ottawa,Canada,2004*

22. *karavetsios, P. & Economics, AA.* ***"Performance Comparison of Distributed Routing Algorithm in Ad-Hoc Mobile Networks"*** *WSEAS Transaction on Communications, Vol.3, Issues 1, PP.317-321, 2004.*

23. *Tracy Camp, Jeff Boleng ,Vanessa Davies,* ***"A Survey of Mobility Models for Ad-Hoc Network Research "*** *Dept. of Math and computer Science Colorado school of mines , Golden, CO, 10 September 2002.*

24. *Fan Bai and Ahmed Helmy,* ***"A Survey of Mobility Models in Wireless Ad hoc Networks"*** *University of Southern California, U.S.A, 2004.*

25. *Anders Nilsson* ***"Performance Analysis of traffic load and node density in Adhoc Networks"*** *Deptt of communication systems Lund University Sweden.*

26. *Charles E. Perkins and Elizabeth M.Royer.* ***"Ad-hoc on-demand distance vector Routing."*** *Technical report, Sun Micro Systems Laboratories, Advanced Development Group, USA.*

27. *Krishna Gorantala* ***"Routing Protocols in Mobile Ad-hoc Networks"*** *Master's Thesis in Computing Science, Umea University Department of Computing Science SE-901 87 UMEA Sweden. June 15, 2006*

28. *David B.Johnson,* ***"Routing in Adhoc Networks of Mobile Hosts"*** *proceedings of the workshop on Mobile Computing Systems and Applications, IEEE Computer Society, Santa Cruz, CA,Pages158-163, December 1994,*

29. *Thomas H.Clausen and philipee jacquet* ***"Optimized Link State Routing Protocol"*** *IETF RFC 3626- Experimental Standard, October 2003.*

30. *Yili Gong, yongqiang Xiong, Qian Zhang, Zhensheng zhang, Wenjie Wang, Zhiwei Xu,* ***"Anycast Routing in Delay Tolerant Networks."*** *In IEEE Globecom 06, San Francisco, CA Nov. 27- Dec. 1, 2006*

31. *S. R. Das, R. Castaneda, J. Yan and R.Sengupta,* ***"Comparative Performance Evaluation of Routing protocols for MANETs"*** *In proceedings of 7th* International Conference on computer communications and Networks (IC3N), Lafayette, LA, October 1998, Pages 153-161.

32. *Charles E. Perkins and Pravin Bhagwat."* ***DSDV routing over a multi hop wireless network of mobile computers."*** *Technical report, IBM Research and University of Maryland, USA.*

33. *T. Clausen and P. Jacquet (2003),* ***"Optimized Link State Routing Protocol (OLSR)"****, RFC 3262, IETF Network Working Group,* October 2003.