Performance Analysis of MANET Routing Protocols in different Mobility Models

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DECLARATION

We, hereby declare that this research work has not been copied from any source. It is further declared that we have developed this research entirely based on our personal efforts under the supervision of Dr. Syed Afaq Hussain & Mr. Raza Hasan Abedi. If this thesis is proved to be copied or reported at any stage, we accept the responsibility to face the subsequent consequences. No part of this work inscribed in this thesis has either been submitted to any other university for the award of degree/qualification.

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DEDICATION

We dedicate this research project to our beloved Parents, Family members, respected Teachers and sincere Friends

A dissertation submitted to the
Faculty of Engineering & Technology,
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As a partial fulfillment of the requirements
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Performance Analysis of MANET Routing Protocols in different Mobility Models.

Abstract:

The main motivation of the research project is to analyze different performance parameters of three well-known MANET routing protocols (AODV, DSDV, DSR) in multiple mobility models with varying nodes' speed. As in real world the movements of nodes are almost always random, therefore we considered three random mobility models, RandomWalk mobility model, RandomWay mobility model and Random Direction mobility model.

In the above mentioned three mobility models we evaluated the performance of these three protocols. First, we generated mobility files with different mean speeds of 5, 10, 15, 20 and 30 m/s. Finally these protocols are challenged in an identical mobility environment; therefore we can directly compare their performance parameters like Packet delivery ratio, Packet lost, Packet received and Average Delay. This gives the researchers an idea that how different protocols perform under different mobility scenario.

The final results show that AODV and DSR performed better than DSDV. The performance of DSDV is significantly affected by variations in speed. AODV and DSR show unpredictable performance with varying speeds and mobility models. All the three protocols performed comparatively better in RandomWalk and RandomWay mobility model. In Random Direction mobility model, protocols' performance is relatively poor.

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Chapter 1

Introduction

Objective:

The purpose of this chapter is to understand:

- *Basics of data communication*
- *OSI and TCP/IP models*
- *Internet*
- *MANET*
- *Characteristics and Applications of MANET*
- *Routing and Routed Protocols*

1. Introduction

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

1.1 Background

The 1970 and 1980 saw a merger of the field of computer science and data communication that changed the technologies, products and companies of the now combined communication industry [1].

The early 1980s saw tremendous increases in the numbers and sizes of networks. As companies realized they could save money and gain productivity by using networking technology, they added networks and expanded existing networks almost as rapidly as new network technologies and products could be introduced.

By the mid 1980s, these companies began to experience some problems from all the expansions they made. It became harder for networks that used different specifications and implementations to communicate with each other. They realized that they needed to move away from proprietary networking systems. Proprietary systems are privately developed, owned and controlled. In the computer industry, proprietary is the opposite of open. Proprietary means that one or a small group of companies controls all usage and evolution of the technology. Open means that free usage of the technology is available to the public.

To address the problem of different network systems being incompatible and incapable of communicating with each other, the International Organization for Standardization (ISO) researched network schemes, such as DECnet, SNA and TCP/IP, to find a set of rules. As a result of this research, the ISO created a network model that could help vendors create networks that would be compatible with, and interoperate with, other networks.

1.1.1 OSI Layers

The process of moving information between nodes is divided into seven smaller and more manageable steps:

A. *Application Layer:* It provides network services such as file access and printing, to the user's application. It doesn't provide services to any other layer, but rather, only to applications outside the OSI model. For example, spreadsheet program and bank terminal program.

B. *Presentation Layer:* This layer ensures that the information that the application layer of one system sends out, is readable by the application layer of another system. That is, providing common data format. Data translation, encryption and compression are main functions of this layer.

C. *Session Layer:* This layer establishes, manages and terminates sessions between two communicating nodes. It synchronizes dialog between two hosts' presentation layers and manages their data exchange.

D. *Transport Layer:* This layer segments data from the sending host's system and reassembles the data stream on receiving host's 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.

E. *Network Layer:* It is a complex layer that provides connectivity and path selection between two host systems that might be located on geographically separated networks. Path selection, routing and logical addressing are main functions of network layer.

F. *Data Link Layer:* The link layer provides the transit of data across a physical link. In doing so, the data link layer is concerned with physical topology, media access and error detection.

G. *Physical Layer:* This layer defines electrical, mechanical, procedural and functional specifications for activating, maintaining, and de-activating the physical link between end systems. Voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, and physical connectors are attributes defined by physical layer specification.

1.1.2 Internet

The Internet is a worldwide, publicly accessible network of interconnected computer networks that transmit data by packet switching using the standard Internet Protocol (IP). It is a "network of networks" that consists of millions of smaller domestic, academic, business, and government networks, which together carry various information and services, such as electronic mail, online chat, file transfer, and the interlinked Web pages and other documents of the World Wide Web[3].

In 1967, ARPA presented the idea for ARPANET, a small network of connected computers. In 1969, ARPANET became a reality. In 1972, Vint Cerf and Bob Kahn published a paper on TCP. After a short time, TCP was split into two protocols, that is, TCP and IP.

Internet communication is based on packet switching. In packet switching, there is no resource allocation for a packet in advance. Thus resources are allocated on demand. In this approach each packet is treated independently. Packets in this approach are known as datagrams. Datagram network is also sometimes referred to as connectionless network, that is, there is no setup or tear down phase.

In datagram approach, each packet contains full route information in its header. A switch in datagram approach uses the routing table based on destination address in the header of each packet to route the packet to the correct destination.

The packets of same message may arrive out of orders. It is the responsibility of destination transport mechanism to arrange the packets in correct order. Thus communication on the Internet is based on the following assumptions [4]:

- *Continuous, Bidirectional End-to-End Path:* A continuously available bidirectional connection between source and destination to support end-to-end interaction.
- *Short Round-Trips:* Small and relatively consistent network delay in sending data packets and receiving the corresponding acknowledgement packets.
- *Symmetric Data Rates:* Relatively consistent data rates in both directions between source and destination.

- *Low Error Rates:* Relatively little loss or corruption of data on each link.

Internet is using four layer TCP/IP model instead of OSI model. In next section, we will give a brief review of TCP/IP model.

1.1.3 TCP/IP Model

The historical and technical open standard of the Internet is Transmission Control Protocol/Internet Protocol (TCP/IP). This protocol stack makes data communication possible between any two nodes, anywhere in the world. Figure 1.1 shows protocol graph of TCP/IP model. Following are four TCP/IP model layers:

1. *Application Layer:* Also known as *process layer*. This layer combines the functionalities of application, presentation and session layers of OSI model. That is, encoding and dialog control.
2. *Transport Layer:* This layer is also sometimes known as the *host-to-host layer*. This layer deals with end-to-end reliability, flow control and retransmission. One of its protocols, TCP provides excellent and flexible ways to create reliable, well-flowing network communication. It is connection-oriented while UDP is connection-less working on this layer for delay sensitive communication.
3. *Internet Layer:* The important protocol on this layer is Internet protocol (IP). The purpose of this layer is to send source data from any network on the internetwork and have they arrived at the destination independent of the path and networks they took to get there. Best path determination that is, routing and packet switching occur at this layer.
4. *Network Access Layer:* It is also called the *host-to-network layer*. This layer is concerned with all the issues that an IP packet requires to actually cross a physical link from one device to a directly connected one.

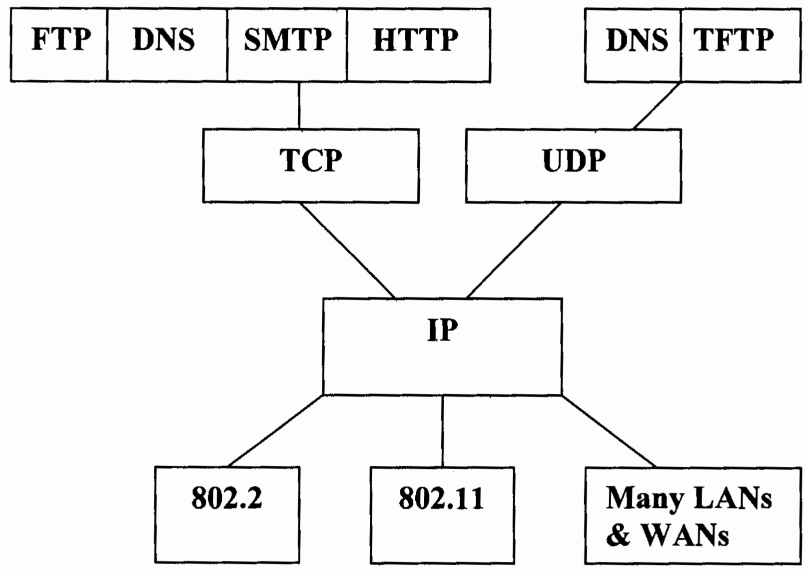

Figure.1.1: TCP/IP Protocol Graph

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

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.

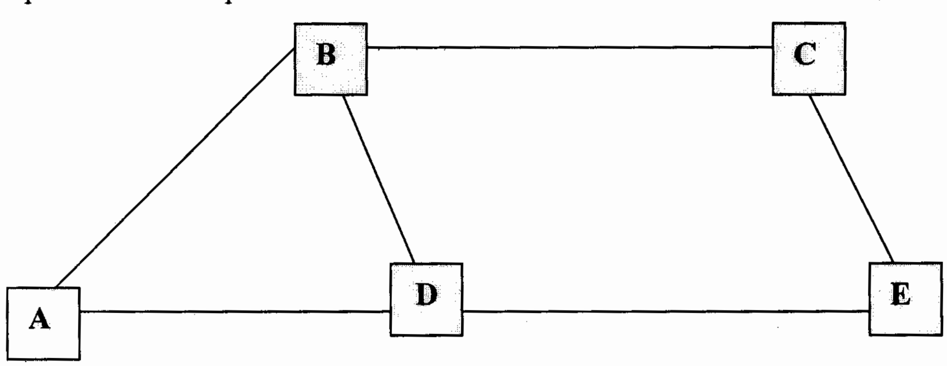

Figure1.2: Example of an ad hoc network

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.

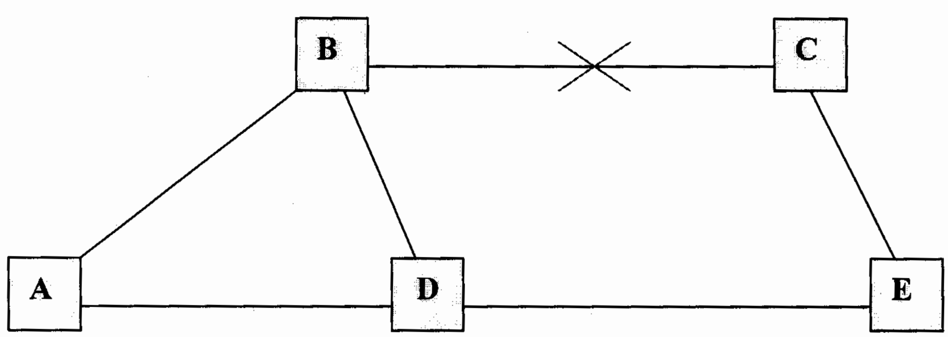

Figure 1.3: Topology update due to a link failure

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.

1.2.1.1 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.

1.2.1.2 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.

1.2.2 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:

1. Routed Protocols
2. Routing Protocols

1.2.2.1 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. For a protocol to be routable or routed, it must provide the capability to assign a network number, as well as a host number to each individual device on the network. IP requires that you provide a complete address and a subnet mask. The network address is obtained by ANDing the address with a subnet mask.

Other routed protocols such as IPX and AppleTalk DDP also provide layer 3 supports but are not in common use nowadays. However, some protocols exist that don't support layer 3; and are classified as non-routable protocols such as NetBEUI.

1.2.2.2 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. As this chapter is devoted to building general concepts, therefore we are going to explore conventional routing protocols.

A protocol that allows the routers to communicate with other routers to update and maintain the routing table is called routing protocol. Routing protocols determine the paths that routed protocols follow to deliver user data to their destination.

Most common conventional routing protocols are divided into two main categories:

1. Distance-Vector
2. Link-State

1.2.2.2.1 Distance-Vector

In distance-vector routing protocols, the router advertises all the known routes out on all its interfaces, called routing updates, to other routers that share the same physical network. Neighbours receive the routing updates and learn the routes. The routing updates contain a series of entries, with each entry representing a subnet and a metric. A metric represents how good the route is from that router's perspective, with a small number being a better route. The receiving router adds the routes only if the routing update describing a route to a subnet that it didn't know before or the describing route that is already known, but a newly learned route has a better (lower) metric.

The distance-vector protocol offers the following potential benefits:

- Requires less storage space on routers.
- Easier to implement.
- More computation efficient.

The major problem in distance-vector routing protocols is the formation of routing loops.

Routing loops

Distance-vector routing protocol keep track of any changes in the internetwork by broadcasting periodic routing update to all active interfaces. The slow convergence can pass inconsistent routing tables resulting in the formation of routing loops. Following are different techniques adapted to avoid routing loops in distance-vector routing protocols.

- Maximum hop-count
- Split horizon
- Trigger updates
- Route poisoning
- Hold down timer

RIP and CISCO proprietary IGRP are examples of conventional distance-vector routing protocol.

RIP- An Example

A brief summary of RIP is given below:

- Based on distance-vector logic
- Uses hop-count as a metric

- Sends full routing table periodically after every 30 seconds
- Convergence time is high, often take 3-5 minutes
- Support classful routing only

1.2.2.2.2 Link-State

Link-state routing is the second major class of intra domain routing protocol. The largest difference between distance-vector and link-state routing is the mechanism they use to fill the routing table. A distance-vector protocol in router hears a routing update; the update says nothing about the routers beyond those neighbouring routers that sent the update. Conversely, link-state protocols advertise a large amount of topological information about the network, and the routers perform some CPU-intensive computation on the topological data. They even discover their neighbours before exchange of routing information.

OSPF- An Example

OSPF (Open Shortest Path First) is an important conventional wired line link-state protocol. The basic working mechanism of link-state routing is discussed above. Now we are going to spell out the process of learning routes when OSPF is activated first time.

- Each router discovers its neighbour on each interface. The list of neighbour is kept in a neighbour table.
- Each router uses a reliable protocol to exchange topology information (LSAs) with its neighbours.
- Each router places the learned topology information in its topology database.
- Each router runs the SPF algorithm against its own topology database to calculate the best routes to each subnet in the database.
- Each router places the best route to each subnet in the IP routing table.

Loop Avoidance

To figure out the current best routes, a router processes the link-state topology database using an algorithm called *Dijkstra Shortest Path First algorithm.* This detailed topology information, along with the Dijkstra algorithm, helps link-state protocols avoid loop and converge quickly. The SPF algorithm prevents loops as a natural part of the processing of topology database with the SPF algorithm. Thus there is no need of additional loop-avoidance features. As no additional time consuming loop-avoidance features are needed, which means that link-state protocol can converge very quickly. With proper design OSPF, a link-state protocol can converge as quickly as 5 seconds after a router notices a failure in most cases.

Problems with Link-State Routing Protocols

Link-state routing offers loop-free environment and low convergence time but also have some problems, as summarized below:

- Requires more memory on each router.
- High CPU processing power.
- A single interface-status change (up-to-down or down-to-up) forces every router to run SPF again.

Comparison of Distance-Vector and Link-State routing

The list given below in table 1.1 summarizes the key points of comparison between the two routing techniques.

Feature	Link-State	Distance-Vector
Time to converge	Low	High
Loop avoidance	Built-in	Extra features to be added
Memory & CPU requirements	Large	Low

Table 1.1: Link State vs. Distance Vector protocol

Apart from above mentioned distance-vector and link-state routing, we also have following other routing techniques:

1.2.2.2.3 Source Routing

In source routing the data source put all information (about intermediate nodes in case of multi-hop network) in every packet header necessary for the delivery of a packet. No routing tables are maintained at every node. Source routing protocol produces more overhead as routing information is attached with every packet. Delay is introduced before a packet departure as route is to be investigated first. Loop freedom the fantastic feature of source routing.

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Chapter 2

MANET Routing & Mobility

Objective:

The purpose of this chapter is to understand:

- *Routing in MANETs*
- *Classification of MANET routing protocols*
- *In-depth analysis of DSR, DSDV & AODV*
- *Different mobility models*

2. MANET Routing and Mobility

In previous chapter we discussed general concepts. In this chapter we are going to explain topics that are closely related to our research topic that is routing in MANETs and different mobility patterns.

2.1 Routing in MANET

In chapter1 we discussed routing in general. But routing in MANETs is relatively different from other conventional wired and wireless networks. Below we are going to spell out some points summarizing, why routing in MANETs 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

2.1.1 Desirable properties of an efficient routing algorithm

From the above section it is clear that routing in MANET is more challenging task, therefore, MANET routing protocols should have more capabilities to handle these MANET specific routing characteristics.

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 [5]. These properties have been listed on next page:

⇒ *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 MANET 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.

⇒ *Localized reaction to 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.

2.1.2 Classification of Routing Protocols

In section 2.1.1, we discussed different desirable properties of an efficient routing algorithm. 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 MANET routing protocols as follow:

2.1.2.1 Reactive vs. Proactive

This is the first and very important classification of MANET routing protocols.

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 [6],
- Optimized Link State Routing (OLSR) [7]

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) [8],
- Dynamic Source Routing (DSR) [9]

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

2.1.2.2 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.

2.1.3 MANET Routing protocols

In recent years, MANETs have attracted researchers because of its unique application. Therefore, lots of routing algorithms have been suggested. A list of well-known routing protocols is given below.

⇒ Destination Sequenced Distance Vector (DSDV)
⇒ Dynamic Source Routing (DSR)
⇒ Ad Hoc On-Demand Distance Vector (AODV)
⇒ 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.

2.1.3.1 Destination Sequenced Distance Vector (DSDV)

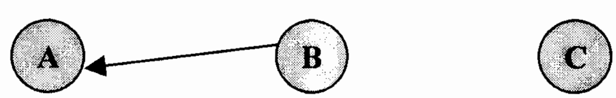
Destination sequence distance vector (DSDV) [25] is one of proactive routing protocol proposed for mobile ad hoc networks. Each node in DSDV maintains routing table, having all available destination with number of hopes to each. Each node in DSDV routing protocol advertise its routing information to neighbor nodes periodically or incrementally, according to topology condition. DSDV uses destination sequence number to avoid routing loop and count-to-infinity problem [12] [19] [14].

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).

2.1.3.2 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 [12] [17].

2.13.3 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 [12] [13] [18].

2.1.4 Mobility Models

There are numerous mobility models, but since we have taken three mobility models for our research, so we are going to explain them. They are:

2.1.4.1 Random Walk Mobility Model

One of the most widely used mobility model is Random Walk Mobility Model [11]. The movement of many entities in nature is unpredictable, like the movement of molecules of air [11]. 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 [11]. 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.

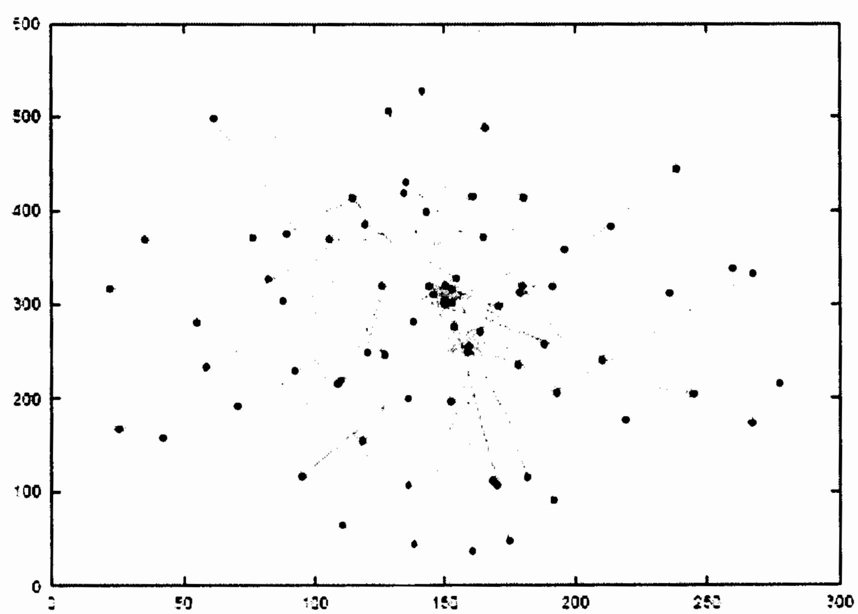


Figure 2.1 – Traveling pattern of an MN using the 2-D Random Walk Mobility Model

2.1.4.2 Random Waypoint Mobility Model

Another one of the most commonly used mobility model is Random Way Point [17, 4]. 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 [11].

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

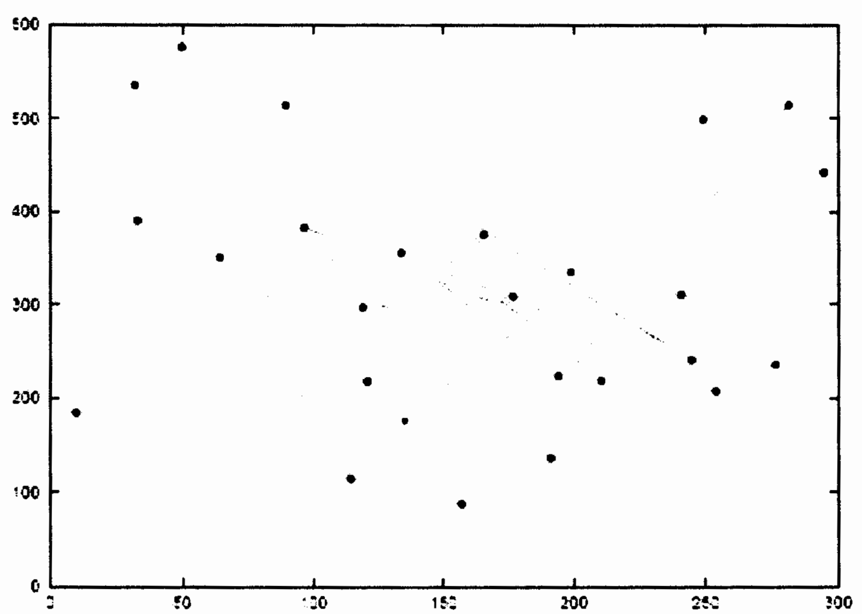


Figure 2.2 - Traveling pattern of an MN using the Random Waypoint Mobility Model

2.1.4.3 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.

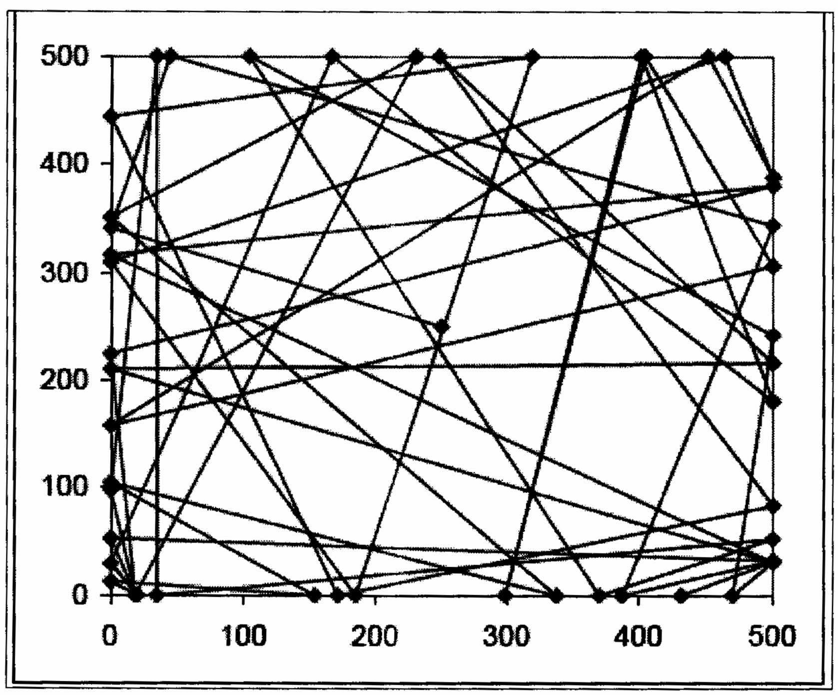


Figure 2.3 - Traveling pattern of an MN using the Random Direction Mobility Model.

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Chapter 3

Literature Review

Objective:

The objective of this chapter is to have a fair understanding of the work already done by researchers around the globe related to our research project. .

3. Literature Review

This chapter provides an overview of the related work to our research project.

3.1 Quantitative Analysis of MANET Routing Protocols

A number of papers are available on the quantitative analysis of MANET routing protocols. In this section an overview of some papers is covered.

In paper titled "*Performance Analysis of Adhoc Network Routing Protocols*" [12], by Mr. P. Chenna Reddy and Dr. P. Chandrasekhar Reddy have analyzed the performance of four routing protocols (DSDV, DSR, AODV and TORA). But they have considered only one mobility model, the Random Waypoint Model while evaluating different protocols.

After introducing basic routing techniques like link-state and distance-vector, the authors have described the above-mentioned protocols.

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" [13] 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*" [14] 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 R̲ 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" [15] 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.

3.2 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 [11] 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 [16], 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 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 [17] 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 [19] 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 4

Introduction to NS-2

Objective:

The objective of this chapter is to understand:

- *Network Simulator*
- *NS-2 benefits and limitations*
- *NS-2 packages etc*

4. Introduction to NS-2

We have carried out our simulation, to analyze the different performance parameters of MANET routing protocols in different mobility environment using NS-2 (version 2.31) [10] simulator. NS-2 offers some potential benefits, listed below:

Benefits

⇒ *Economy and ease of installation* are important factors while using NS-2 simulations. Because physical simulation demands lot of capital and hard work.

⇒ *Speed* is also an important factor, forces us to NS-2. Because physical simulation is very time consuming. Also modifications in NS-2 are easier and faster than actual scenario.

⇒ *Less space* is required as compared to physical networks. Because in physical networks, one have to put a lot of machines, power cables and other network components while in simulation one have to only install simulator on a machine.

⇒ *Open source and free* software: There are also other simulators like OPNET, which is very expensive. The research version of OPNET costs more than Rs. 3200000. While NS-2 is freely available on Internet.

Limitations

NS-2 offers above mentioned exciting features but it is very difficult to work in NS-2 for new user.

4.1 NS-2 Simulator

The simulator is written using a dual object-oriented design in C++ and OTcl. The C++ compiled components run the core simulation engine, event schedulers and agents. The OTcl based interpreter is used to setup the simulation configuration and controls of the C++ data path. The dual design benefits from the execution speed of the C++ compiled network objects and rapid reconfigure-ability of interpreted OTcl configuration objects.

Most often in simulation studies the parameters change with every new simulation, but the underlying protocols and data agents remain the same. Therefore, it is useful to have a rapidly reconfigurable simulator as the basis for using the dual interpreter/compiled class hierarchy. Since OTcl are interpreted changes in simulation parameters do not have to be recompiled, a researcher can run large sets of simulation with a one-time compilation of the C++ network objects. The control parameters and functions of the C++ compiled objects are exposed to the OTcl interpreter via OTcl linkage. For every OTcl object invoked in the interpreter hierarchy there is a mirrored object created in the C++ hierarchy.

4.2 Network Animator (NAM)

NAM, network animator, is used for visualisation of network scenario. It provides visualization of

- Packet flows, different packets can be coloured.
- Nodes' native packets queue.
- Packets which are dropped.

For wireless network simulation, nam plays an important role because it can help that whether a node is within range of another node. NAM is very important to analysis the mobile nodes' movements during simulation.

Following OTcl procedures are used to set node attributes, they are methods of the class Node:

```
$node color [color]                         ; # sets color of node
$node shape [shape]                         ; # sets shape of node (circular by default)
$node label [label]                         ; # sets label on node
$node label-color [lcolor]                  ; # sets color of label
$node label-at [ldirection]                 ; # sets position of label
$node add-mark [name] [color] [shape]       ; # adds a mark to node
$node delete-mark [name]                    ; # deletes mark from node
```

4.3 NS-allinone Components

NS-allinone is a package which contains required components and some optional components used in running NS. The package contains an "install" script to automatically configure, compile and install these components. After downloading, run the install script. We have found NS-allinone easier than getting all the pieces manually.

The NS-allinone-2.31 package that we have used contains following components:

- Tcl release 8.4.11 (required component).
- Tk release 8.4.11 (required component).
- Otcl release 1.11 (required component).
- TclCL release 1.17 (required component).
- NS release 2.31 (required component).
- Nam release 1.11 (optional component).
- Xgraph version 12 (optional component).
- CWeb version 3.4g (optional component).
- SGB version 1.0 (optional component, builds sgblib for all UNIX type platforms).
- Gt-itm gt-itm and sgb2ns 1.1 (optional component).
- Zlib version 1.2.3 (optional, but required should Nam be used).

4.4 Operating Systems for NS-2

NS can be used on the following plateforms:

- UNIX (Free BSD, SunOS, Solaris).
- Linux (RedHat 9, Enterprise Edition, FEDORA 4)
- Microsoft Windows

However for windows, Cygwing emulator is required for NS. The favorable operating system for NS is Linux/Unix operating system. We have used RedHat 9.

4.5 Built-in Support

Currently in NS-2 following ad hoc routing protocols are supported for wireless mobile nodes

- Destination Sequence Distance Vector (DSDV)
- Dynamic Source Routing (DSR)
- Temporally ordered Routing Algorithm (TORA)
- Adhoc On-demand Distance Vector (AODV).

Random Waypoint is the mobility model built-in to NS-2. The format of Random Waypoint model is given below:

$./setdest -n <num_of_nodes> -p <pausetime> -s <maxspeed> -t <simtime> -x <maxx> -y <maxy> > <outdir>/<scenario-file>

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Chapter 5

Implementation Details & Simulation Methodology

Objective:

- *To discuss different parameters of simulation environment*
- *To discuss implementation details*
- *System block diagram*

5. Implementation Details and Simulation Methodology

In previous chapters, we covered background and general concepts required to understand our research project. Also in the last chapter, we explored basics of NS-2, the simulation tool, we are going to use for implementation of our scenario.

This chapter discusses the implementation specifics related to the simulation model and the various components of the simulation environment. It also provides descriptions of the various simulation parameters and analysis used in this study.

In an effort to stick to our goals that is to conduct performance analysis of different routing protocols, we keep other variable parameters such as the amount of data traffic, size of the data packets and the link capacity constant through out the simulations. Thus the different test scenarios arise by varying *mobility models* and *mean speeds* of nodes and the employed *routing algorithm,* to see how the DSR, AODV, and DSDV perform in various scenarios.

5.1 Basic Scenario

Our scenario contains 50 nodes and simulation area is 670 x 670 pixels. Out of 50 nodes, 10 nodes are communicating with each other, that is, act as source or destination as shown in figure 5.1. Since we know that in MANETs, nodes act both as host and router. Therefore, rests of the 40 nodes are acting as routers, providing forwarding functions.

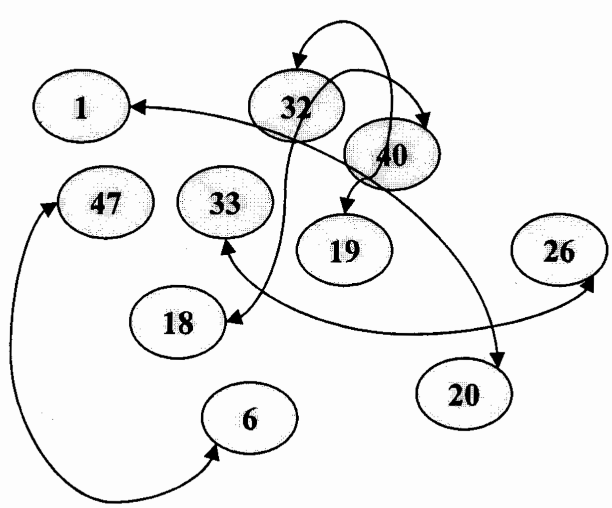


Figure 5.1: Communicating nodes attached pattern

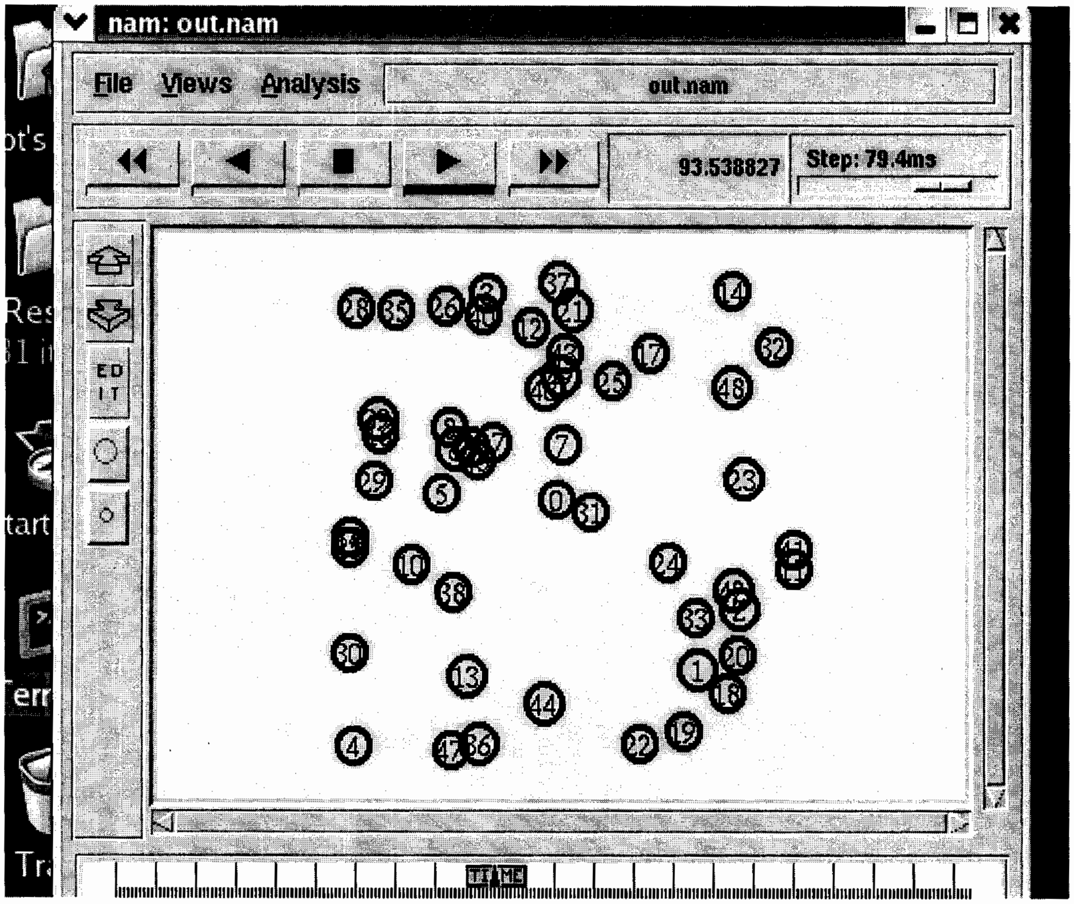


Figure5.2: Screen shot showing movements of 50 nodes

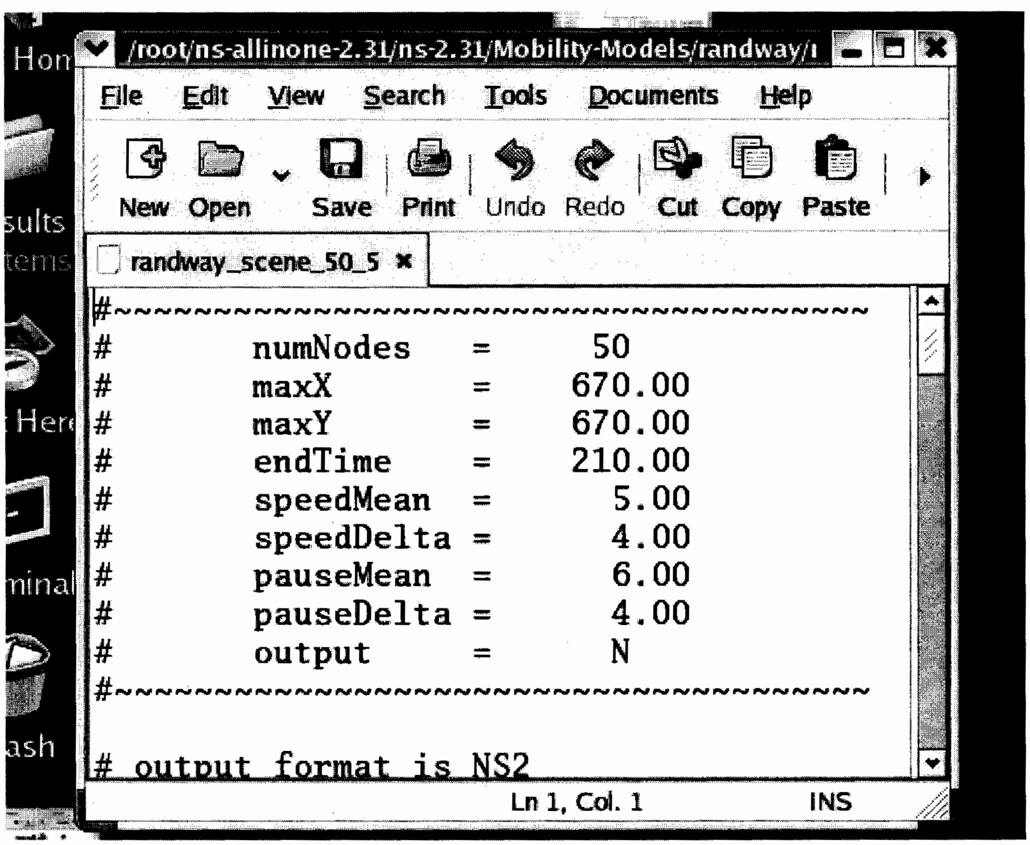
Figure 5.2 shows the movements of 50 nodes. Each mobile node in the simulation has the transmission range of 110m. The simulation is allowed to run for 210 seconds.

Here we have considered 50 ad hoc network nodes for the simulations. In real scenarios there may be less or more than 50 nodes. For example in case of small and medium size organizations the mobile nodes may not be more than 20 (as all employees don't have such devices). But in certain cases like high capacity Air bus such nodes will be more than couple of hundreds. Therefore, we considered a number lies some where between the two extremes and covers most of the realistic scenarios (considering small and medium size organization). Also most of the researches related to ad hoc network performance evaluation consider 50 (or around 50) nodes for their simulations [23] [11] [12] [24].

In our simulation we have considered variable mean speeds of mobile nodes ranging from 5 m/s (18 km/h) to 30 m/s (108 km/h) and intermediate values of 10, 15 and 30 m/s. We considered range of speeds to cover maximum nodes movements in real world scenarios. For example low speed pedestrian user, medium speed cycle riders and high speed vehicles. Also these speeds are used in literature [11] [24].

5.2 Traffic Generation

One of the important uses of MANET is in deploying a dynamic rapid communication network setup in disaster relief and military operations. These operations usually involve video and voice communication applications, which are mainly constant data rate datagram applications. To emulate similar loads, constant bit rate (CBR) traffic was used as the application traffic model running over a User Datagram Protocol (UDP) transport connection [12]. The CBR traffic generation scripts available in NS-2 were modified to generate a packet after every 0.02 seconds. Figure 5.3 on next page shows different parameters of simulations.



Figur5.3: Screen shot showing above mentioned parameters of simulations

5.3 Layered architecture of simulation environment

In this section, we are going to spell out the specification of different OSI layers in our simulation environment to have a clear view of the simulation. Figure 5.4 shows specification of different layers in our simulation.

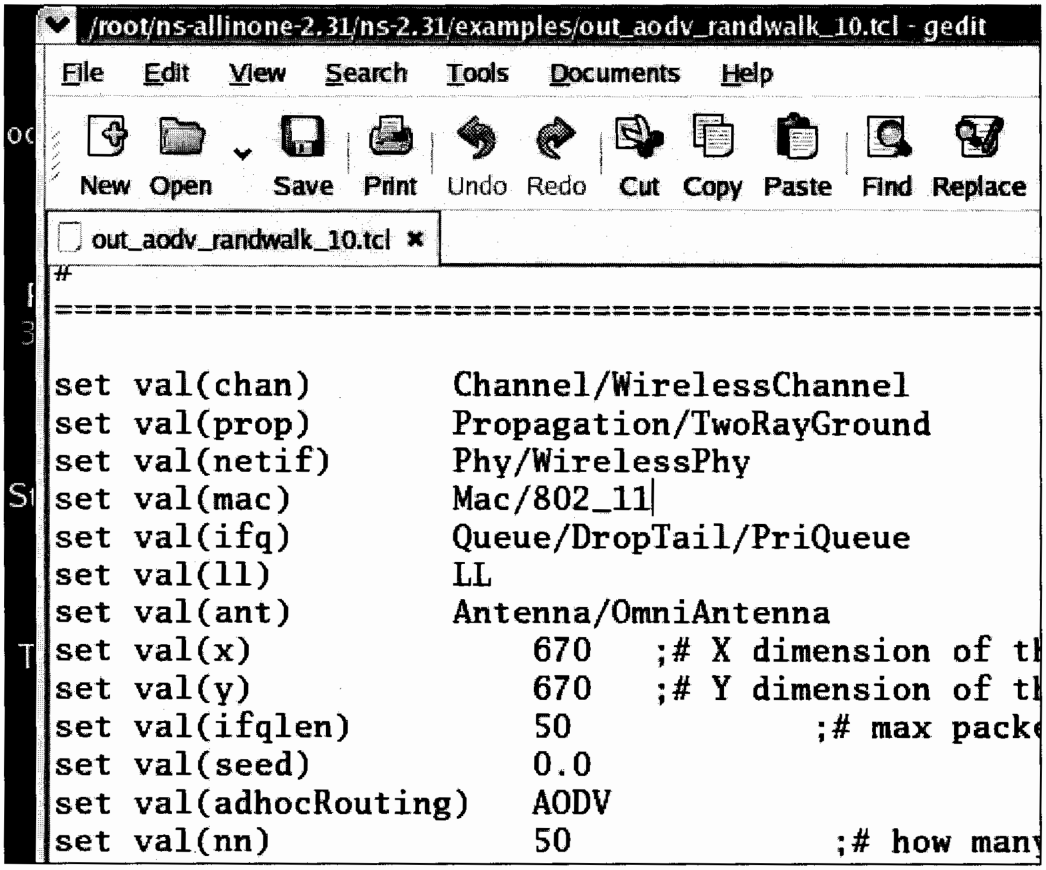


Figure 5.4: Screen shot shows different layer specifications

Physical layer: As we are simulating MANETs, therefore, we have a wireless physical layer. We are using default TwoRayGround propagation model. We are using omni-directional antenna. The antenna and other specifications are shown in figure 5.5 and tabulated in table 5.1.

Link layer: We are using IEEE 802.11 specifications at data link layer.

Network Layer: Internet protocol (IP) is used as an Internet layer protocol.

Transport Layer: UDP is used as a transport layer protocol. We preferred UDP over TCP because MANETs are most often employed in disaster relief and military operations. In such operations, voice and video are communication applications where delay is more

Application layer: We are using CBR (constant bit rate) for application traffic.

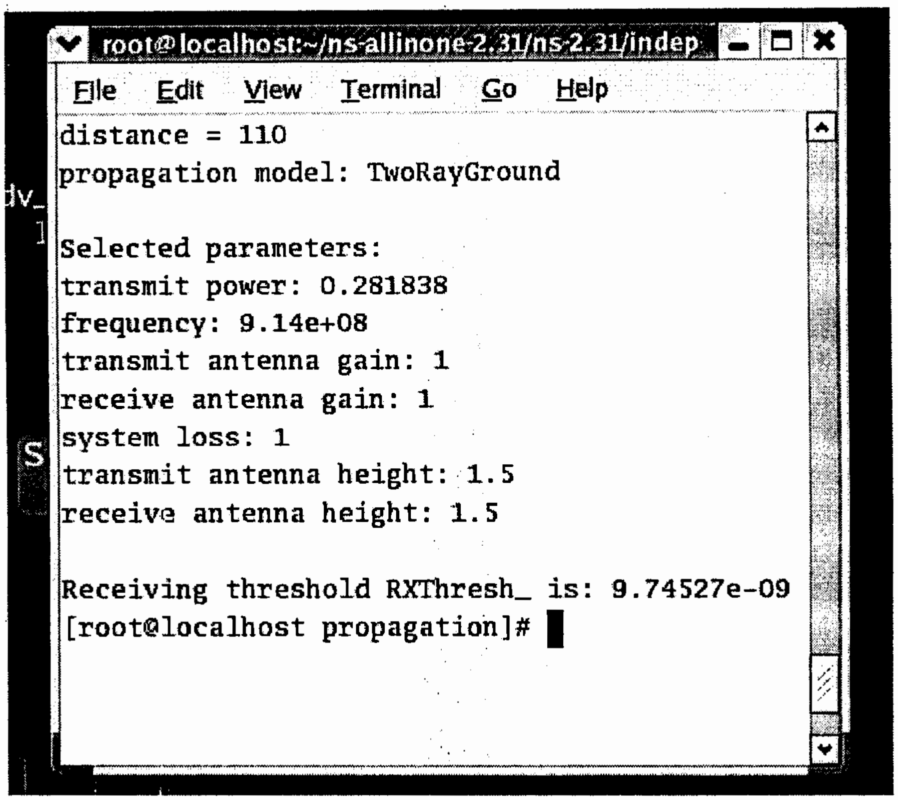


Figure 5.5: Screen shot of different antenna specifications.

Parameters	Specifications
Channel type	Wireless Channel
Radio-propagation model	Two Ray Ground
Network interface type	Wireless Physical Layer
MAC type	802.11
Interface queue type	DropTail/Priority Queue
Link layer type	Traditional Link Layer (LL)
Antenna model	Omni-directional (unity gain)
Transmit and receive antenna height	1.5 meters
Transmit & receive antenna gain	1

Table 5.1: Simulation parameters and their specifications

Finally we get the program named as ***out.tcl,*** by modifying the tcl code according to the specifications mentioned in table 5.1.

5.4 Mobility Pattern and Movement Scenarios

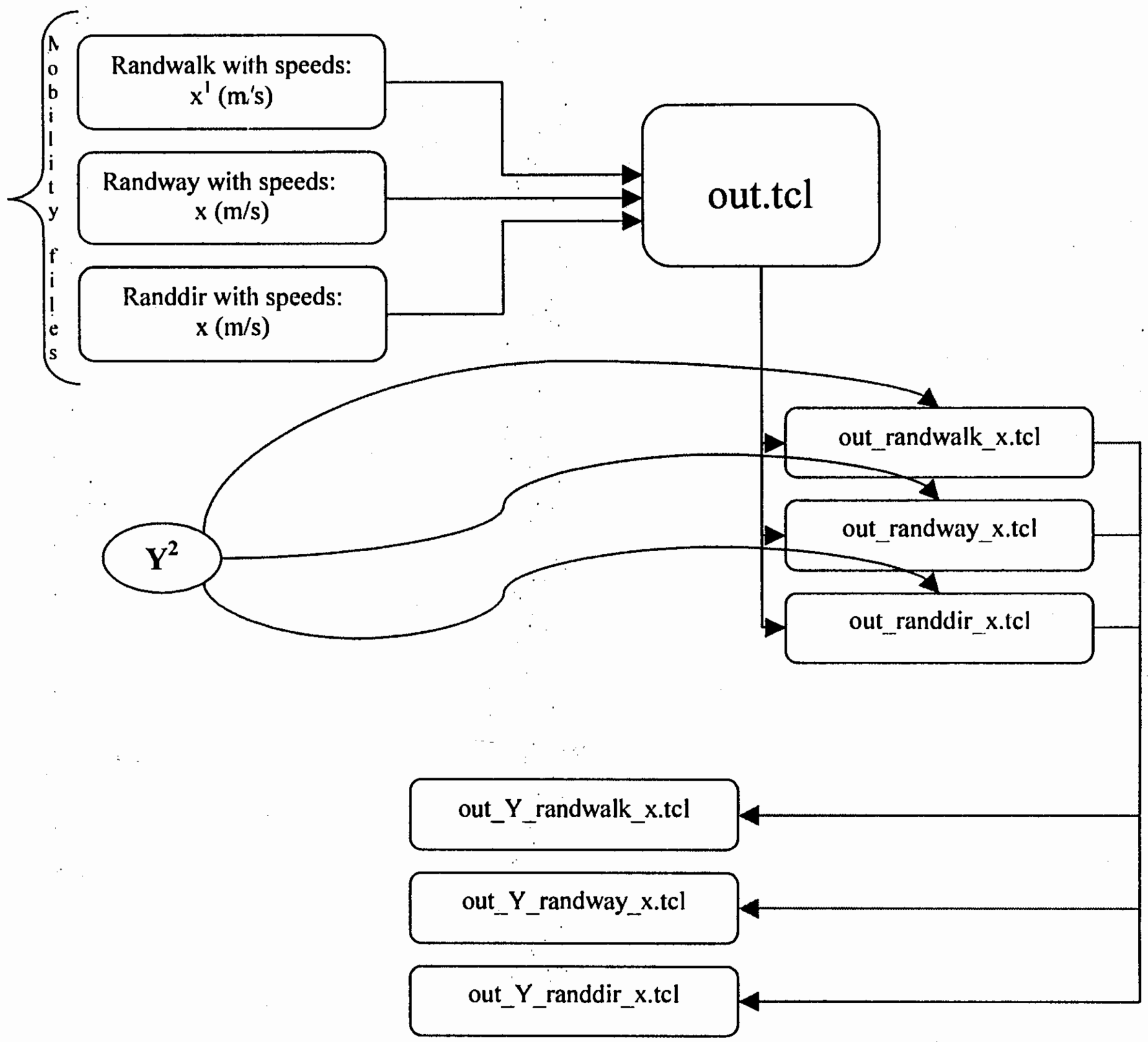
We have considered three random mobility models which are, Random walk, Random way, and Random direction mobility models. Further we are changing the mean speeds of mobile nodes in each mobility model. We selected the speeds as 5, 10, 15, 20, and 30 meters per second.

Therefore, we have created five mobility files for speeds 5, 10, 15, 20, 30 (m/s) in each model. Thus we get total of 15 mobility files. An example of generating such mobility files is shown in figure 5.6.

```
root@localhost:~/ns-allinone-2.31/ns-2.31/Mobility-Models/randwalk
File  Edit  View  Terminal  Go  Help
[root@localhost root]# cd ns-allinone-2.31
[root@localhost ns-allinone-2.31]# cd ns-2.31/
[root@localhost ns-2.31]# cd Mobility-Models/
[root@localhost Mobility-Models]# ls
boundless  col-perp       gaussmarkov  probrandwalk  randwalk  readme.txt
col-line   COPYRIGHT.TXT  license.txt  randdir       randway   rpgm
[root@localhost Mobility-Models]# cd randwalk
[root@localhost randwalk]# ls
makefile    randwalk.o            randwalk-scene-50-20  readme
randwalk    randwalk-scene-50-10  randwalk-scene-50-30  sece_randwalk
randwalk.c  randwalk-scene-50-15  randwalk-scene-50-5
[root@localhost randwalk]# ./randwalk
Usage:  randwalk <number of nodes>
                 <max-x> <max-y> <end time>
                 <speed mean> <speed delta>
                 <travelTime> <'N' or 'G'>
                 'N' implies NS2 mobility file
                 'G' implies gnuplot path file
```

Figure 5.6: Screen shot- An example of mobility file generation

After generating mobility files for each speed in each mobility model, we supplied these files to the ***out.tcl*** that we created earlier. Figure 5.7 on next page shows the above mentioned implementation methodology.



[1]Mean Speeds: 5, 10, 15, 20, 30
[2]Protocols: AODV, DSDV, DSR

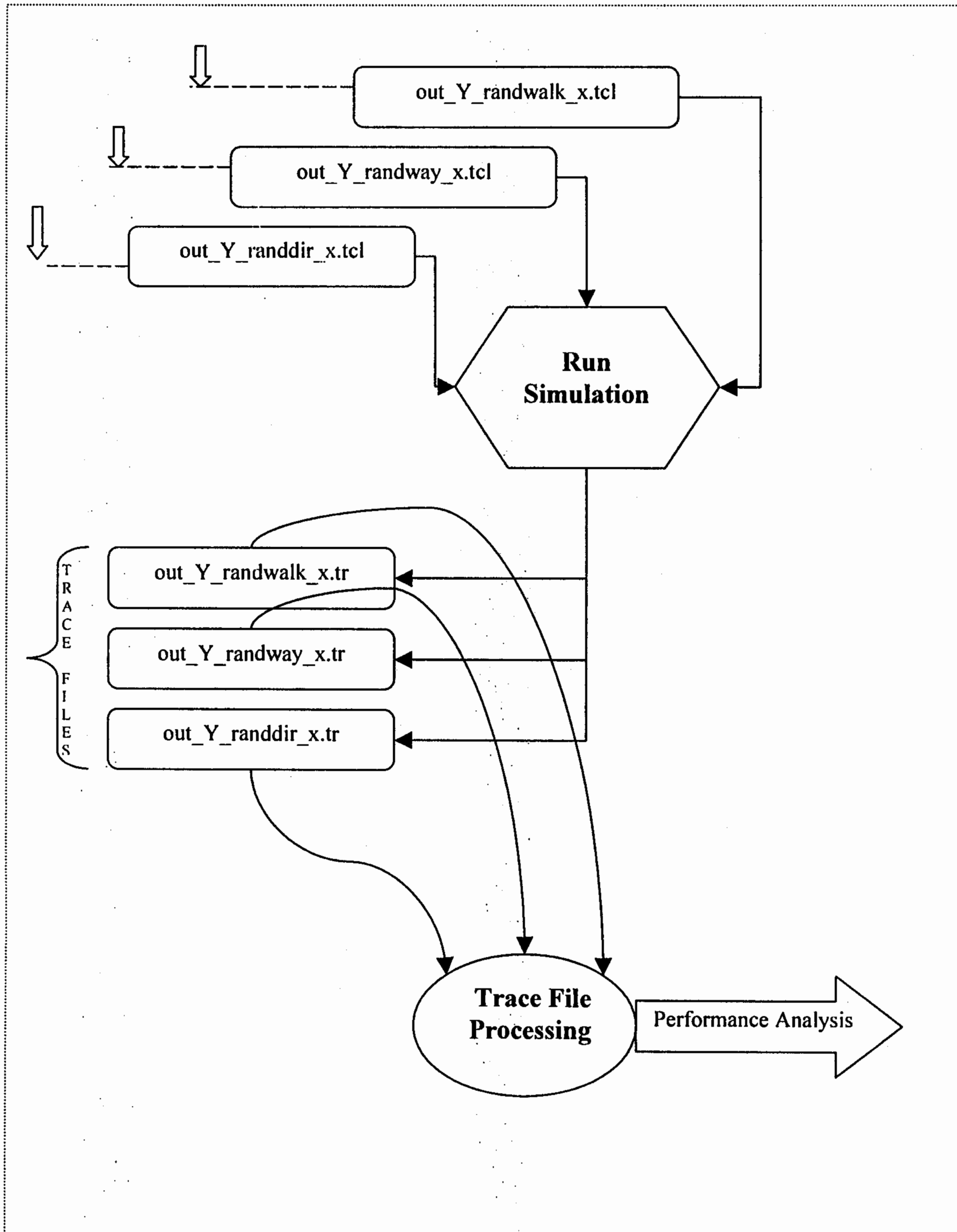


Figure5.7: Block Diagram of Scenario Implementation

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Chapter 6

Objective:

- *To understand different performance metrics*
- *To understand trace file*
- *To display actual Results*
- *Conclusions*

Performance Evaluation

6. Performance evaluation

This is the most important chapter in our thesis, since it deals with the performance evaluation of protocols. All previous chapters can be considered as the stage preparation process for performance evaluation.

6.1 Performance Metrics

For the performance analysis of AODV, DSR, & DSDV routing algorithms, we chose following parameters which are commonly used in the literature to evaluate the performance of various MANET routing protocols. They are:

⇒ *Packet dropped:* The number of packets transmitted by the source but not received by the target. We have considered different reasons for the evaluation of dropped packets like Collisions, time outs, looping etc.

⇒ *Packet received:* No. of packets received by the target successfully.

⇒ Average End-to End Delay: The average time taken by the data packet to reach the intended destinations. Here we considered Avg. 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 applications like multimedia application. It is also very important for applications where data in processed online.

End-to End Delay = (Packet received time) – (Packet sent time)

⇒ *Packet Delivery Ratio*: Ratio of the number of received packets over sent ones. This metric actually tells us how much reliable our ad-hoc network is. The greater this ratio is, the more reliable the ad-hoc network will be. We investigate the behavior of this metric by changing different operating simulation parameters of the ad-hoc network under study.

Packet Delivery Ratio = [(No. of packets received) / (No. of packets sent)] * 100

As stated earlier in the project description that for all our simulations we have kept the number of data packets sent out as constant, so the number of packets successfully received at their destinations will give us a comparison as to how efficient the underlying routing algorithm is under similar traffic load. Also all other simulation parameters have been kept constant while simulating the different routing algorithms. We have produced different scenarios by changing the mobility model and speed within each mobility model.

6.2 Performance evaluation methodology

As we are checking three protocol performance (AODV, DSR, DSDV) in three different mobility models. Further we are considering 5 different speeds (5, 10, 15, 20, 30 m/s) in every mobility model. Therefore, we have 15 scenarios for each protocol. After executing 15 scenarios for each protocol, we get total 45 trace files[1].

6.2.1 Trace File

The format of Trace file is given below:

```
s 40.720000000 _18_ AGT  --- 1066 cbr 500 [0 0 0 0] ------- [18:0 40:0 32 0] [11]
0 0
r 40.731770535 _40_ AGT  --- 1066 cbr 520 [13a 28 f 800] ----- [18:0 40:0 31 40]
[11] 2 0
s 40.740000000 _18_ AGT  --- 1067 cbr 500 [0 0 0 0] ------- [18:0 40:0 32 0] [12]
0 0
s 19.500000000 _1_  AGT  --- 690  cbr 500 [0 0 0 0] ------- [1:0 20:0 32 0] [450]
0 0
D 19.505433418 _7_  RTR  CBK 689  cbr 520 [13a 7 7 800] ------ [1:0 20:0 31 20]
[449] 1 0
D 19.505433418 _7_  RTR  CBK 690  cbr 520 [13a 7 7 800] ------ [1:0 20:0 31 20]
[450] 1 0
s 19.520000000 _1_  AGT  --- 691  cbr 500 [0 0 0 0] ------- [1:0 20:0 32 0] [451]
0 0
```

Table 6.1: Trace file format

6.2.2 Analysis of Trace File

The most challenging task in ns-2 is the correct interpretation of trace file. In this section we are going to discuss the meaning of each column in the trace file shown in table 6.1.

Action: [s|r|D]: s -- sent, r -- received, D -- dropped

When: the time when the action happened

Where: the node where the action happened

[1]Figur 5.7 in chapter 5 explains the whole process

LAYER:	AGT -- application, RTR -- routing, LL -- link layer (ARP is done here) IFQ -- outgoing packet queue (between link and mac layer)
MAC Layer:	-- mac,
Physical Layer	-- physical
SEQNO:	the sequence number of the packet
Type:	the packet type cbr -- CBR data stream packet DSR -- DSR routing packet (control packet generated) RTS -- RTS packet generated by MAC 802.11 ARP -- link layer ARP packet
SIZE:	The size of packet at current layer, when packet goes down, size increases, goes up size decreases
[a b c d]:	a -- the packet duration in mac layer header b -- the mac address of destination c -- the mac address of source d -- the mac type of the packet body
[a:b c:d e f]	source node ip : port_number destination node ip (-1 means broadcast) : port_number ip header ttl ip of next hop (0 means node 0 or broadcast)

So we can interpret the below trace

```
s 76.000000000 _98_ AGT --- 1812 cbr 32 [0 0 0 0] ------- [98:0 0:0 32 0]
```

as Application 0 (port number) on node 98 sent a CBR packet whose ID is 1812 and size is 32 bytes, at time 76.0 second, to application 0 on node 0 with TTL is 32 hops. The next hop is not decided yet.

6.3 Simulation Results

6.3.1 Packet Lost

Packet lost in Random Walk Mobility Model

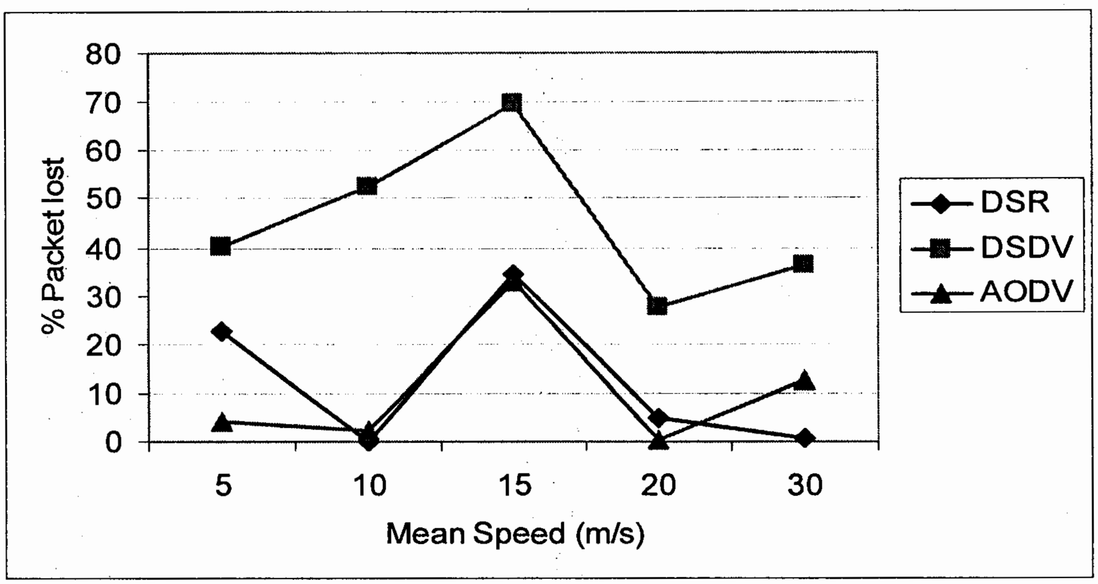

Figure 6.1: Packet lost vs. mean speed in RandomWalk mobility model.

Analysis: All three protocols have maximum packet loss between 10 and 15 m/s. Both DSR and AODV perform well at high speeds. In case of DSDV, we recorded almost same packet loss at both very low and high speeds. Thus DSDV perform poor at all speeds than other two protocols.

Packet lost in Random Way Mobility Model

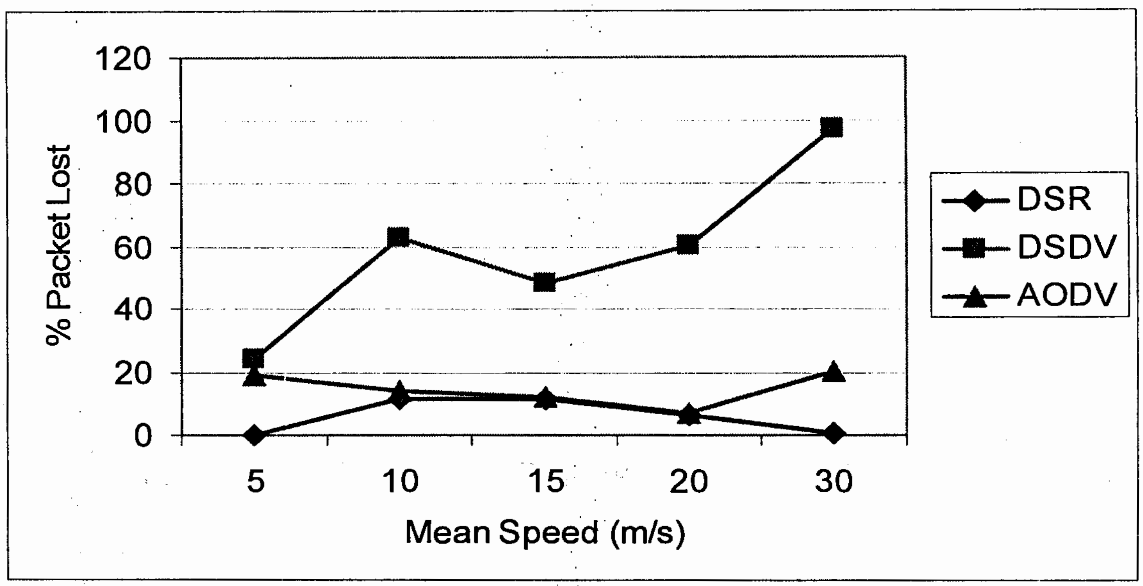

Figure 6.2: Packet lost vs. mean speed in RandomWay mobility model.

Analysis: In Random way, again DSDV packet loss is higher than other protocols, at all speeds. However, DSDV perform well at low speed.

DSR and AODV have same packet loss from 10 to 15 m/s. At low speed DSR is better than AODV, while at high speed the reverse is true.

Packet lost in Random Direction Mobility Model

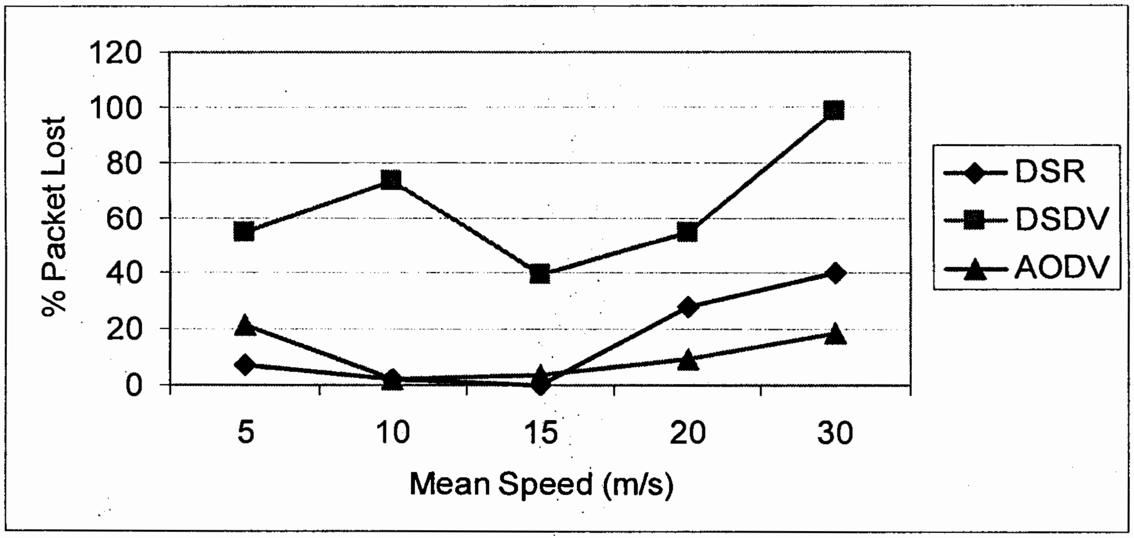

Figure 6.3: Packet lost vs. mean speed in Randomdir mobility model.

Analysis: Trend of increased packet loss is observed in all three protocols at high speed. All the protocols perform well, having less packet loss at 15 m/s. As a whole, DSDV shows greater packet loss at all speeds. DSR is good at low speed, while AODV perform better at high speed.

6.3.2 Packets Received

Packet received in Random Walk Mobility Model

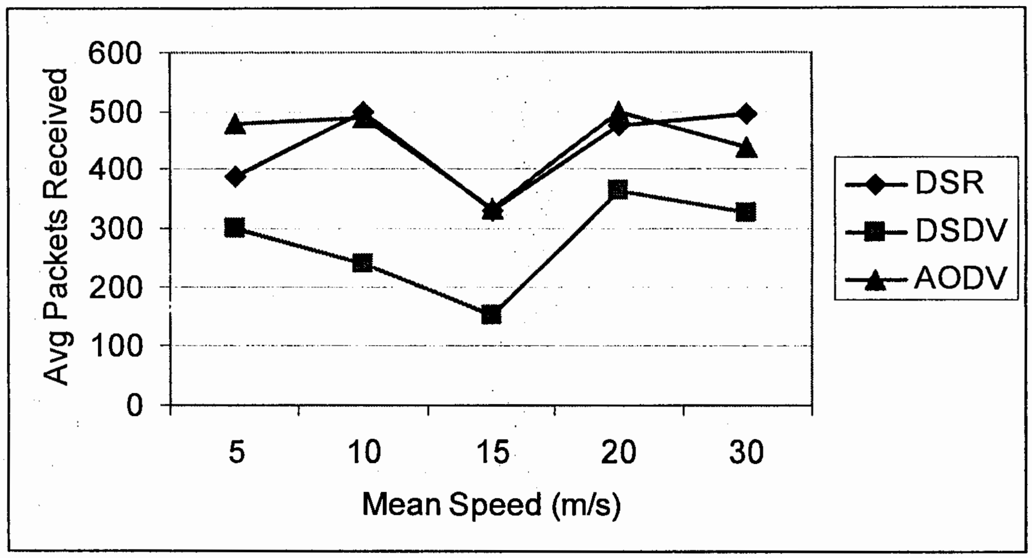

Figure 6.4: Packet received vs. mean speed in RandomWalk mobility model.

Analysis: At mean speed equal to 15 m/s all three protocols perform poorly in terms of packet received. At low speed AODV perform better than other two protocols while at high speed DSR performance is best in terms of packet received. DSDV is poor at all speeds compare to other two protocols while peak value for DSDV is recorded at 20 m/s.

Packet received in Random Way Mobility Model

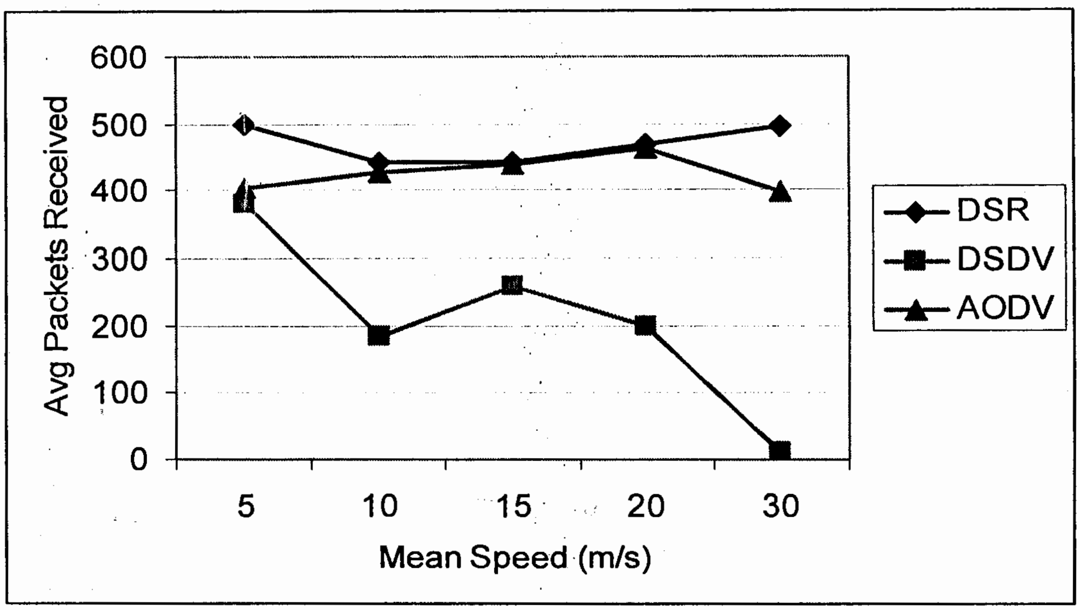

Figure 6.5: Packet received vs. mean speed in RandomWay mobility model.

Analysis: In RandomWay mobility model DSR shows good performance at all speeds and peaks are recorded at both very 5 and 30 m/s respectively. DSR is followed by AODV in terms of packet received; it shows good performance from 10 to 20m/s. Finally DSDV, which is relatively good at low speed but completely fails in terms of packet received as mean speed keeps on increasing.

Packet received in Random Direction Mobility Model

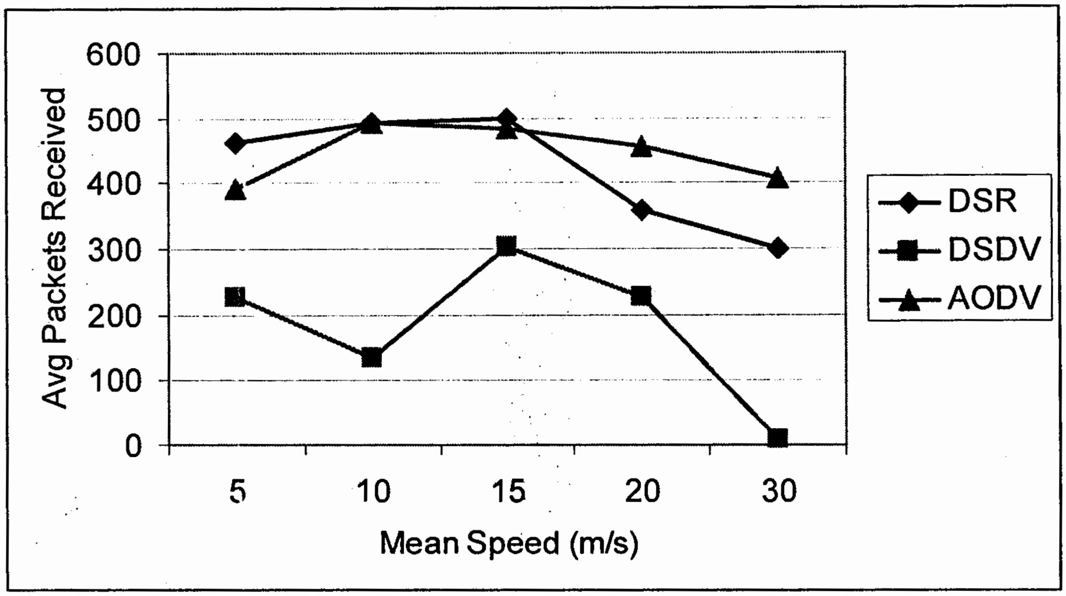

Figure 6.6: Packet received vs. mean speed in Randomdir mobility model.

Analysis: In Random direction model all protocols perform poor at high speed. At low speed DSR is better than AODV and DSDV while at high speed AODV is best in terms of packet received. DSDV as ever is better at low speed but perform very poorly at high speed.

6.3.3 Average End-to-End Delay

Average End-to-End delay in Random Walk Mobility Model

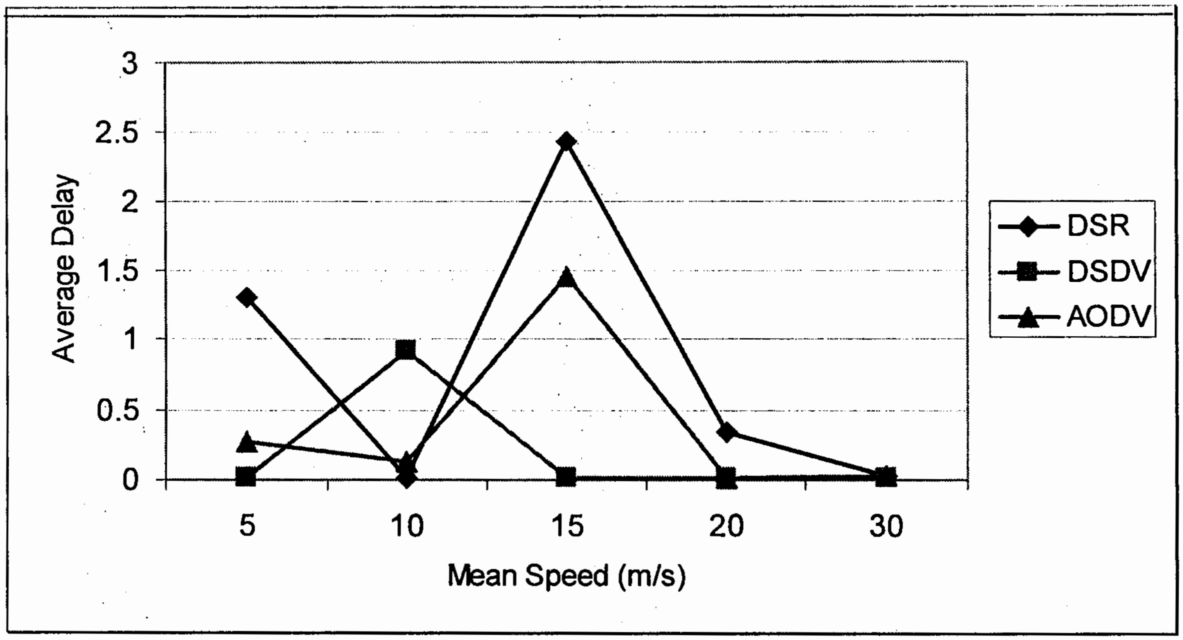

Figure 6.7: Average Delay vs. Mean Speed in RandomWalk mobility model.

Analysis: In random Walk model both DSR and AODV show peak values at 15 m/s. Both have minimum delay at 30 m/s. in terms of delay AODV is better than DSR at low speed. DSDV shows uniform low delay, except at speed 10 m/s where maximum value is observed.

Average End-to-End delay in Random Way Mobility Model

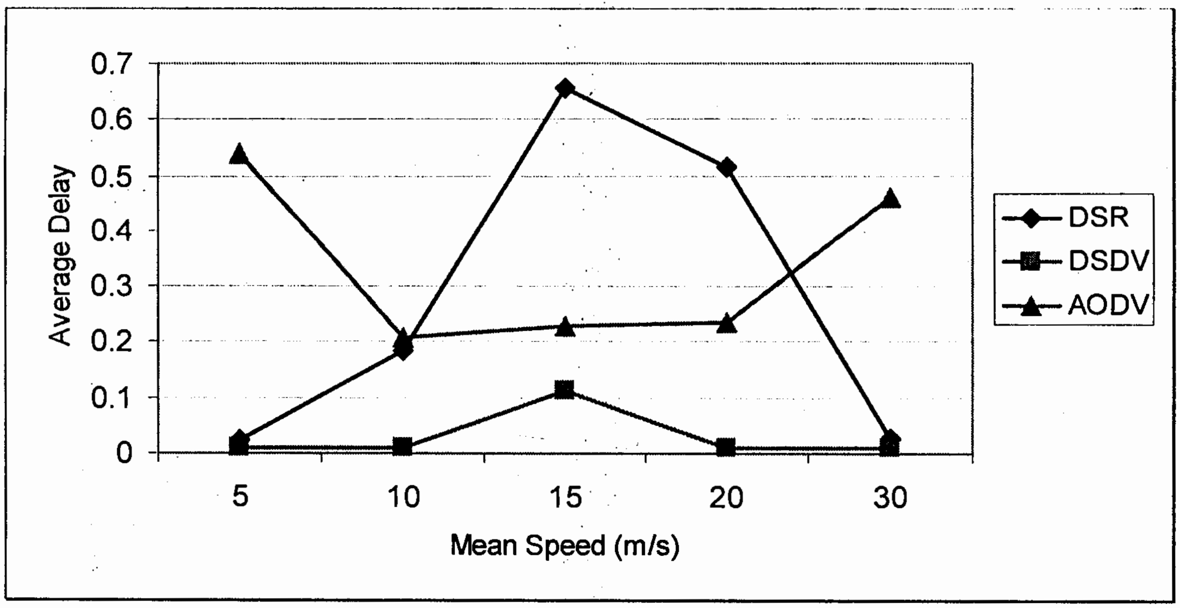

Figure 6.8: Average Delay vs. Mean Speed in RandomWay mobility model.

Analysis: We observe most fluctuations in DSR between 10 to 20 m/s. DSR and DSDV show peak values at 15 m/s. Both show minimum delay at very high and low speeds. AODV shows almost uniform delay from 10 to 15 m/s. High average delay is observed for AODV both very low and high speeds.

Average End-to-End delay in Random Direction Mobility Model

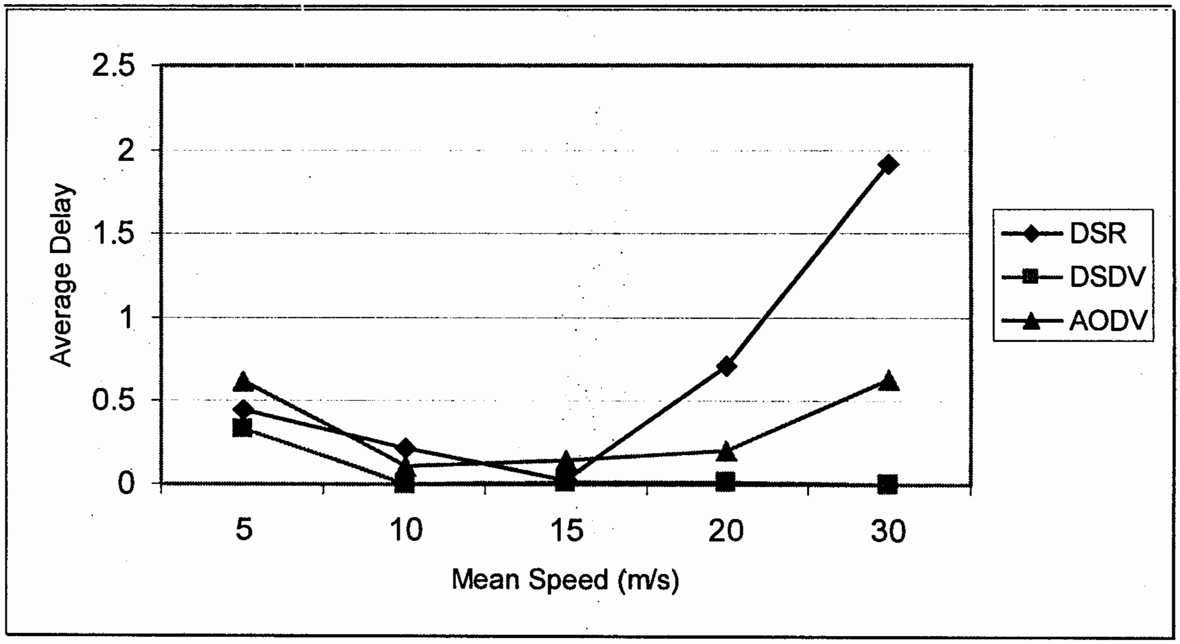

Figure 6.9: Average Delay vs. Mean Speed in Randomdir mobility model.

Analysis: In Random direction model, DSR and AODV show peak values at 30 m/s. For both protocol, minimum values are recorded from 10 to 15 m/s.

At 5 m/s DSDV shows maximum delay, while delay kept on decreasing and line become smooth at higher speeds.

6.3.4 Packet Delivery Ratio

Packet delivery ratio in Random Walk Mobility Model

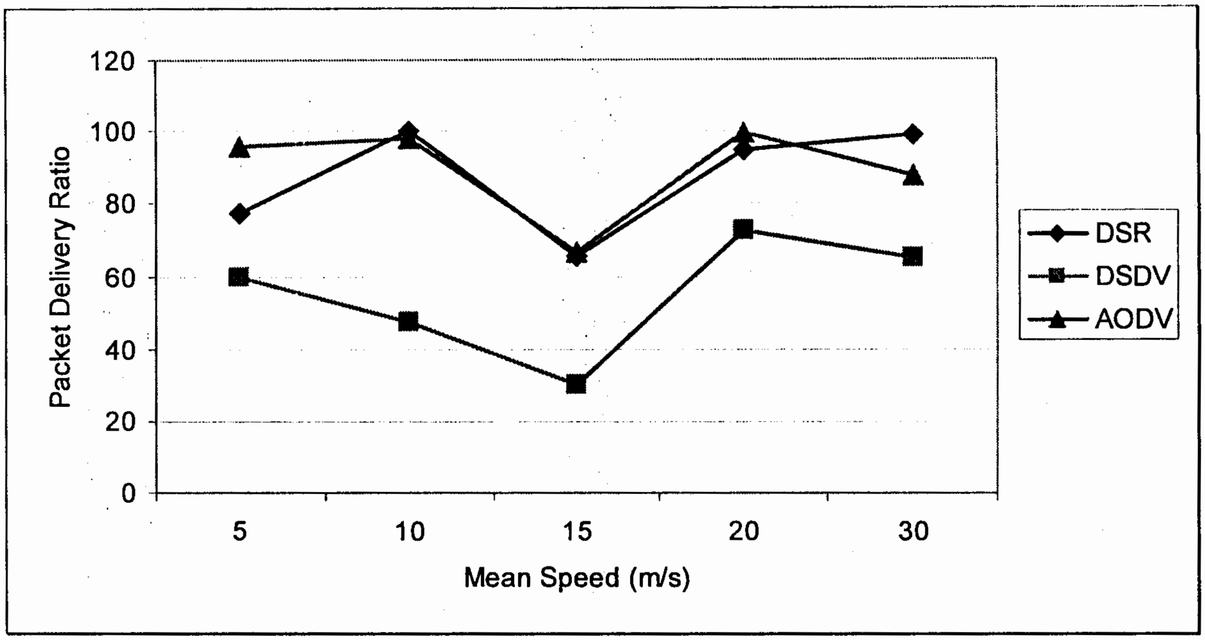

Figure 6.10: Packet delivery ratio vs. mean speed in RandomWalk mobility model.

Analysis: In RandomWalk mobility model, AODV is better than other protocols at low speed. As we increase mean speed, Packet delivery ratio of all protocols keep on dropping. At speed equal to 15 m/s, we noted minimum packet delivery ratio for all three protocols. Further increase results, increase in packet delivery ratio. At speed 30 DSR deliver more than AODV. DSDV perform poor for all speeds compare to DSR and AODV.

Packet delivery ratio in Random Way Mobility Model

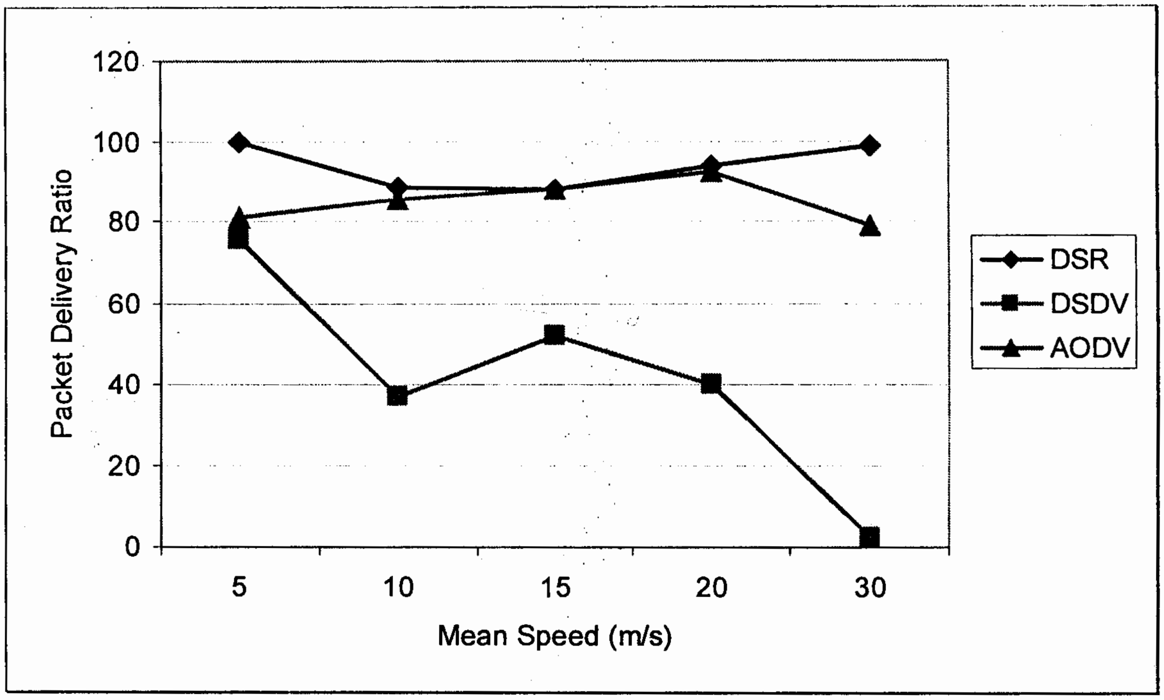

Figure 6.11: Packet delivery ratio vs. mean speed in RandomWay mobility model.

Analysis: Both DSR and AODV show almost same values for packet delivery ratios. DSR has peak values at both low and high speed. DSR perform well both at very low and high speed from AODV. Again DSDV is poor in terms of packets delivered compare to other two protocols. It is comparatively good at low speeds, but very inefficient at high speed.

Packet delivery ratio in Random Direction Mobility Model

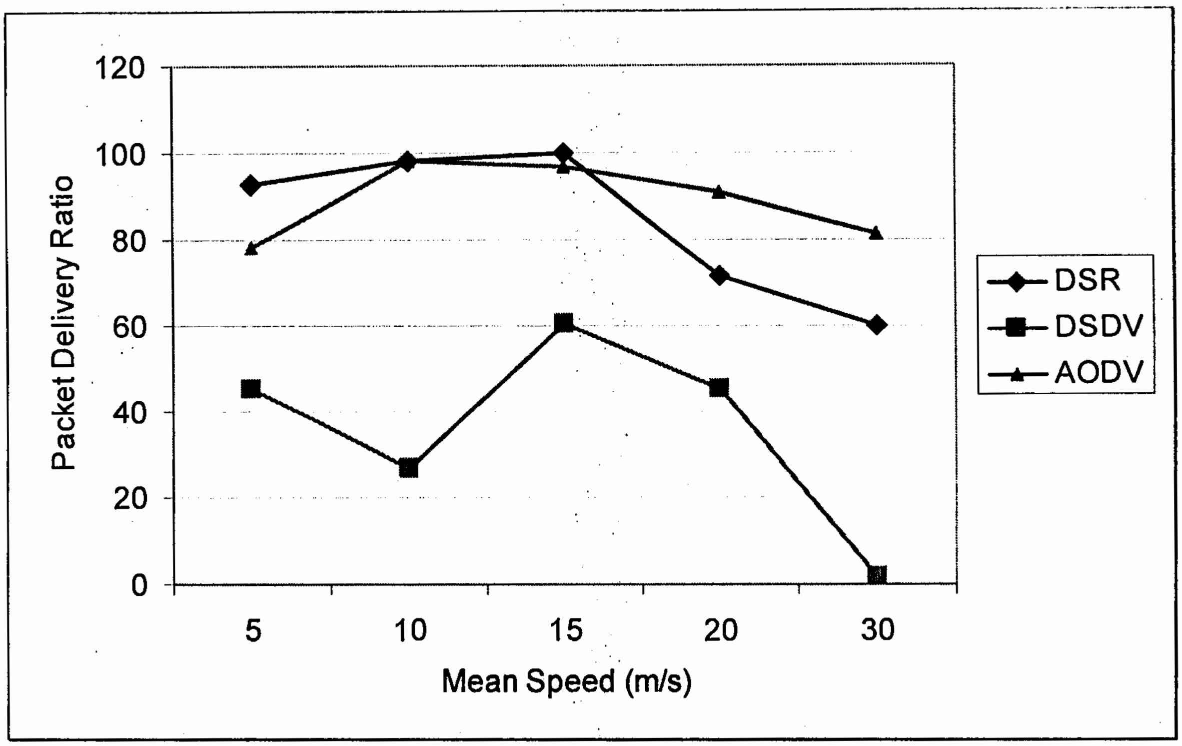

Figure 6.12: Packet delivery ratio vs. mean speed in Randomdir mobility model.

Analysis: At low speed DSR is better in terms of packet delivered in Random direction model, followed by AODV and DSDV. Peak values are recorded for three protocols at mean speed equal to 15 m/s. After this with further increase in mean speed cause the reduction in delivery ratios for all three protocols. DSDV is severely affected by increase in speed in terms of packets delivered.

6.4. Conclusions

From the above results, we obtain some conclusions listed below:

1. From figure 6.1 to 6.12, it is clear that MANET routing protocols' performance is changing in an unpredictable fashion by changing mobility models and nodes' speeds.
2. The mobility model plays critical role in the performance of an Adhoc network routing protocol [11]. From figure 6.1 to 6.12 it is clear that changing mobility model for a protocol results in completely different performance parameters.
3. By closely analyzing the figures from 6.7 to 6.12, we conclude that all the three routing protocol results in low delivery ratio and higher end-to-end delay in Random direction mobility model. Since the Random Direction Mobility Model has each Mobile Node move to the border of the simulation area before changing direction. Thus, protocols performance fall down in Random Direction Mobility Model compared to the other two random mobility models [11].
4. In most mobility model, the peak values of packet lost are recorded at higher speeds with few exceptions. This is because at higher speed the nodes rapidly changing their positions, so new routes are to be discovered. The packets spend more time in buffers waiting for suitable route to destination. The time out may cause packets to drop.
5. From results, it is clear that DSR has maximum Average delay than AODV and DSDV. Since DSR is a pure reactive protocol, requires complete route at the source itself, significant delay is introduced before transferring the packet [12]. AODV also introduces low delays when compared to DSR. Since DSDV is a proactive routing protocol, in most of the cases it uses already established route and tries to get rid of the packets immediately, resulting in low average delay.
6. In a same mobility model, for the same routing algorithm change in a single parameter (in our case it is mean speed), causes significant change in performance of the protocol.
7. From figure 6.1 to 6.3 it is clear that packets dropped by DSDV are increasing rapidly with increase in speed of nodes. Therefore, we observed DSDV as poor

protocol for mobile environment. This is because DSDV is a distance-vector protocol, dependent on periodic broadcast. Therefore it needs some time to converge before a route can be used. This converge time can probably be considered negligible in a static wired network, where the topology is not changing so frequently. In an Adhoc 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.

8. The nodes density also has important effects on the performance of an ad hoc network. As our research project is all about mobility of the nodes, but nodes density is indeed an important factor. There are some research papers available in literature which addresses this issue [21] [22]. It is noted that ad hoc network routing protocols perform well in high density environment and we get high delivery ratio. But with increase in delivery ratio the cost will also be higher as more collisions occur which consume more power and channel bandwidth. The literature also suggests that the nature of this transmission power tradeoff in mobile networks to determine the optimum node density for delivering the maximum number of data packets. It is shown that there does not exist a global optimum density, but rather that, to achieve this maximum, the node density should increase as the rate of node movement increases [21].

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APPENDIX

Two-Ray Ground Reflection Radio Propagation Model

Radio propagation in direct line-of-sight (LOS) communication can be modeled using the Friis free space model. The free space model computes received power at a distance *d*, when *d* is small using

$$P_r(d)=\frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

Here P_t is the power transmitted, G_t and G_r are the gain of transmitter and receiving antennas which is set to 1 in ns-2. L is the system loss, set to 1 in NS-2. λ is the radio signal wavelength.
When d is large, the propagation loss is more accurately modeled using the Two-Ray Ground Reflection model, which considers both the direct ray and the reflected ground ray. The Two-Ray Ground Reflection model computes received power at distance d by

$$P_r(d)=\frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L}$$

Here G_t, G_r and L are same as for the free space model and h_t, h_r are the heights of the transmit and receive antenna, set to 1.5 in NS-2. In the Two-Ray Ground Reflection model received power deteriorates faster with an increase in distance, but does not produce accurate results at a shorter distance.
The distance at which Two-Ray Ground Reflection model is accurate over the free space model is called cross-over distance d_c. The cross-over distance d_c is computed using

$$d_c=\frac{(4\pi h_t h_r)}{\lambda}$$

When the distance between nodes is less than d_c, the free space model is used and when distance between transmitting and receiving nodes is larger than d_c then the Two-Ray Ground Reflection model is used. This selection is done automatically by the simulator NS -2.

In the simulation for this study, the default wireless physical device available in NS-2, a Lucent WaveLAN direct-sequence spread-spectrum (DSSS) radio interface was used. The default for λ is 0.32822757, which corresponds to a frequency of 914 MHz and P_t is 0.28183815. The power received P_r computed from P_t and the propagation model described above should be greater than the receiving threshold (RXThreshold) for the packet to be received at another node. The value of RXThreshold for a given radio range can be calculated using the threshold utility.

List of Key Words

Acronym	Expansion
AODV	Adhoc On-demand Distance Vector
ARPA	Advanced Research Projects Agency
ARPANET	Advanced Research Projects Agency Network
CBR	Constant Bit Rate
CPU	Central Processing Unit
DDP	Datagram Delivery Protocol
DNS	Domain Name System
DSDV	Destination Sequenced Distance Vector
DSR	Dynamic Source Routing
FTP	File Transfer Protocol
HTTP	Hyper Text Transfer Protocol
IGRP	Interior Gateway Routing Protocol
ISO	International Organization for standardization
LAN	Local Area Network
LSA	Link State Advertisement
MAC	Media Access Control
MANET	Mobile Adhoc Network
MN	Mobile Node
NAM	Network AniMator
NS-2	Network Simulator-2
OLSR	Optimized Link State Routing
OSI	Open System Interconnection
OSPF	Open Shortest Path First
PDA	Personal Digital Assistant
QoS	Quality of Service
RIP	Routing Information Protocol
SMTP	Simple Mail Transfer Protocol
SNA	System Network Architecture
SPF	Shortest Path First
TCP/IP	Transmission Control Protocol/Internet Protocol
TFTP	Trivial File Transfer Protocol
TORA	Temporally Ordered Routing Algorithm
UDP	User Datagram Protocol
WAN	Wide Area Network
ZRP	Zone Routing Protocol