Simulation and Comparison of AODV Variants under Different Mobility Models in MANETs

Thesis Report

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Submitted By

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, ***"Simulation and Comparison of AODV variants under different mobility conditions in MANETs "*** , in partial fulfillment of the requirements for the award of degree of Master of Engineering in ***Computer Science and Engineering*** submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of ***Dr. Anil Kumar Verma*** and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

Today in the world of computer communications the concept of adhoc networking is at boom. Those users who wants to communicate with each other forms a temporary network in which the nodes acts both as host as well as router. Nodes are connected wirelessly that is free from any centralized administration. In these type of networks, nodes change their positions frequently. For this purpose, routing protocol is needed for MANETs.

AODV (Ad-hoc On Demand Distance Vector) is a reactive routing protocol for MANETs and it enables multihop routing within the mobile nodes taking part in initiating and preserving an ad-hoc network. In multihop routing, route is requested only when it is required and it does not keep track of routes to the destination node. Primary idea of this paper is to assess the AODV variants underneath acquainted mobility models. We have proposed this analysis in MANETs(Mobile Adhoc Networks). We have considered three mobility conditions i.e. Group mobility model, RandomWaypoint and Manhattan model. In our paper, performance metrics like PDR (Packet delivery ratio), Throughput and End to End Delay are used to evaluate the performance of AODV variants. The performance metrics are examined with varying node density and Ns-2 is used as an network simulator to carry out these simulations.

Keywords: AODV; AOMDV; MAODV; MANET; Mobility Models; PDR; Throughput.

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AODV Adhoc On-Demand Distance Vector

AOMDV Adhoc On-Demand Multipath Distance Vector

IEEE Institute of Electrical and Electronics Engineers

DARPA Defense Advanced Research Projects Agency

MANET Mobile Adhoc Network

NS Network Simulator

RERR Route ERRor

RREP Route REPly

RREQ Route REQuest

TCP Transmission Control Protocol

UDP User Datagram Protocol

TCL Tool Command Language

NAM Network AniMator

RPMG Reference Point Group Mobility

1. Introduction

1.1. Networks

The system in which various number of nodes are connected among themselves so that they can share resources and information, this type of system is known as Computer Network [1].

1.1.1. Wired Networks

Wired networks or we can also say Ethernet networks comes under the category of LAN technology i.e. Local Area Networks. Wired network basically consists of atleast two computers connected using ethernet cables. In wired network, computer must contain an ethernet adapter or network interface card (NIC) so that the computer can connect across the network. Ethernet adapters are of two types:

- Internal : Installed within the computer
- External : Installed in a separate case

Computers like Microsoft does not need a separate port for Ethernet adapter because it has a built-in port for adapter.

1.1.2. Wireless Networks

Wireless networks [2] are enjoying its quickest amount of growth in history, owing to enabling technologies which allows widespread deployment. A wireless network use the radio communication for connecting nodes of a network where as a wired network connects devices to the network using cables. The costly process of installing cables into the buildings can be avoided using wireless network technology. Mentioned below are some of the characteristics of wireless network technology which attracts the users towards this technology :

- **Mobility**: In wireless network technology, users can access any information from any place i.e users can ramble freely while still being in grip with the required back-end workplace infrastructure. With mobility, users can communicate with more efficiency.

- **Reachability** : Whether users are in remote places or they are in normal places, wireless network technology allows the users to be connected and be reachable.

Figure 1.1 Wireless Networks

- **Simplicity**: Wireless network technology is easy and quick to deploy as compared to the cabled network. At the initial stage, installation cost may be slightly higher but the benefits of this technology overcome this installation cost.

- **Maintainability** : To maintain the wireless networks, time and cost required is very less as compared to wired networks.

- **Roaming Services** : Anywhere and anytime services are provided using wireless network technology like in airplanes, trains and buses etc.

- **Easy Setup:** Installation is easy and cost-effective as there is no wire connectivity.

- **Expandable:** Wireless networks can be easily expanded using existing equipments whereas to expand wired network, additional wiring is required.

- **Robust :** Wireless networks are robust in nature i.e. the networks performs well both in ordinary as well as unusual conditions.

Wireless network on the basis of infrastructure are classified into two types of networks.

Infrastructure Based Network

An infrastructure based network or centralized network is a network consists of fixed base stations also known as access points. These networks provides wireless connectivity to the mobile terminals throughout a given area. All the base stations in the network are connected to other networks via wires. These base stations provides the coordinated control between the mobile terminals [2].

Figure 1.2 Infrastructure Based Networks

Infrastructure less Network

An infrastructure less network or a decentralized network is a network which does not contain any base station, wires, etc i.e. it is the network without any infrastructure. In this network, all the mobile nodes are routers. It consists of mobile nodes that are located in dynamic manner such that the interconnections between mobile nodes are maintained on a continual basis. Some key constraints of infrastructure less networks are:

- No existing infrastructure is required
- Node mobility is there as shown in Figure 1.3, firstly mobile node B is connected to A,D and E, but then due to dynamic nature it moves, and is now connected to A and E only.

- Scalability is there i.e. these networks work efficiently when there is requirement of large networks.

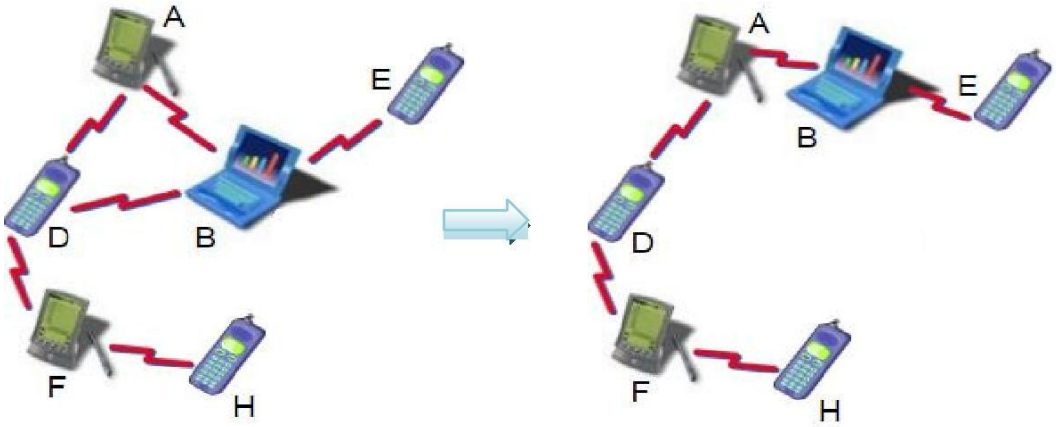

Figure 1.3 Infrastructure less Network

- **Adhoc Network:** Adhoc networks are also known as infrastructure less networks or multi-hop networks. A wireless adhoc network is a kind of temporary network i.e the network is created when it is required. Every node of this network uses a radio communication to communicate with other nodes. To transmit data packets from one node to another node , there is no need of any existing infrastructure.

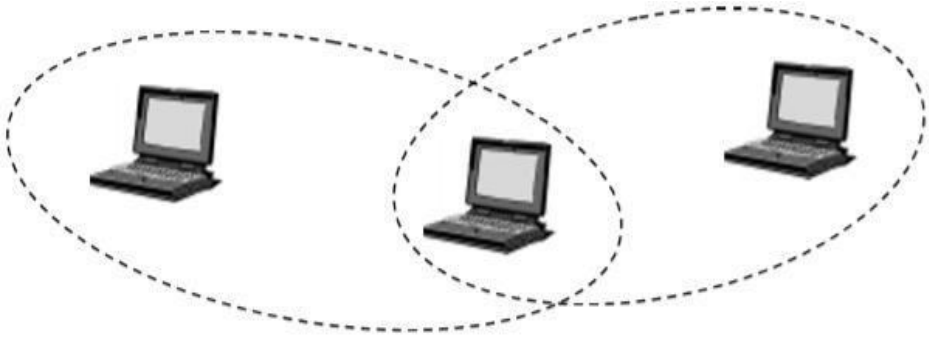

Figure 1.4 Example of a Wireless Adhoc Network

In Figure 1.4, we are showing the example of a wireless adhoc network of three nodes. The outer nodes are those are not in the transmitter range of each other forms a temporary network with middle node to communicate with each other. Middle node act as a router here. In this way, these three nodes forms an adhoc network.

- **Mobile Adhoc Network (MANET):** It is the network of mobile nodes

connected wirelessly which does not need any infrastructure and hence is self-configuring. It is the network in which the mobile nodes has a characteristic of anywhere and anytime access i.e the nodes can roam freely across the whole network. Due to the dynamic nature of mobile nodes, the topology of the network change quickly and unpredictably with time.

1.2 HISTORICAL DEVELOPMENTS OF MANET

In the early period of 1970, the Mobile Adhoc Networks (MANETs) [3] had been known from the name "packet radio network", that was supported by "Defense Advanced Research Projects Agency" (DARPA). This agency had a project which was named as "packet radio" consists of various wireless terminals that might communicate among themselves on battlefields. One of the interesting facts that should be known by everyone is that these systems anticipates the Internet but also were the reason for the inspiration of the original "Internet Protocol suite". Adhoc networks systems are basically distinguished into the following categories:

- First generation
- Second generation
- Third generation.

At present, third generation adhoc networks systems are taken into consideration.

In 1972 i.e the first generation, the adhoc network systems were known as Packet Radio Networks (PRNET). CSMA (Carrier Sense Medium Access) and ALOHA (Arial Locations of Hazardous Atmospheres) with PRNET approaches simultaneously for medium access control. A form of distance-vector routing PRNET were used on a attempt basis so that it can provide totally different networking capabilities in a combat atmosphere.

In 1980s i.e the second generation, adhoc network systems had been become more efficient. These were implemented as a part of the program which was known as SURAN (Survivable Adaptive Radio Networks). In the infrastructure less environment this program had provided a packet switched network to the battlefield of mobile.

Idea of economical adhoc networks comes with the notebook computers as well as

other communication devices in 1990s i.e. the third generation and within the same period, the concept of a group of mobile nodes was given in various gatherings of researchers. The term "Adhoc networks" had been adopted by IEEE 802.11 subcommittee and the possibility of deploying adhoc networks systems in many other applications is taken into consideration

1.3 Mobile Adhoc Networks: MANETs

In the coming era of wireless networking technology, quick deployment is required for the independent mobile nodes. For example, in military networks or in disaster prone areas, there is need to establish dynamic, efficient and survivable communication. As these network scenarios can be built in remote type areas, so these scenarios cannot rely on centralized connectivity. These scenarios are built using Mobile Adhoc Networks (MANETs).

A "MANET" or Mobile Adhoc Network forms an autonomous system [4] of the set of mobile nodes connected wirelessly. As the network is not centralized, all the nodes are routers i.e. they themselves deliver the messages and discover the topologies. All the functionality of routers is performed by mobile nodes itself.

Mobile Adhoc network are completely different from other networks due to the self organising capability. The network has the property called "degree of freedom" due to which mobiles nodes have the ability to roam freely and has the chance to make their own temporary network.

Figure 1.5 Mobile Adhoc Network [7]

1.4 CHARACTERISTICS OF MOBILE AD HOC NETWORKS

The mobile adhoc networks consists of the following characteristics[5][6]:

- Dynamic network topology
- Autonomous terminal
- Multihop routing
- Distributed operation
- Light-weight terminals
- Fluctuating link capacity

1.4.1 Dynamic Network Topology

Due to the dynamic nature of the mobile nodes, the topology of the network and the connectivity across the mobile nodes change unpredictably and rapidly with time. Mobile adhoc networks ought to adapt both propagation and traffic conditions simultaneously. Other than these conditions it should also adapt the mobility patterns of the nodes dynamically moving across the network. As the mobile nodes moves across the network, they dynamically form their own temporary network and establish routing among themselves. Mobile nodes in the MANET might not solely operate among the adhoc network, however it also require access to internet.

1.4.2 Autonomous Terminal

The autonomous property of the mobile nodes in MANET allow the mobile nodes to act as a host and a router simultaneously. As we all know, the basic ability of the nodes is to act as a host but in MANETs the nodes act as a router as well and thus can perform switching functions also. Therefore, one cannot distinguish between the switches and endpoints.

1.4.3 Multihop Routing

Based on various routing protocols and link layer aspects, adhoc routing algorithms are basically categorized into single-hop and multihop Single-hop routing is simpler to implement as compared to multihop and it also costs less in terms of applicability and functionality. In multihop routing, one or more than one intermediate nodes are

used to deliver the packets from source toward destination which is out of its transmission range.

1.4.4 Distributed Operation

In MANETs, since there is no centralized administration in the background i.e no one control the networks operations. Therefore, all the network management and control is distributed to the nodes itself. The nodes in MANET must work in cooperation so that they can implement routing and security in network.

1.4.5 Light Weight Terminals

MANET mobile nodes are light weight terminals i.e. the mobile nodes are having small memory size, less capability of CPU processing and low power storage. Due to these reasons, these nodes requires mechanisms and algorithms which are optimized that might implement some functions of communication and computation.

1.4.6 Fluctuating Link Capacity

In wireless connection of MANETs, bit error rate is too high. Many sessions often share the end to end path. As compared to wired network, the channel across which the mobile nodes communicate with each other is exposed to interference, fading and noise.

1.5 ISSUES TO BE CONSIDERED WHEN DEPLOYING MANET

The main issues[6] to be considered while deploying MANETs are:

- Unpredictability of Environment
- Unreliability of Wireless Medium
- Resource-Constrained Nodes
- Dynamic Topology
- Transmission Errors
- Node Failures
- Link Failures
- Route Breakages

- Congested Nodes or Links

1.5.1 Unpredictability of Environment

Adhoc networks can be deployed in environments ranging from hazardous conditions, unknown terrains to even hostile environments where node destruction can take place at any point of time. Also the node failures may occur often depending on the environment

1.5.2 Unreliability of Wireless Medium

The wireless medium communication is often unreliable and can be erroneous. EMIs, Bad weather or some other varying environmental conditions can deteriorate the quality of a wireless link and make it unpredictable

1.5.3 Resource-Constrained Nodes

The MANETs nodes offer a number of issues. They have less processing capabilities. Also sometimes in areas, where they are located, it is not possible to re-charge them and thus they have short life span. Because of all these issues, the nodes should be implemented on energy efficient algorithms with very less memory resources. Nodes often don't release the consumed energy (by operating at full link) thus limiting the available wireless medium bandwidth

1.5.4 Dynamic Topology

The topology in an Ad hoc network changes incessantly because of mobility of nodes. New links between nodes are created while some old links gets broken whenever nodes move, they are not in range of each other

MANETs are prone to a number of faults due to the above mentioned issues. These are:

- **Transmission Errors**

  The wireless medium being unpredictable and unreliable can lead to

transmitted packets being mixed and the received packets being full of errors.

- **Node Failures**

  The nodes often fail in different types of hazardous conditions of environment. The nodes may get disconnected from the network either voluntarily or owning to energy supply depletion

- **Link Failures**

  node failures, changing environmental conditions (e.g increased levels of EMI etc are the reasons for the breakdown of nodes. Link failures also causes the source node to discover new routes through other links.

- **Route Breakages**

  Node failures in the network can cause the network topology to change. This can make the routes out-of-date and eventually erroneous. Packets which are forwarded across the failed routes might be be dropped depending on the transport protocol of the network.

- **Congested Nodes or Links**

  Congestion of nodes (also called over utilized nodes) occurs because of the change in the network and the how routing protocol behaves in a network. This often leads to larger delays or packet loss

1.6 APPLICATIONS OF AD HOC NETWORKS

These types of networks are used in many situations i.e. to locate the infrastructure which is not cost effective or unavailable . Some of the detailed applications [7][8] are as follows:

1.6.1 Business Applications

In Business, Adhoc networks are used in meetings which are held outside the office with the clients related to brief description of the assignments. Game theory is derived from economics and is used in various domains, one of them is to used to analyze the network and in multi-person decision making in which every decision maker tries

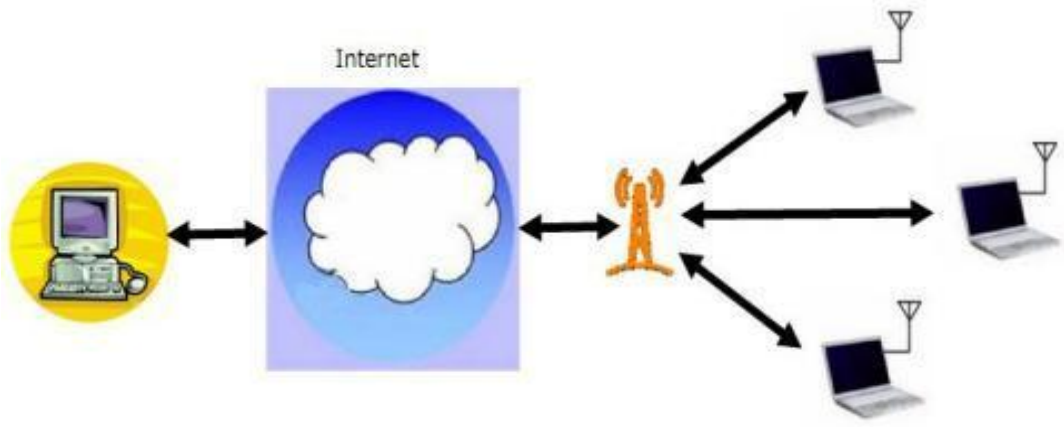

Figure 1.6 Client Server Model

maximize his utility. Research is still going on in game theory and its approach used in Tele-Communications. Client-Server model is used by the players (Single or Multiple users) to play games over the internet with remote host. If there is multiple users then we use common server. Figure 1.6 illustrates the client-server model

Drawbacks of Client Server Model are :

1. Client cannot play games
    - If there is no infrastructure.
    - If there is a bad connection.
    - If Server is unavailable or maximum number of users exceeded.
2. Clients can suffer from joining , randomly discovering and announcing a networked game.

1.6.2 Military Applications

Researchers have been motivated by military applications on Ad hoc networks. For quick setup of a network in hostile territory, infrastructure less environment supports

the friendly forces with various benefits on battlefield. All tanks, soldiers and various other vehicles are linked with Ad hoc network by a mobile device that represents the mobile nodes of the network. The idea automated vehicles in which no man is required in fighting (Recent Advancement in Robotics) are sent into battle. For reliable and robust communication across the dynamic network, self organized mechanism is used.

1.6.3 Emergency Operations

This type of operations covers disaster prone areas for recovery operations including rescue and research. For example,

- In airline systems, search and rescue operations are performed by attaching the micro-device to the life jackets below the seats. Suppose there is an emergency landing in sea or river due to some technical problem. When search and rescue team arrive there then the complete information about location and passengers are provided to them through the transponders. It is the duty of the rescue team to reach at the victims location and then check there vital signs by monitoring there pulse rate using mobile devices. After which, the team give proper treatment to those who are alive.

- When disasters occurs such as bombings, blackouts or earthquakes then it destroys all the built in infrastructure and one cannot contact to emergencies. In these type of situations, adhoc networks are used rapidly so that it can take the place of destroyed infrastructure . For future safety purpose, wireless network is used because they can be deployed quickly.

1.6.4 Home, Office, and Educational Applications

If wireless base stations are not present, adhoc networks are used in homes. This network provides the simple and direct method that is used in networking in laptops, WLAN- enabled devices.

In Education, the major use is in the knowledge provided by the lecturer to students, Meetings, Notes, Virtual classrooms.

2. Literature Survey

2.1 Routing in Adhoc Networks

Within the network, Routing in adhoc networks is the process of moving data packets from one end (source) to another (destination) across the network through one or more intermediate nodes. This is not the recent concept of computer technology, the idea of routing is developed in early period of 1970s. At that time the networks were used in homogenous environments and were terribly straightforward. People comes to know about this idea in the mid period of 1980s.Basically two activities are performed by routing:

- To determine the best routing path
- moving data packets from one end to another within the network

After the concept of routing, the concept named packet switching comes into existence. Packet switching is a very simple concept but path determination might be difficult.

Many metrics are available to determine the optimal path for moving data packets from source to its destination. To determine path, first of all, routing tables are initialized and maintained by routing algorithms which contains the whole information for the data packets about route. The information generated by routing algorithms differs from one algorithm to another and is filled in routing tables like ip-address prefix, next hop.

Switching is comparatively straightforward in determining path. In this, a host finds out that it ought to send data packet to another host. By using some methods, it gets the router address and then it sends data packets to the MAC address of router. Now, the router analyze the address of protocol and check whether it can transfer data packets from one end to another. If it has knowledge of transferring data then it moves the data packets to the destination. If it is not aware then it drop the data packets. Many routing algorithms are there to design adhoc networks. Categorization of adhoc routing protocols is shown in Figure 2.1.

• Topology Based

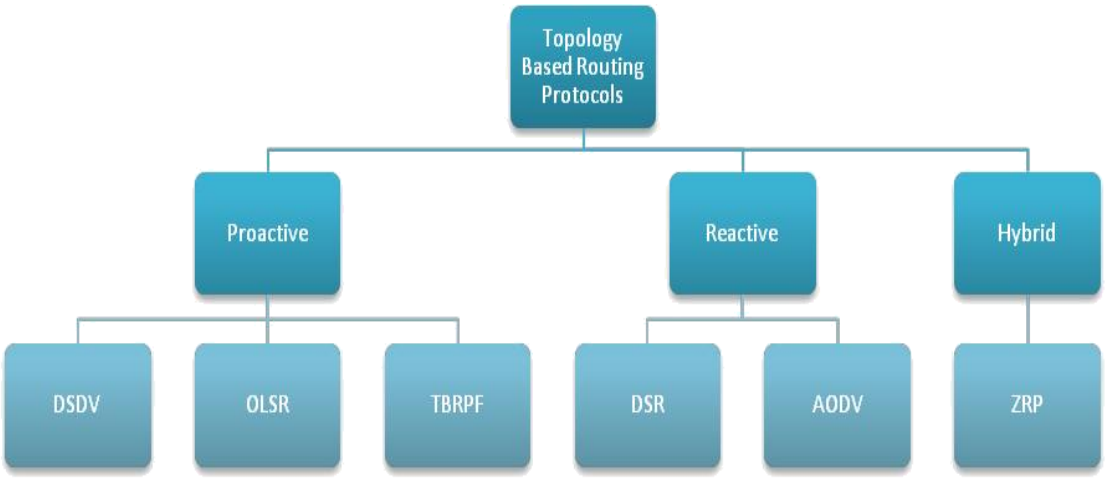

Figure 2.1 Based on Topology Classification of Routing Protocols

2.1.1 Routing Protocols based on topology

The information related to the already existing links across the network can be used to do the routing of the packets in these type of protocols [9]. Topology based (when and how they change the link state) routing protocols are classified into following subcategories :

- **Proactive Routing Protocol:** Every node in this routing protocol shares its complete information of routing with its routing table in regular intervals of time. This routing information is used to recognize the path for the nodes and make the plan of the internetwork. shown in Figure 2.2.

  The major benefit of these protocols is that they took very limited period of time to acquire the path up till destination[9]. However, to update the information, lot of bandwidth gets consumed which costs too much.

  There are various algorithms which are proposed beneath this category like DSDV, WRP and OLSR.

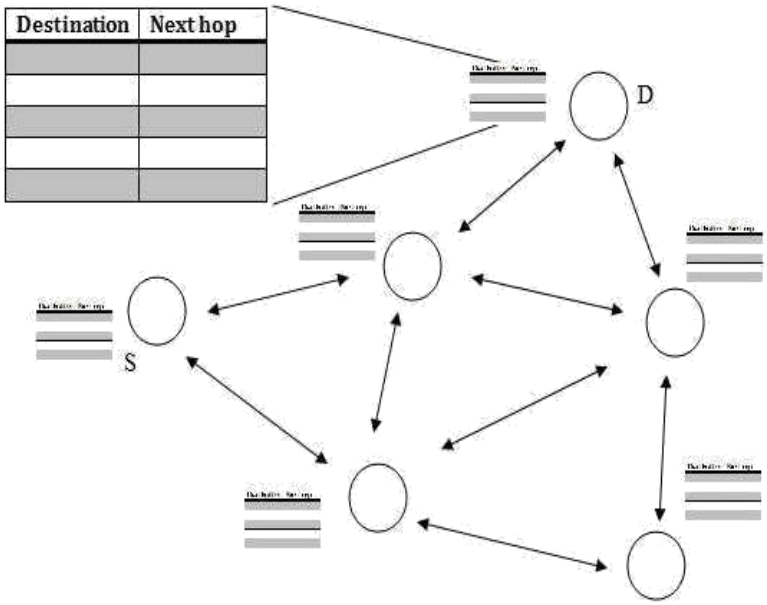

Figure 2.2 Scheme of Proactive Routing Protocols [9]

- **Reactive Routing Protocols:** The Reactive routing protocols do not broadcast the routing information within regular intervals. Indeed, these protocols broadcast their routing information only if it is required.

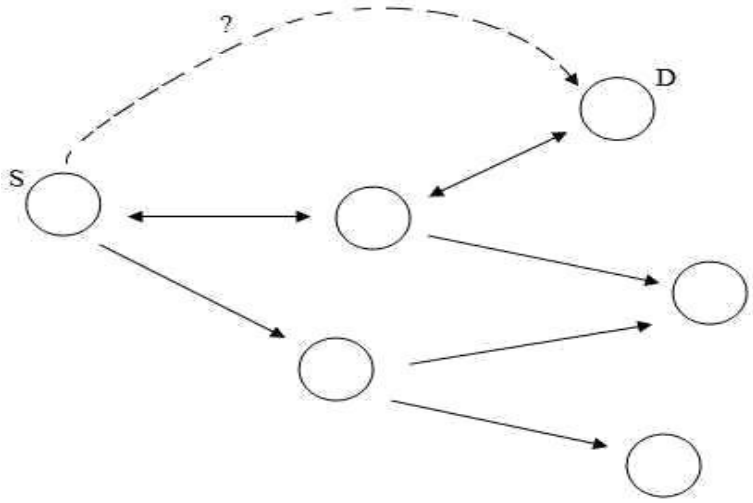

Figure 2.3 Scheme of Reactive Routing Protocols [9]

Therefore, they rarely use the network bandwidth. Because of the reactive

nature of these protocols, they suffer from some disadvantages such as, there is increase in delay of packet delivery from one end to another as compared to proactive protocols. Due to the dynamic nature of the mobile nodes, these protocols take more time to choose an intermediate. Algorithms like AODV, ABR and DSR [9] are proposed in this category.

- **Hybrid Routing Protocol:** These protocols are composition of both proactive and reactive routing protocols. This protocol is designed to overcome the limitations of both routing protocols i.e. reactive and proactive[9]. Because of the large overlapping zones, these protocols are not suitable for scalable networks with more than 100 nodes. For example, ZRP.

2.2 AODV Variants

2.2.1 AODV(Ad-hoc On Demand Distance Vector)

AODV [10][11] is a reactive routing protocol. As the definition of AODV says, it is an On Demand routing protocol, neither the nodes in the chosen path should maintain the route nor they should participate in the exchange of tables. It is pure-on-demand procurement system. AODV provides a procedure to route messages across various mobile computers. AODV allows the mobile computers to deliver messages through their adjacent nodes to nodes who are unreachable from mobile computers. AODV discovers the routes through which messages can be delivered and make effort to discover the loop-free route which is shortest. If it finds any error, AODV maintains the routes by creating new routes.

AODV routing table entries[12]

Destination Ip-Address- It provides IP Address for the destination.

Hop Count- How many hops are required to send data to the destination.

Destination Sequence Number- It specifies the sequence number of the destination.

Next-hop Address- The address of the adjacent node which is appointed to forward packets to the destination for the purpose of current route entry.

Life-time- How long this path can be used.

A broadcast Route Discovery Mechanism

- **RREQ: (**Route Request packet) is broadcasted to find a route. This packet contains broadcast id, destination ip address, destination sequence number, source ip address, source sequence number and hop count which is shown in Figure2.4.

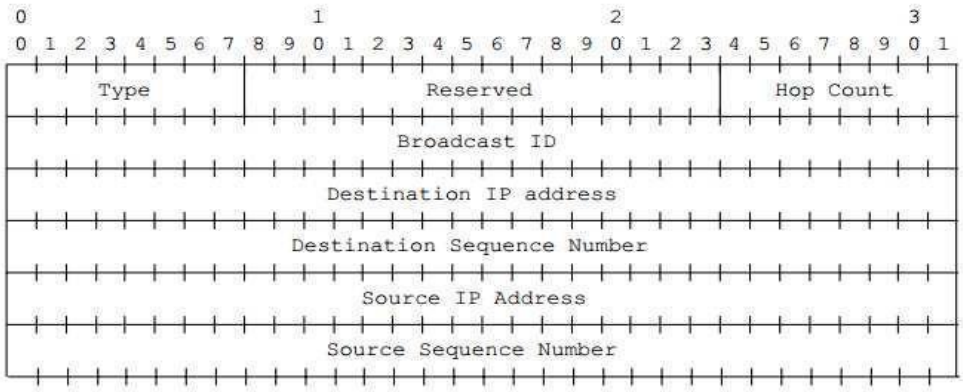

Figure 2.4 RREQ Format [12]

- **RREP:** Route Reply packet is used to set up a forward path. These messages are send back to the originator [12]. Figure 2.5 represents the format of RREP packet.

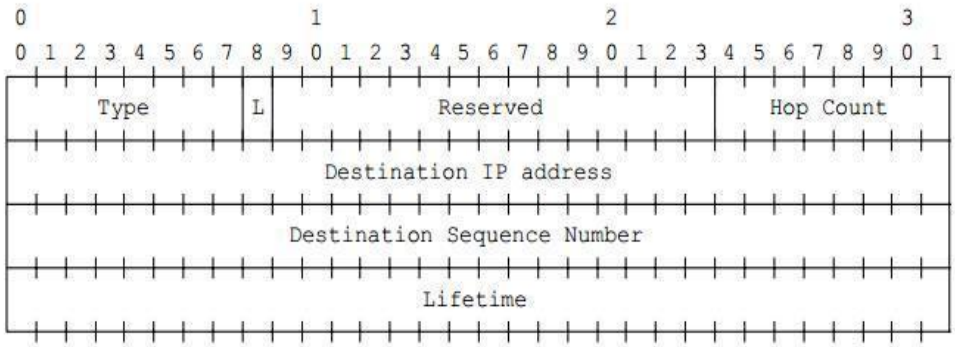

Figure 2.5 RREP Format [12]

RERR: (Route Error Packet**)** If any link breakage is there in a route, these packets are send to all the nodes across the network telling them about the link breakage.

Route Discovery: If source node likes to send a packet to the node at the destination, it acquires a path to the destination by broadcasting a RREQ(route request packet) across its adjacent nodes [13][14]. If any of the adjacent nodes has a route towards destination then these nodes reply with a RREP packet.

Route Maintenance: If any node identifies that a path to an adjacent node is no longer valid then the routing entry is discarded and link failure message is passed across the network. The affected sources will receive the message and they can either requests a new route by broadcasting a new RREQ packet or they can stop sending data.

2.2.2 AOMDV(Ad-hoc On-demand Multipath Distance Vector Routing)

AOMDV is a supplement of the eminent AODV routing protocol[15][16]. In every route discovery process, it locates multiple routes within the destination node and the source node. It is used to determine various link disjoint and loop-free paths. These multiple paths can be used for loop spreading and when main route fails these paths serve as a backup routes. In this routing protocol, RREQ packet moves from the source node towards the destination node and multiple number of reverse routes has been established at intermediaries and at the destination[17]. Several RREPs move across these reverse routes in backward direction so that multiple number of forward routes can be created from the source and intermediaries to the destination.

2.3 Mobility Models

Mobility models[18] can be differentiated with respect to random models, geographic restriction models and spatial dependency models.

- Random Models: In this model there is no restriction when mobile nodes moves across the network i.e they can move randomly.
- Spatial Dependency Models: In this model, mobile nodes have a mutual relationship among them. They propagates from source to destination in a correlated way[19].

- Geographic Restriction Models: In this models, mobile nodes may be halted by buildings, obstacle, freeways or streets.

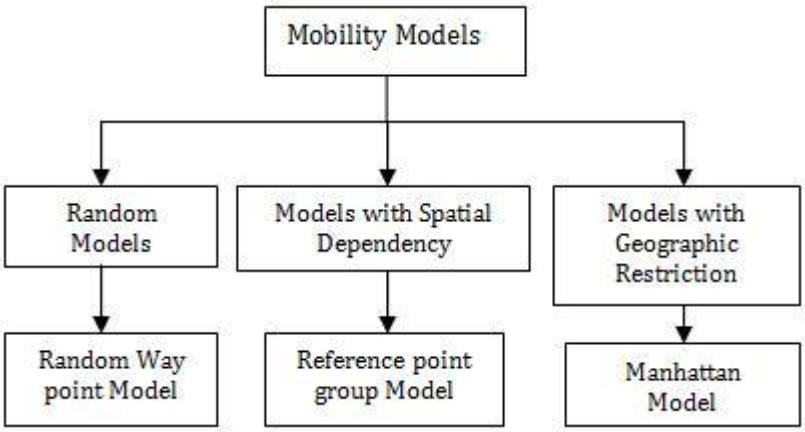

Figure 2.6 Mobility Models

2.3.1 RandomWayPoint

RandomWaypoint[20] is widely used mobility model. It became a standard model to assess and analyze the routing protocols of MANET. Every moment a node move towards the destination chosen randomly with a desired uniform velocity. It includes pause times whenever the node changes its direction or velocity till it approaches its destination. This action is constantly repeated till the end of the duration of the simulation.

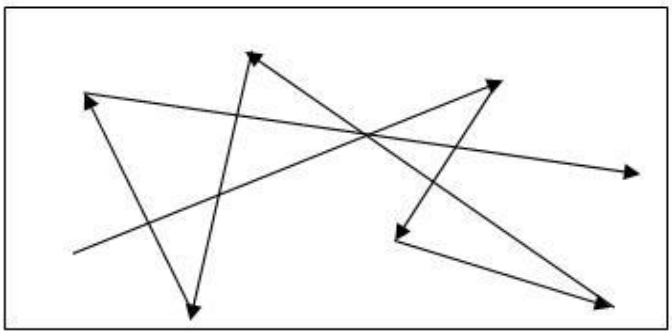

Figure 2.7 RandomWayPoint Mobility Model

2.3.2 RPMG(Reference Point Group Mobility)

Each group of this mobility model[21] consists of either a *group leader node* or a *logical center*. The nodes in a group[22] of this model are randomly placed in adjacent to its reference points. Afterwards due to the scheme of reference point which allows every node to have its own speed and direction. In addition to group motion, each node has an independent motion i.e. it deviates from its group leader randomly.

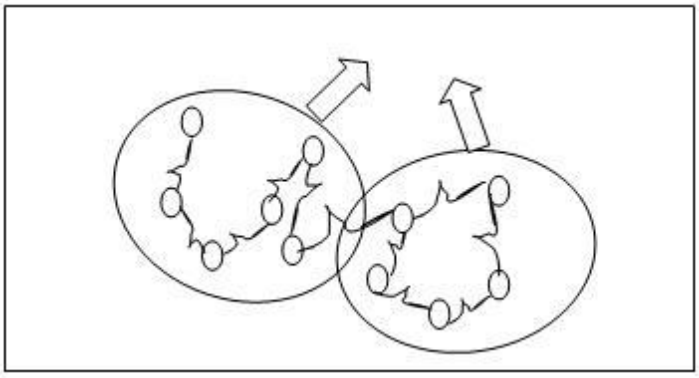

Figure 2.8 RPMG(Reference Point Group Mobility Model)

2.3.3 Manhattan Mobility Model

Mobile nodes in this model imitate the movement scheme of locomotives on roads as stated by maps[23]. In this model the mobile nodes moves in psuedo random manner on already defined pathways in the simulation area.

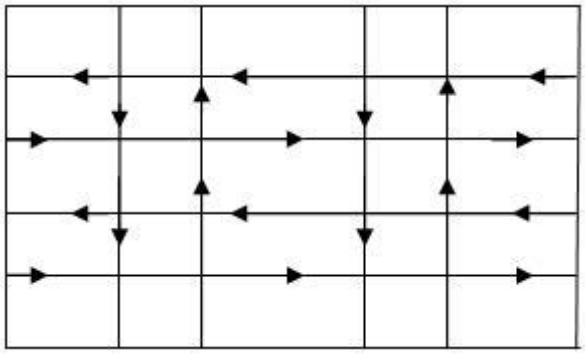

Figure 2.9 Manhattan Mobility Model

3. Problem Statement

3.1 Problem Statement

The performance of the MANET is affected by the fact that how routing performs across the network. This is one of the major issues of the MANET. Due to the dynamic nature of mobile nodes, routing algorithms used in wired networks cannot be used in MANETs. Mobile nodes dynamically forms their own temporary network. Nodes move in a random manner with changing direction and speed at regular time intervals causing the link breakage between different hosts of MANETs.

To realize the applications of real world, efficient algorithms might modify themselves with the dynamic network topology and should deliver the data packets successfully to the destination and indeed maintain the performance.

In this work, survey of some mobility models is presented and to simulate an ad-hoc network, these models are used. The objective of this research is to analyze the AODV variants performance under different mobility conditions using varying node density. RandomWaypoint is used as reference model in previous studies. MANETs in another era are supposed to be used with various node configurations and topologies. Therefore, one ought to grasp the influence of varied mobility conditions on protocol performance along which they should develop an thorough understanding of these models. . In this, performance metrics like PDR (Packet delivery ratio) and Throughput are used to evaluate the performance of AODV variants. The performance metrics are examined with varying node density and Ns-2 is used as an network simulator to carry out these simulations and for creating mobility scenarios, tool named as bonnmotion is used.

3.2 Objective

The emphasis of this research is to simulate and analyze the adhoc routing protocols like AODV and AOMDV under MANETs so that one ought to grasp which protocol can perform well under various mobility conditions.

- To simulate AODV and AOMDV for MANETs.
- To compare and analyze using performance metrics like Packet Delivery Ratio and Throughput.
- To determine which is the best protocol among AODV and AOMDV by analyzing the results.
- To verify and validate the best routing protocol under different mobility conditions.
- To select the best mobility model for the best protocol in MANETs.

3.3 Methodology

- Simulation environment is configured for AODV and AOMDV using NS-2.
- AWK scripts have been used to get the value from trace file.
- Mobility Scenarios are generated using tool named BonnMotion.
- Protocols are simulated using different mobility conditions.
- Performance metrics like- Packet Delivery Ratio, Throughput and End to End Delay are used to analyze the results.

4. Simulation

4.1 Simulation

To design a real system model the process called simulation is used. Experiments are conducted in this model so that the system behavior can be understood and system operations might be evaluated using different strategies[24].

To implement MANETs at practical level costs too high. Therefore, to verify and validate the routing protocols, simulators are used. The first step to implement MANET routing protocol is the simulation of a protocol. Number of network simulators are available to evaluate network protocols like Qualnet, NS-2[25], OPNET. The most important aspect to simulate the adhoc network is the node mobility. Results taken from the simulator gives the correct real world performance of MANETs if mobility models are used efficiently. A tool named BonnMotion developed in java is used to generate mobility scenarios for MANET simulation

4.2 System Environment

In table 4.1, to carry out simulation the system environment used is described.

Table 4.1 System Environment

System	Sony Vaio
System Type	64-bit
Ram	6GB
Hard disk	500GB
Operating System	Ubuntu 14.04
Processor	Intel(R) Core™ i3

4.3 Network Simulator

NS-2 is a network simulator which is developed in C++ and use interpreter as a front end named as OTCL. It is a application-level simulator developed at university of berkeley. C++ language is used for to implement different type of protocols and to extend the libraries of simulator. OTCL interpreter is used to control and develop the simulator environment. NS-2 supports various types of protocols like TCP (Transmission Control Protocol), UDP (User Datagram Protocol) etc [26]. Even both wired and wireless networks are also supported by NS-2. It is updated by researchers at regular time intervals thus the support of satellite and adhoc networks are also added.

4.4 Architecture of NS-2

Theoretical Architecture of NS-2 is shown in Figure 4.1. "ns" is an executable command in NS-2 which takes the name of the tcl script file as an input argument. NS-2 is a combination of two language which are known as OTCL (object oriented command language) and C++. After executing the command on simulator , the output consists of either animation-based and text- based results. The tool named NAM i,e the network animator outputs the results graphically.

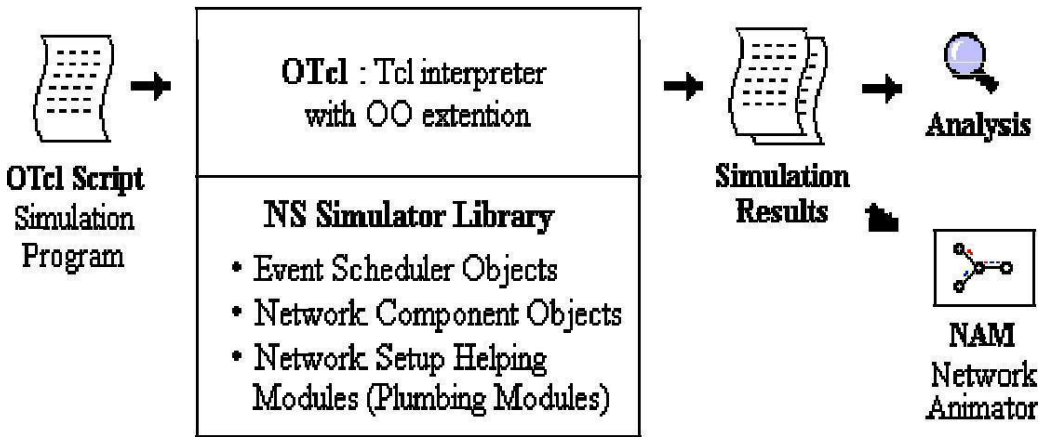

Figure 4.1 Architecture of Network Simulator[26]

4.5 NAM (Network AniMator)

Nam is a visualization tool which provides a visual construct of the topology of the network. This application was designed under VNIT project .NAM visualization is shown in Figure 4.2

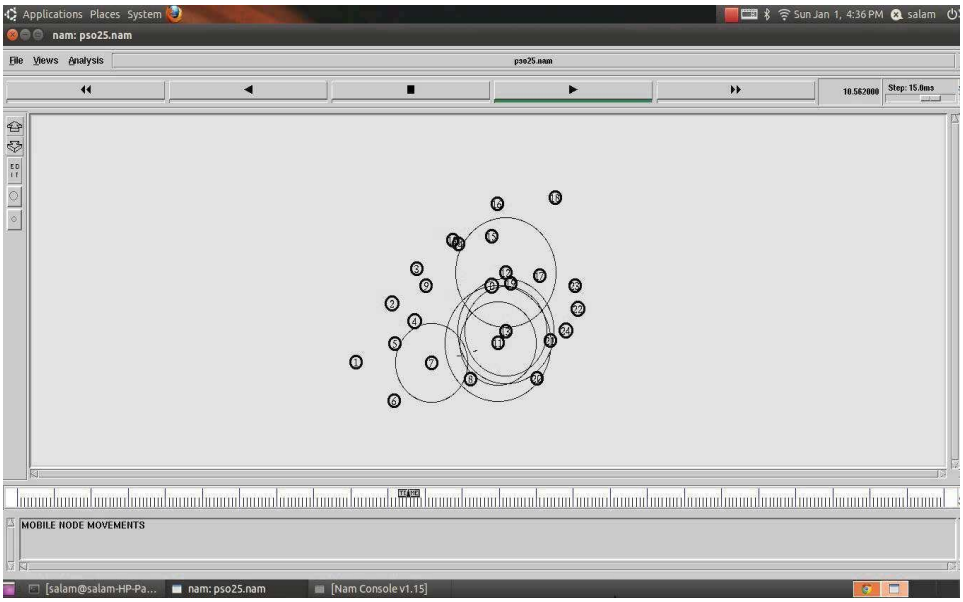

Figure 4.2 NAM for 25 Nodes

4.6 Trace File Format

The trace script file represents an ASCII code file and the trace file format having 12 fields is shown in Figure 4.3.

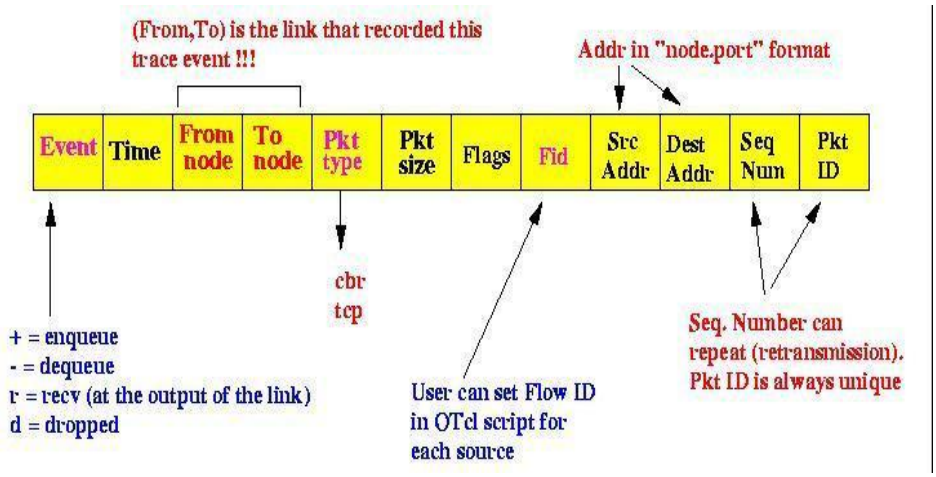

Figure 4.3 Format of Trace File [26]

The explanation of the trace file fields is given below:

1. The four variables represent the event perform in the simulation and these are given below:
    - r : receive
    - + : enqueued
    - - : dequeued
    - d : dropped.
2. Time of occurrence of event.
3. The link of input nodes where the event occured.
4. The link of output nodes where the event occured.
5. This field represents the packet type like TCP or CBR.
6. Size of the packet
7. Flags
8. IP flow identifier
9. Data Packet source node address
10. Sequence number
11. Unique packet identifier

4.7 Installation and Configuration

NS-2 is a network simulator free of cost. NS-2 is compatible among several platforms like windows, linux and Mac systems. As NS-2 is developed in the system i.e. unix so the installation of NS-2 is very easy. The source codes of NS-2 can be downloaded in a package called "all-in-one"[26]. The one who is new to simulators, NS-2 is recommended

Following are the steps to install NS-2 all-in-one

4.7.1 Installation of Networks Simulator

- **Step1**: Download ns-2.35 all-in-one package from the link http://www.isi.edu/nsnam/ns

- **Step2**: Move the package from downloads to the home directory and then

unzip it using the following command in console i.e. **“tar -xzvfns-allinone 2.35.tar.gz”.**

- **Step3**: Now in the console, execute the command” **sudo apt-get update”** and to build essential feature use the command **“sudo apt-get install build-essential autoconfautom akelibxmu-dev”**

- **Step4**: Next command to execute is to change the directory "**cd ns-allinone-2.35"**and then run the command ./install

- **Step5**: To install xgraph, run the following command in the console **“Sudo apt-get install xgraph”.**

- **Step6**: Update the environment variables by opening the file named .bashrc by running this command “ **gedit ~/.bashrc**”.

- **Step7**: Then at last, run this command “ **source ~/.bashrc**”.

- **Step8**: To check whether NS-2 is installed or not, type "ns" on console, if % symbol comes, it shows the successful installation of NS-2.

4.7.2 BonnMotion

For different mobility conditions, one need to create and analyze the mobility scenarios, the tool that is used to do this is named as BonnMotion which is developed in java. Researcher use this tool to observe and verify the features of adhoc networks [27]. The mobility scenarios generated by BonnMotion can be among different platforms of network simulators like NS-2, NS-3 and MiXiM.

Installation

BonnMotion needs two key packages, java development Kit (JDK) and Java Run Time Engine (JRE).

- **Step1**: Install packages jdk and jre by running this command on terminal **"sudo apt-get install openjdk-7-jre openjdk-7-jdk**"
- **Step2**: Next step is to download and extract bonnmotion-2.0 by using this command **"unzip bonnmotion-2.0.zip"**
- **Step3**: Change the directory by typing this command on terminal **"cd bonnmotion-2.0"**
- **Step4**: The last step is to edit the file named "install" and run **". /install"**

Now the terminal will put a question by asking java path:
User should enter the java binary path [/usr/bin]: Press Enter
Then the message might be displayed on terminal: BonnMotion successfully installed.

Running BonnMotion

BonnMotion consists of a wrapper script called as "\bm" that is required to run all the applications [27]. One can run the wrapper using the following command

./bm <parameters names><application><application parameters>

One of the applications is the mobility model which is used observe the characteristics of the scenario. If one starts the script without writing the parameters of command line then the help option will be displayed.

Scenario Generation

To create a mobility scenario, scenario generator writes all the parameters in a file and thus settings are saved in this way. Therefore, parameters of the scenario can be updated without re-entering scenario parameters. The input arguments i.e. the parameters are described below:

- [-n] - It represents the number of nodes one need to have in scenario generation.
- [-d] - How long the scenario will run (in seconds)
- [-i]- i represents the time in seconds , at the beginning of the scenario, up till i

the seconds are skipped.

- [-x] It represents the width of simulation area (in meters)
- [-y] It represents the height of simulation area (in meters)

Example: ./bm -f scenario1 RPGM -n 50 -d 600 -i 3600

This command creates a RPGM scenario having 50 nodes with duration of 600 seconds. An initial phase of 3600 seconds at the beginning of the scenario is skipped. This scenario is saved in two files:

- "name.params" which contains the whole set of parameters required for simulation
- "name.moveme nts.gz" which contains the movement data of nodes.

5. Results and Analysis

5.1 Simulation Parameters

The performance of AODV variants is assessed by varying node density. Simulation parameters to assess AODV variants are described in Table 5.1.

Table 5.1 Simulation Parameters

S.No	Parameters	Values
1.	Simulator	NS-2.34
2.	Protocols	AODV, AOMDV
3.	Simulation Duration	150 seconds
4.	Simulation Area	1000 m × 1000 m
5.	Number of Nodes	20, 30, 50, 80, 100
6.	Transmission Range	250 m
7.	Mobility Models	Random Way Point, Reference point group model, Manhattan Model
8.	MAC Layer Protocol	IEEE 802.11
9.	Pause Time	100 seconds
10.	Max Speed	20 m/s
11.	Packet Rate	4 packets/second
12.	Traffic Type	CBR(UDP)
13.	Data Payload	512 bytes/packet

5.2 Performance Parameters

While analyzing the AODV variants two performance metrics has been considered which are Packet Delivery Ratio (PDR) [28] , Throughput and End to End Delay

- **PDR(Packet delivery ratio)**

  It is the proportion (in terms of percentage) of all the data packets which are received with success at the destination with the amount of packets that is sent by CBR sources.

- **Throughput**

  It is the mean of the messages delivered with success at the destination per second or we will say it is the mean of bits delivered per unit time.

- **End to End Delay**

  The time taken to reach to its destination by a packet is called End to End Delay. In addition, it also consists of the delay occurred due to route discovery and the delay due to queue .

$$\text{End to End delay} = \frac{(\text{arrival time} - \text{send time})}{\text{number of connections}}$$

5.3 Simulation Results of Adhoc Routing Protocols AODV and AOMDV in Random Way Point Mobility Model

We have taken 10 readings for each value corresponding to the graph and then the average of these readings are plotted. The results are plotted on graph and are shown below.

5.3.1 Number of Nodes vs Packet Delivery Ratio

Table 5.2 shows the Analysis of Average Packet Delivery Ratio for AODV and AOMDV in random way point mobility model.

Table 5.2 Node density vs. Packet Delivery Ratio (%)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	99.54	99.014	99.4164	98.0817	98.8138
AOMDV	99.4224	99.4798	99.3485	98.0989	99.0565

The graph is shown below in Figure 5.1.

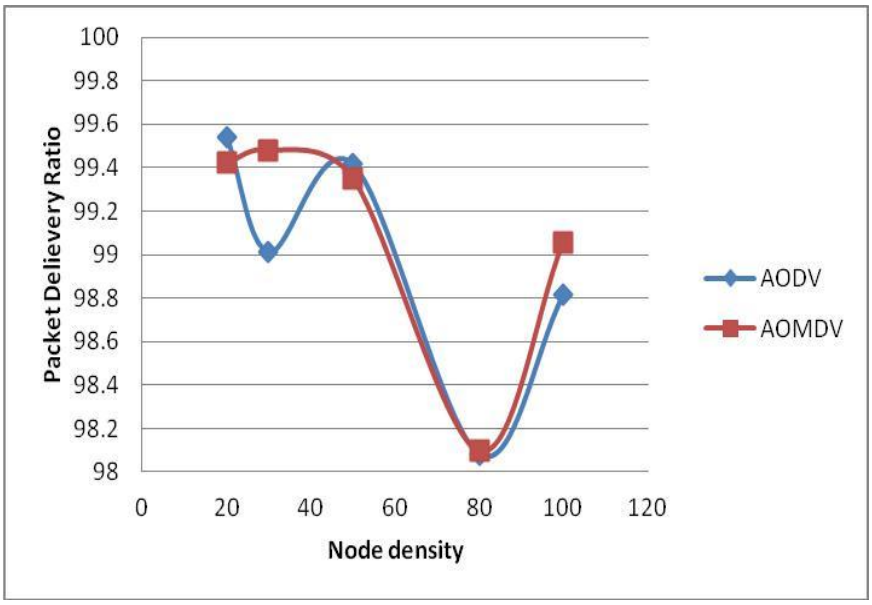

Figure 5.1 Node Density vs Packet Delivery Ratio

5.3.2 Number of Nodes vs Throughput

Table 5.3 shows the Analysis of Average Throughput for AODV and AOMDV in random way point mobility model.

Table 5.3 Node density vs. Throughput

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	133.55	99.44	115.54	113.05	107.92
AOMDV	144.78	128.41	126.42	92.05	127.47

The graph is shown below in Figure 5.2.

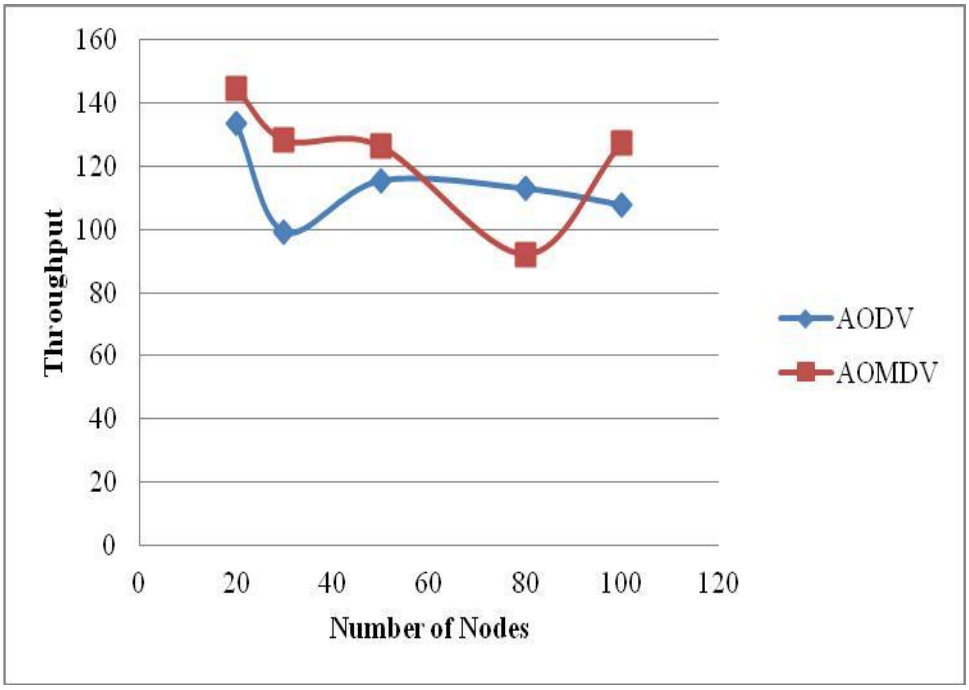

Figure 5.2 Node Density vs Throughput

5.3.3 Number of Nodes vs End to End Delay:

Table 5.4 shows the Analysis of End to End Delay for AODV and AOMDV in random way point mobility model.

Table 5.4 Node density vs. End to End Delay (ms)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	83.1535	65.5186	146.022	52.5962	78.5543
AOMDV	31.8595	53.0627	70.7533	33.4568	49.6873

The graph is shown below in Figure 5.3.

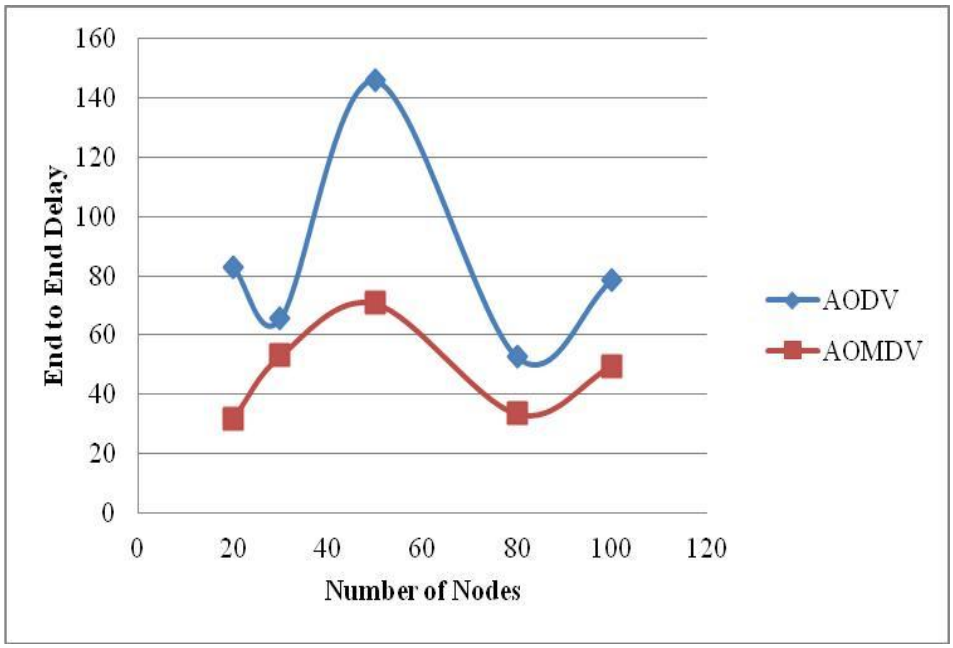

Figure 5.3 Node Density vs End to End Delay

5.4 Simulation Results of Adhoc Routing Protocols AODV and AOMDV in Reference Point Group Mobility Model

5.4.1 Number of Nodes vs Packet Delivery Ratio

Table 5.5 shows the Analysis of Average Packet Delivery Ratio for AODV and AOMDV in reference point group mobility model.

Table 5.5 Node density vs. Packet Delivery Ratio (%)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	99.6756	99.2097	99.3304	98.5965	99.5376
AOMDV	99.5982	99.7327	99.6464	99.7461	99.7629

The graph is shown below in Figure 5.4.

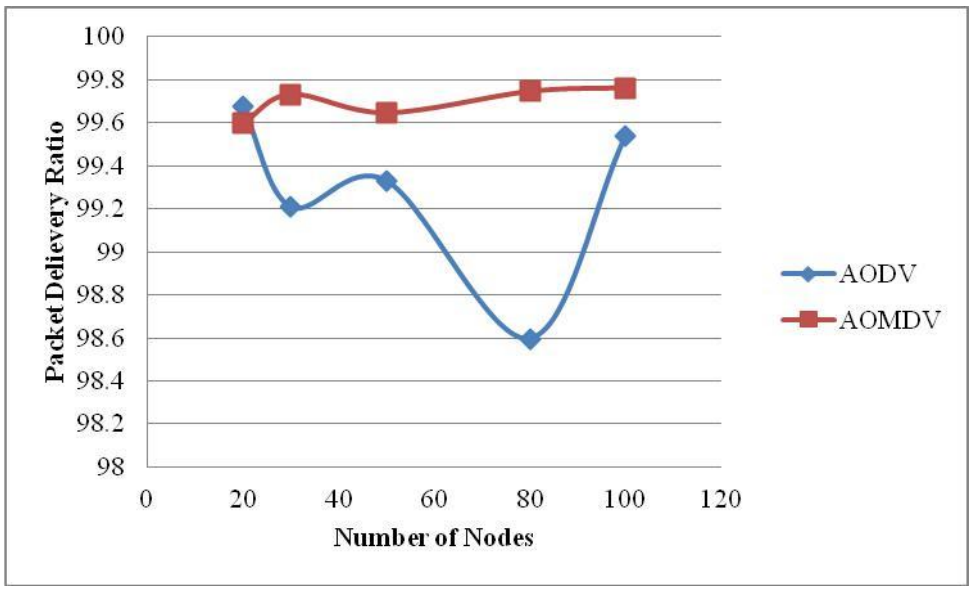

Figure 5.4 Node Density vs Packet Delivery Ratio

5.4.2 Number of Nodes vs Throughput

Table 5.6 shows the Analysis of Average Throughput for AODV and AOMDV in reference point group mobility model.

Table 5.6 Node density vs. Throughput

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	152.12	128.56	140.85	151.51	154.76
AOMDV	137.86	146.80	131.87	141.23	136.97

The graph is shown below in Figure 5.5.

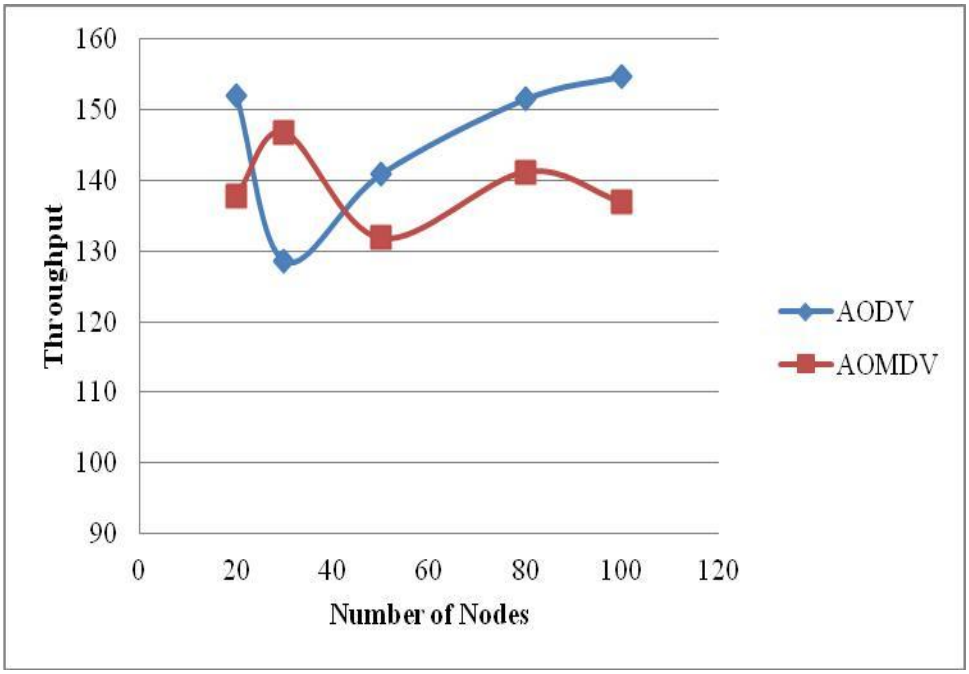

Figure 5.5 Node Density vs Throughput

5.4.3 Number of Nodes vs End to End Delay

Table 5.7 shows the Analysis of End to End Delay for AODV and AOMDV in reference point group mobility model.

Table 5.7 Node density vs. End to End Delay (ms)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	146.348	149.063	140.464	87.604	41.045
AOMDV	156.28	160.172	152.586	151.957	168.687

The graph is shown below in Figure 5.6.

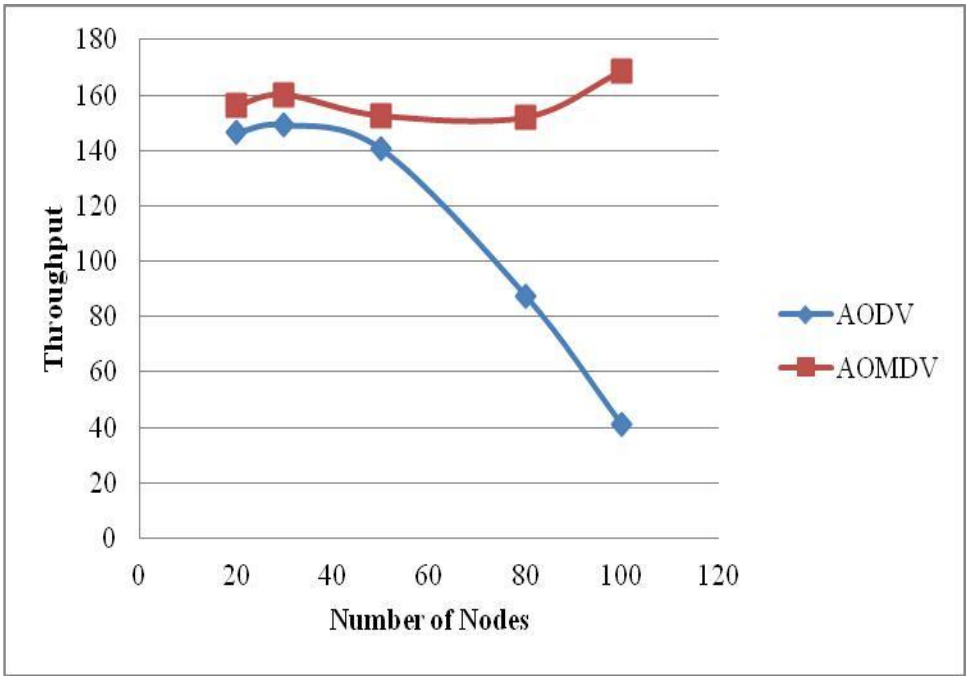

Figure 5.6 Node Density vs End to End Delay

5.5 Simulation Results of Adhoc Routing Protocols AODV and AOMDV in Manhattan Grid Mobility Model

5.5.1 Number of Nodes vs Packet Delivery Ratio

Table 5.8 shows the Analysis of Average Packet Delivery Ratio for AODV and AOMDV in Manhattan grid mobility model .

Table 5.8 Node density vs. Packet Delivery Ratio (%)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	99.82	99.6016	99.6536	98.5487	99.6936
AOMDV	99.695	99.6918	99.5901	99.7167	99.7579

The graph is shown below in Figure 5.7.

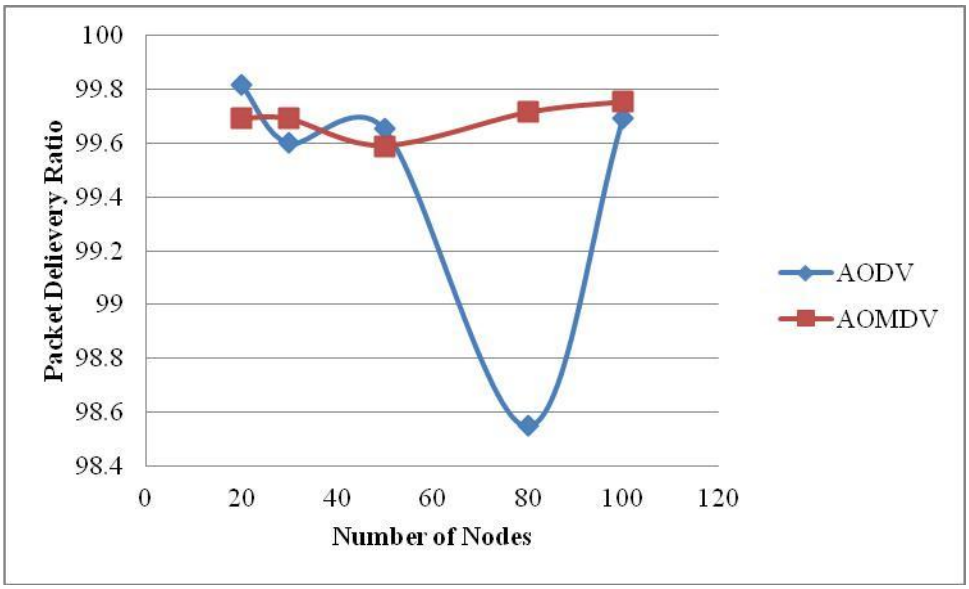

Figure 5.7 Node Density vs Packet Delivery Ratio

5.5.2 Number of Nodes vs Throughput

Table 5.9 shows the Analysis of Average Throughput for AODV and AOMDV in Manhattan Grid mobility model.

Table 5.9 Node density vs. Throughput

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	157.96	154.31	146.34	139.14	150.04
AOMDV	149.42	148.32	145.35	137.39	139.73

The graph is shown below in Figure 5.8.

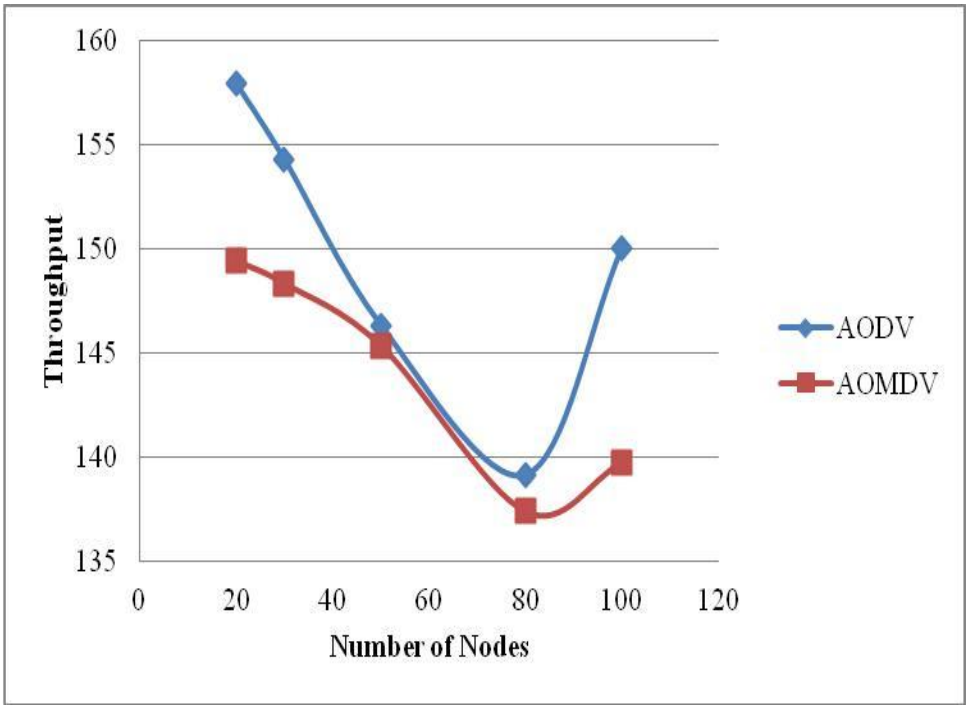

Figure 5.8 Node Density vs Throughput

5.5.3 Number of Nodes vs End to End Delay

Table 5.10 shows the Analysis of End to End Delay for AODV and AOMDV in Manhattan Grid mobility model.

Table 5.10 Node density vs. End to End Delay (ms)

Routing Protocol	Number of Nodes				
	20	30	50	80	100
AODV	147.828	182.644	135.474	115.31	177.683
AOMDV	135.901	199.163	181.077	185.228	171.376

The graph is shown below in Figure 5.9.

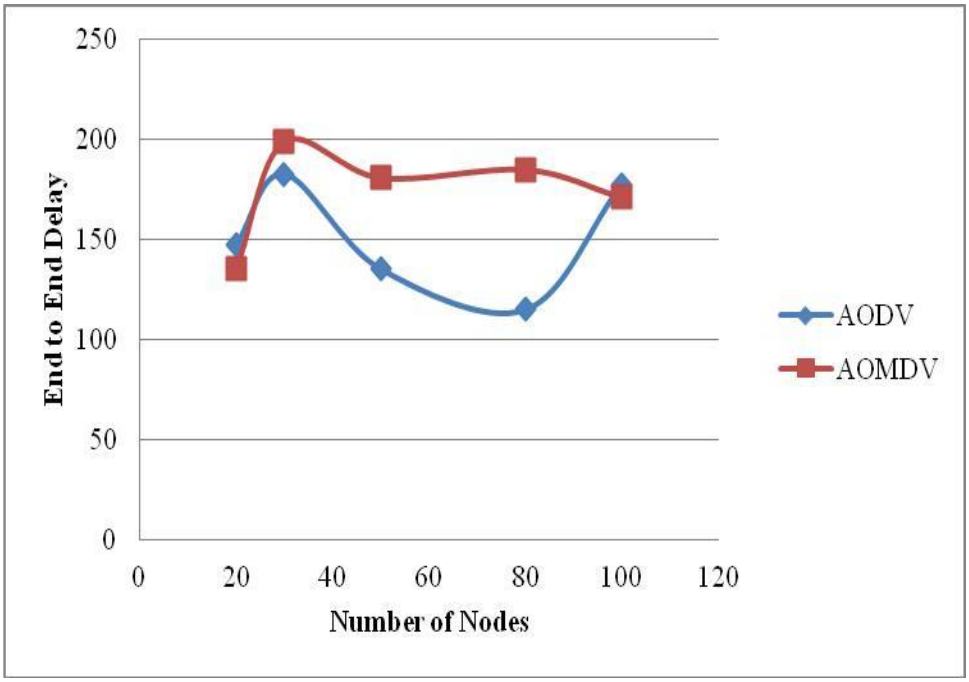

Figure 5.9 Node Density vs End to End Delay

5.6 Simulation Analysis

As already declared, we have taken two variants of AODV, namely AODV(Ad-hoc On Demand Distance Vector), AOMDV(Ad-hoc On-demand Multipath Distance Vector Routing). Mobility models used are Manhattan Model, RPMG(Reference Point Group Model) and RandomWaypoint Mobility model.

Simulation of AODV and AOMDV adhoc routing protocols is performed in RandomWayPoint Mobility Model and result obtained is shown in table5.2, table5.3 and table5.4. Then the graphs are drawn using the corresponding tables. From the graph in Fig. 5.1 , we come to the conclusion that AODV and AOMDV performs in a similar manner with increasing number of nodes. As the number of nodes increases, Packet Delivery Ratio of AODV and AOMDV decreases but as the node density reaches up to 100 percent, Packet Delivery Ratio of both AODV and AOMDV gets increased. From the graph in Fig. 5.2 , it is observed that AOMDV has a better throughput than AODV. From the graph in Fig. 5.3 , it is observed that AODV has more end to end delay as compared to AOMDV. Hence, in MANETs, after observing all the metrics in random way point mobility model, we can say that AOMDV performs better than AODV.

Now, Simulation of AODV and AOMDV adhoc routing protocols is performed in Reference Point Group Mobility Model and result obtained is shown in table5.5, table5.6 and table5.7. Then the graphs are drawn using the corresponding tables. From the graph in Fig. 5.4 , we come to the conclusion that AOMDV and has better PDR than AODV with increasing number of nodes. The better PDR implies the more accurate and suitable routing network. From the graph in Fig. 5.4 , it is observed that AODV has a better throughput than AOMDV.From the graph in Fig. 5.5 , it is observed that AOMDV has more end to end delay as compared to AODV. Hence after observing all the metrics in reference point group mobility model, we can say that AODV performs better than AOMDV in MANETs.

Now, to simulate the AODV variants in Manhattan Grid mobility model, the tables are drawn for every performance metric which are shown in table5.8, table5.9 and table6.0. From the graph shown in Fig. 5.6, AOMDV has consistent PDR with increasing number of nodes, but other than this it has better PDR than AODV. Now,

From the graph in Fig. 5.7 , it is observed that AODV has a better throughput than AOMDV. When the node density gets increased, traffic increases which results in congestion and data loss, but due to multipath nature of AOMDV, AODV gives better throughput as contrast to AOMDV. From the graph in Fig. 5.8 , it is observed that AOMDV has more end to end delay as compared to AODV. Hence after observing all the metrics in Manhattan grid mobility model, we can say that AODV performs better than AOMDV in this model.

5.7 Summary

Adhoc routing protocols i.e AODV and AOMDV are simulated with network simulator NS-2 using the mobility conditions which are RandomWaypoint, Manhattan grid and RPGM mobility model. The analysis is done using performance metrics i.e. packet delivery ratio (PDR) , average throughput and end to end delay. The results obtained are carefully analyzed and we come to the conclusion that AODV routing protocol performs better as compared to AOMDV. So it can be used to determine the optimum algorithm for MANETs

6. Conclusion and Future Scope

6.1 Conclusion

In this research, a short description about the AODV variants and various mobility conditions has been described. When the protocols are implemented on MANETs, Analysis done on the adhoc routing protocols gives out the essential features of the protocols. In this research, survey of some mobility models is presented and to simulate an ad-hoc network these models are used. RandomWaypoint is used as reference model in previous studies. MANETs in another era are supposed to be used with various node configurations and topologies. Therefore, one ought to grasp the influence of varied mobility conditions on protocol performance along which they should develop an thorough understanding of these models. We have observed that performance degrades with increasing node density and AODV routing protocol performs better as compared to AOMDV.

6.2 Future Scope

Some issues might occur while deploying MANETs like Unpredictability of Environment, Dynamic Topology, Transmission Errors and many others. So there is need to study different routing protocols using other mobility models to figure out the selection of the optimal protocol.

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List of Publications

S. Garg and A.K. Verma, "Simulation and Comparison of AODV variants under different mobility models in MANETs" *Second International Conference on ICT for Sustainable Development (ICT4SD - 2016),* Goa, India, July 2016. **[Accepted]**

Link of video

https://www.youtube.com/user/Shiwani92