Performance Analysis of Routing Protocols in FANETs

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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in

Information Security

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, ***"Performance Analysis of Routing Protocols in FANETs "***, in partial fulfilment of the requirements for the award of degree of Master of Engineering in ***Information Security*** 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

For the last few years the research area of adhoc network are being explored due to their versatile applications. Newer technologies are proposed by researchers using the concept of MANETs like VANETs and FANETs. FANETs stands for flying adhoc network which is a group of homogenous flying objects or Micro-Air Vehicles (MAVs) that communicate with each other locally and also interact with their environment to get some sort of information, which will provide a distinguish approach to tackle with the emergency situations like natural disaster , military battle field.

We have extended the traditional OLSR, AODV and DSDV protocols for FANET. These three different protocols belong to two different classification of routing protocol, namely reactive and proactive. These protocols were simulated using NS2 and were analysed on various parameters as number of nodes, packet delivery ratio, end to end delay and throughput. The results indicate that OLSR performs better than AODV and DSDV for FANETs. Further we have we have analysed the performance of OLSR for different mobility models such as Random Waypoint, Manhattan Grid, RPGM and Pursue. Our results indicate that performance of OLSR is optimum with Pursue mobility model than other mobility models.

Keywords: OLSR, FANETs, MAVs, Mobility Models, NS2.

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List of Aberivations

AODV	**A**d-hoc **O**n-Demand **D**istance **V**ector
DSDV	**D**estination Sequenced **D**istance **V**ector **R**outing
DREAM	**D**istance **R**outing **E**ffective **A**lgorithm For **M**obility
FANET	**F**lying **A**dhoc **N**etwork
IEEE	**I**nstitute of **E**lectrical and **E**lectronics **E**ngineers
MANET	**M**obile **A**dhoc **N**etwork
MAV	**M**icro **A**ir **V**ehicle
MN	**M**obile **N**ode
MPR	**M**ulti **P**oint **R**elay
NS	**N**etwork **S**imulator
OLSR	**O**ptimized **L**ink **S**tate **R**outing
RERR	**R**oute **ERR**or
RREP	**R**oute **REP**ly
RREQ	**R**oute **REQ**uest
TC	**T**ransmission **C**ontrol
TCL	**T**ool **C**ommand **L**anguage
UAV	**U**nmanned **A**ir **V**ehicle
VANET	**V**ehicular **A**dhoc **N**etwork

1. Introduction

1.1 Wireless Network

Wireless network is a network which uses radio waves to establish and maintain communication channels between two or more nodes or computers. It is a comparatively better alternative than wired networking which basically relies on copper wire between network devices [1]. There are lots of inherent characteristics of wireless network through which it attract users.

Figure 1.1 Wireless Networks

- **Mobility:** Through wireless communications, a user can access information beyond their desk and also can conduct their business activities from anywhere without having wire connectivity.
- **Reachability:** A wireless communications system provides better connectivity and reachability without any limitation like user can be on mountains or in the mid of river etc.
- **Simplicity:** It is very easy and simple to deploy a wireless communication system in comparison of cabled network [1]. In initial setup stage, the cost of wireless system could be high but there are many other advantages which overcome the initial cost.
- **Maintainability:** It is very easy to maintain a wireless system than a wired system. And time spends in maintaining wireless system is very less than wired system.

- **Roaming Services:** By using a wireless network, a user can get services anywhere any time like in trains, busses, airplanes etc.
- **Easy Setup:** Installation is easy and quick as there is no need to make connection through cable [1].
- **Cost Effective:** A wireless network takes less cost than a wired network to operate all the function and communication properly.
- **Expandable:** It is very easy and simple to expand wireless networks with existing equipments, while a wired network takes additional effort and required additional wiring.

1.2 Classification of Wireless Network

Wireless network is classified into two types on the basis of their infrastructure as shown in Figure 1.2 [2].

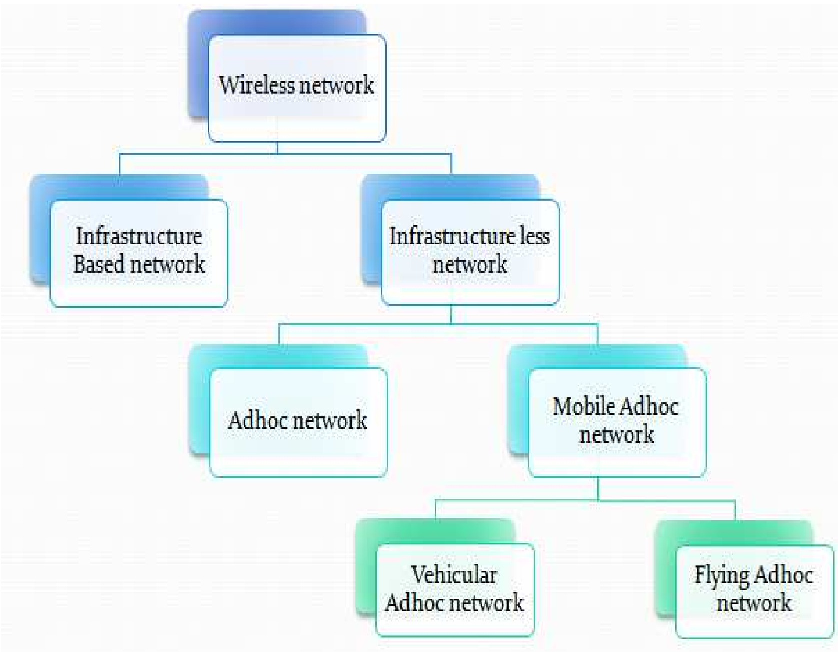

Figure 1.2 Wireless Network Classifications

1.2.1 Infrastructure Based Network

An infrastructure based network is a network which uses fixed base stations called infrastructure. These base stations are responsible for coordinating communication between the moving or mobile nodes [2].

1.2.2 Infrastructure less Network

An infrastructure less network is a network which does not use any existing infrastructure. It is a set of mobile nodes that are dynamically located in such a manner that they are able to maintain the interconnections between nodes on a continual basis.

- **Adhoc Network:** A network is called an adhoc network if it is created only when it is required and it does not use any existing infrastructure for maintaining the interconnection between nodes and transmit data packets between them.
- **Mobile Adhoc Network (MANET):** A mobile adhoc network is a self-configuring infrastructure less network [3]. It is a set of mobile nodes connected by wireless technology. Every device can move freely in the whole network and in any direction and therefore it will change links to its neighbour nodes.
- **Vehicular Adhoc Network (VANET):** Vehicular adhoc network is a sub-class of mobile adhoc Networks. VANET is distributed self-organizing network formed between moving vehicles equipped with wireless communication devices [4]. VANET provides us an infrastructure for developing new systems through which service like driver safety and passengers' safety and comfort, easy tool tax payment without wasting time.
- **Flying Adhoc Network (FANET):** Flying adhoc network is also a sub class of mobile adhoc network. The basic idea behind FANET is that a group of homogenous flying agent communicates with each other locally and also interacts with their environment to get some sort of information. FANET does not support central control.

1.3 Mobile Adhoc Network

A "mobile adhoc network" is an autonomous system of moving nodes (act like a router) connected by wireless links. Mobile Adhoc Network is an infrastructure less network. The nodes are free to move randomly and manage themselves arbitrarily [5]. Thus, the network's wireless topology may change rapidly. The large degree of freedom and self organising capabilities makes mobile adhoc networks totally different from any other network solution. For the first time, users have opportunity to create their own network, which can be deployed without difficulty and economically [6]. However a price for all those features is paid in terms of multifarious technology solutions.

For all those reasons, mobile adhoc network is one of the more pioneering and challenging areas of wireless networking. Adhoc networks are a key step in the advancement of wireless technology. They inherit the traditional problem of wireless and mobile communication, such as transmission quality enhancement, bandwidth optimization and power control. In addition, multi-hop nature and the lack of fixed infrastructure give rise to new research problems such as network configuration, device discovery and topology maintenance as well as security and routing [6]. The major application for mobile adhoc networks is quick deployment and dynamic reconfiguration in scenarios where wire line network is either not available or is not cost effective, such as battlefield communications, search and rescue adhoc networking and other particular environments shown is Figure 1.3.

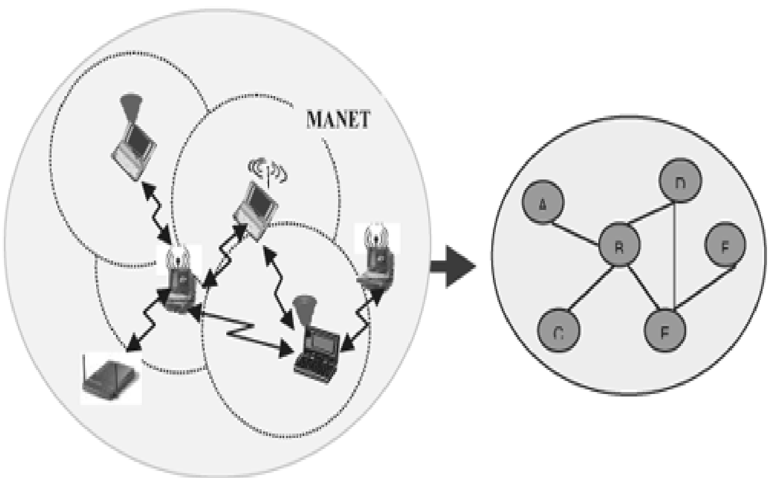

Figure 1.3 Mobile Adhoc Network [7]

1.4 Vehicular Adhoc Network(VANET)

VANET is a subclass of mobile adhoc network. Vehicles are equipped with wireless transceivers to communicate with other vehicles to form a special class of wireless networks, known as vehicular adhoc network or VANET [8]. To enhance the safety of drivers and provide the comfortable driving environment, messages for different purposes need to be sent to vehicles through the inter-vehicle communications.

Vehicular networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and fixed nodes called Road Side Units (RSU) attached to infrastructure that will be deploy along the roads shown in Figure 1.4. Both OBU and RSU devices have both wired and wireless communications capability [8]. OBUs communicate with each other and with the RSUs in adhoc manner.

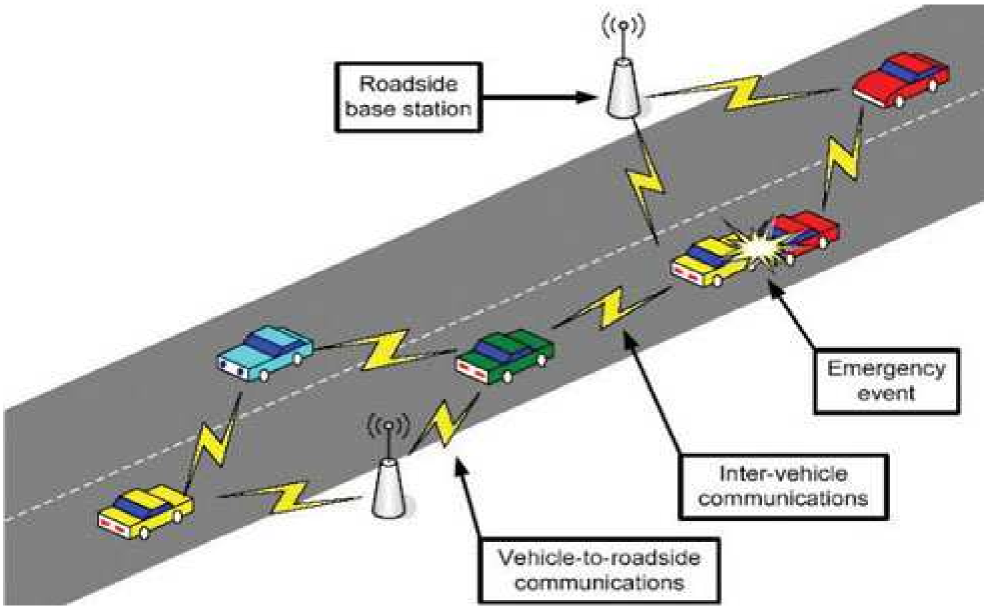

Figure 1.4 Vehicular Adhoc Network [8]

1.4.1 VANET Applications

- Safety applications
- Traffic managements
- Electronic toll collection
- Entertainment Applications
- Internet Access

1.4.2 VANET Challenges

- There are many issues in routing in VANET like end-to-end delay and packet delivery ratio [9].
- Needs secure and reliable framework for VANET communication.
- QoS is also a big challenge in VANET parameters like connection duration.

1.5 Flying Adhoc Network (FANET)

Flying adhoc network is a sub class of mobile adhoc network. FANET uses a group of homogenous flying agent, which communicates with each other locally and also interacts with their environment to get some sort of information. FANET do not support central control. In the situations of emergency as flooding or military battle field it is not feasible to deploy mobile node in the communication area. So, FANET provide the way to tackle this situation with the use of flying object (MAVs). The swarm of MAVs (micro-air-vehicle) is used to communicate in a large area; MAVs organize themselves to establish a wireless communication network [10]. They communicate locally and do not equip with GPS, Cameras, radar. In FANET, position of MAVs changes rapidly and because of this topology changes frequently. Each micro air vehicle communicates to each other and with the base station. There are certain limitations of vehicular adhoc network which are overcome by Flying adhoc network, like it is not possible to deploy vehicular adhoc network in flooded areas and also in other situations like in battlefield sometimes it is not easy to deploy vehicular adhoc network, so Flying adhoc network provide solutions for these problems because the mobile agent have the capabilities of flying through which they can cover those search and rescue areas [11].

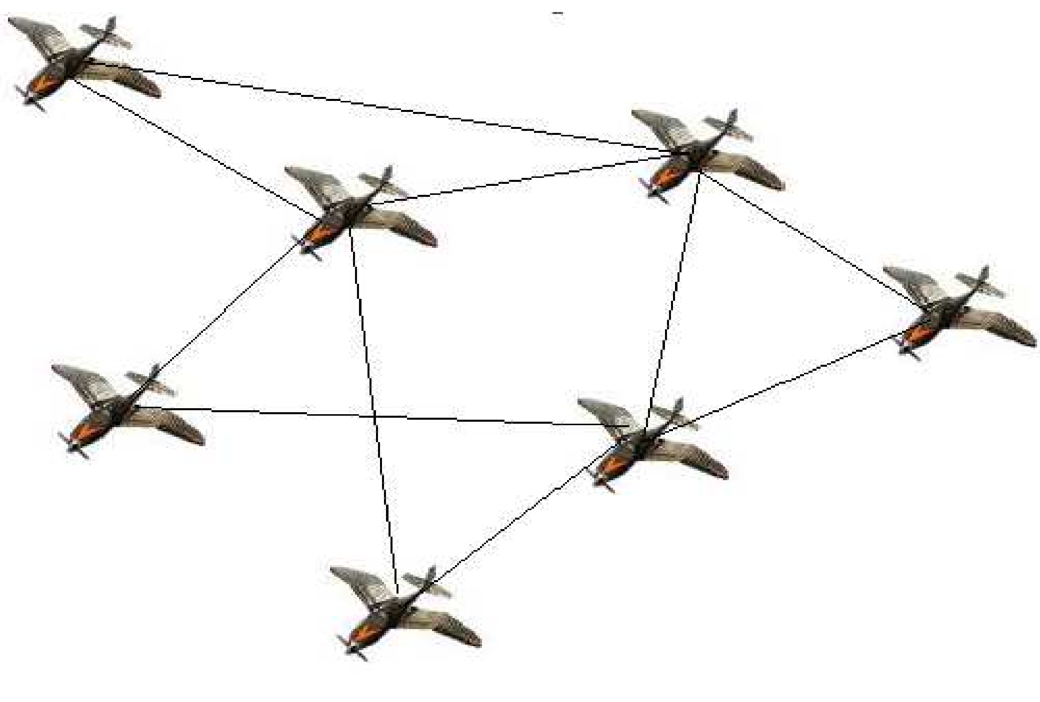

Figure 1.5 Flying Adhoc Network

1.5.1 FANET Applications

- **Disaster Management**: FANET is useful when the existing communication system is damaged due to disaster.
  - flooding
  - earthquake
  - firing
- **In Sensor Networks**: Different sensor devices can be used to collect data to do daily functions.
  - Weather forecasting
  - Activities on earth
- **Location Aware Services:** This type of network can be used in following services [12].
  - Call forwarding anywhere
  - Transmission of actual workspace to current location
  - Advertise location specific services
  - Location specific travel guides
  - Service availability information
- **Military Battle-Field**: FANET allows military to take advantage of network technology to maintain an information network.
  - Among soldiers
  - Soldiers and military headquarters.
- **Search and Rescue Operations**: FANET can be used provide a better way to do search and rescue operations such as rescue operation of hostages [12].
- **Security Purpose**: FANET is capable of getting information quickly. It can be used to collect information for the security purpose of a delegate visiting to a new place.

1.5.2 FANET Challenges

The basic idea behind flying adhoc network is same as mobile adhoc networks and vehicular networks. But there are certain differences like node speed. Hence, FANET faces some additional challenges which already exist in VANET. A lot of research has been done by the researchers to increase the efficiency and productivity of network with flying nodes [13]. But there are still many unsolved problems, so this is the area where a lot of research is required and it provides huge scope to the new researchers. Some of the open challenges are giving as follow.

- **National Regulations**: In present scenario, unmanned-air-vehicles are frequently used in most of the application areas and their importance is recognised in the modern information age. UAVs use a big portion of air space of nation when increase in numbers. But many country air-policies do not allow these types of UAV movements in their national civil air-space. So, this is a very serious concern and there is a need to define some rules and policies through which UAVs can take flights into the national civil air-space [13].
- **Routing:** In a FANET, network topology change very quickly. The movements of the nodes are very high which is very different from low mobility environment. So there is a big challenge in front of researchers to provide an efficient data routing technique. Therefore, the new routing protocols should be able to update routing tables dynamically whenever networks topology change [13].
- **Coordination of UAVs and Manned Air-Crafts:** It is inevitable in the future, UAVs will fly with other manned aircraft. So, there is a requirement of coordination of both UAVs and manned flight through which they can identify and destruct enemy flight with minimum time and losses. At the same time it will be very helpful in other tasks like emergency and jammers for real time video in enemy area.
- **Quality of Service (QoS):** There are many application areas where flying adhoc network can be used. FANET can transport different type of data which includes GPS locations, images, streaming, video/voice, simple text messages etc [13]. So, there is a need to support quality services to satisfy a set of pre-decided service performance constraints like average end to end delay, bandwidth, packet loss, jitter etc.
- **UAV Mobility and Placement:** In FANET, many types of UAVs can be used. Out of these Mini-UAVs are very small in size and carry less payloads, like a thermal camera, single radar, camera, image sensor, etc. If there is a need to use different types of sensors, then they can be loaded on different UAVs. So, this is an open issue to optimize the UAV placement to reduce energy consumption when the retrieved information is taking more time.

2.1 Routing in Adhoc Networks

Routing is a mechanism to establish and to select a specific path in order to send data from source to destination. There are various routing algorithms designed for adhoc networks. Classification of various routing protocols has been shown in Figure 2.1.

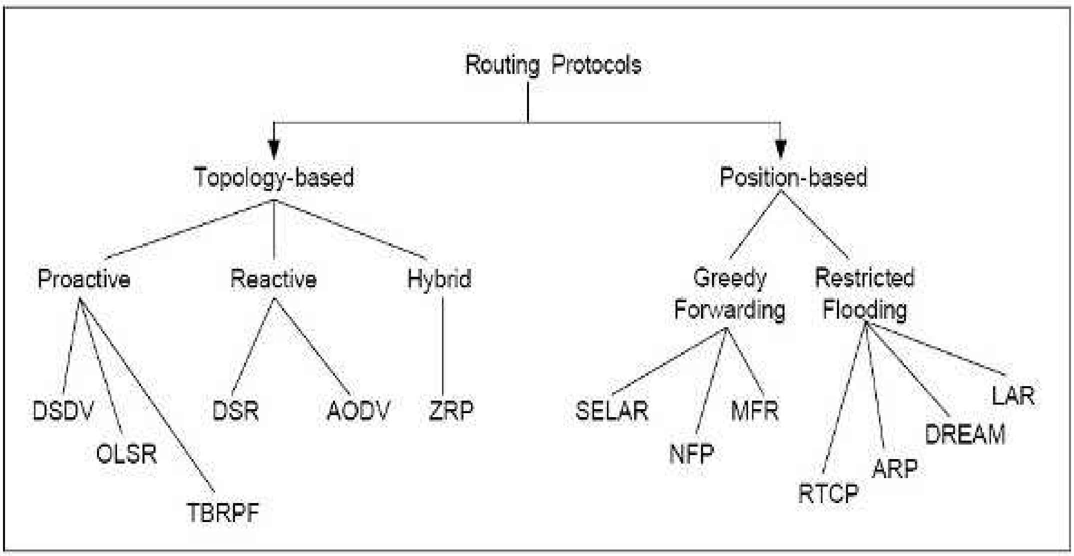

Figure 2.1 Classification of Routing Protocols [14]

Adhoc Network routing protocols can be classified into two categories:-

- Position Based.
- Topology Based

2.1.1 Topology Based Routing Protocols

In topology based Routing protocols, routing of the packets can done using information about the existing links in the network [15]. These protocols are further divided into three subcategories: proactive, reactive, and hybrid protocols based on how and when they update the state of the link.

- **Proactive Routing Protocol:** In this protocol, each and every node in the network shares its routing information from its routing table at regular time interval which is used by the other nodes to identify the path for destination nodes and make the map of whole network as shown in Figure 2.2. The big advantage of these protocols is that these protocols take very short time period to get the path to the destination [15]. But, it costs very much bandwidth consumption to update the information within short period of time thorough which it maintain map of whole network. There are several proposed algorithms under this category like WRP, DSDV and OLSR Fisheye.

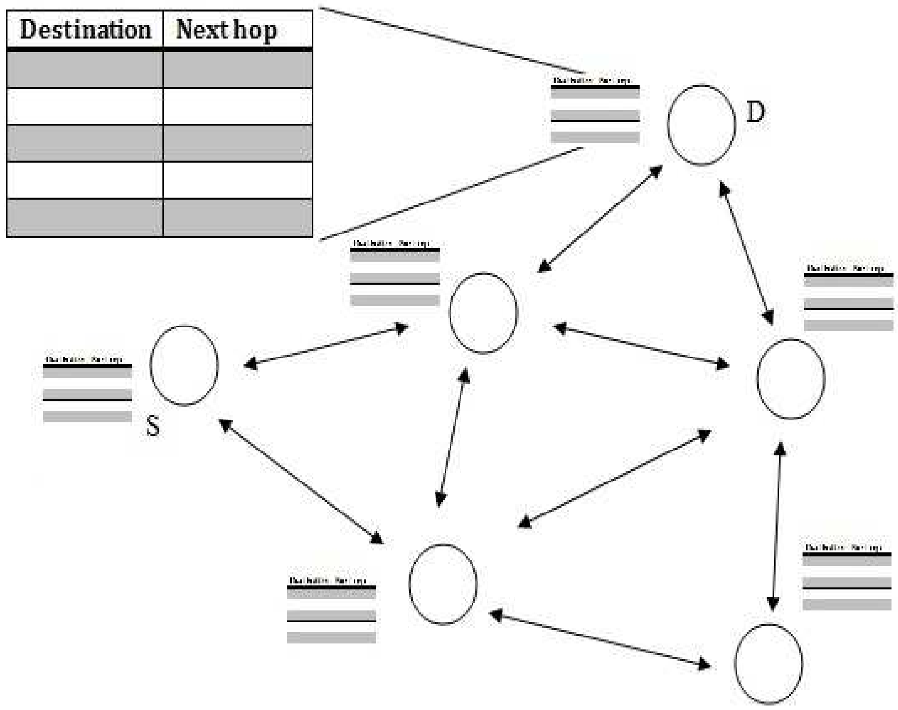

Figure 2.2 Proactive Routing Protocols Scheme [15]

- **Reactive Routing Protocols:** The Reactive protocols do not broadcast their routing table information in regular time interval. They broadcast their routing information only when it is needed. Therefore, they minimize the use of network bandwidth. But, due to the reactive nature there is a disadvantage to these types of routing algorithms, End to End delay of packet delivery is increased as compared to proactive protocols. And they also take more time to select an immediate node to transfer the data packet because of dynamic network topology. Reactive protocols are less likely to use in applications in dynamic environment. Many algorithms are proposed under this category like AODV, DSR and ABR [15].

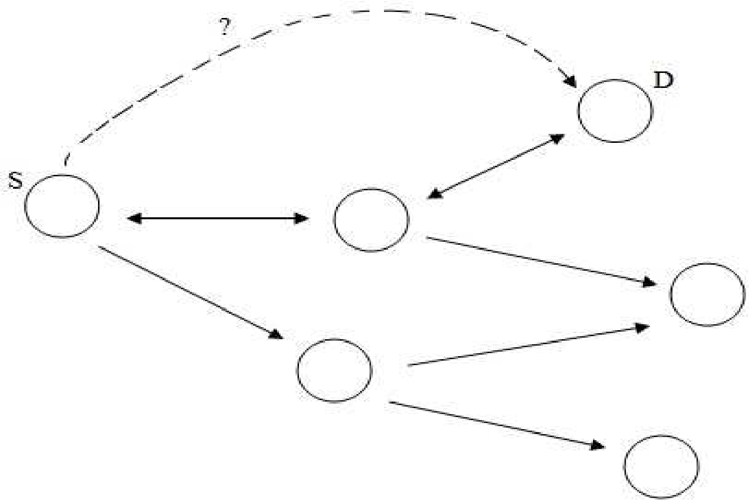

Figure 2.3 Reactive Routing Protocols Scheme [15]

- **Hybrid Routing Protocol:** Hybrid protocols are combination of both proactive and reactive protocols. These protocols are designed to minimize the overhead which is occurred in both types of protocols [reactive and proactive] [15]. But, the protocols under this category are not suitable for large networks having more than hundred nodes because of large overlapping of zones like ZRP.

2.1.2 Position Based Routing Protocols

Position based routing protocol shown in Figure 2.4, uses geographical locations of the build the routing decisions. On the basis of location information of the node, different protocols follow different criteria to transfer the packets. For example, we can see that MFR uses the greedy technique to forward packets, whereas DREAM protocol uses directional flooding of packets and GRID routing uses the dominating set concept. Greedy forwarding is the most popular technique which don't traverse and save path information between source and destination. Source uses piggybacks technique to find position of the destination and selects a neighbour as the next hop that is close to the destination. If a dead end occurs in the path of the packet then it may not be able to find the optimum path between the source and destination, if dead end occurs then they use recovery routing techniques which improve the throughput of the network. Position based routing is similar to the reactive routing because the path to the destination is explored only when it is required.

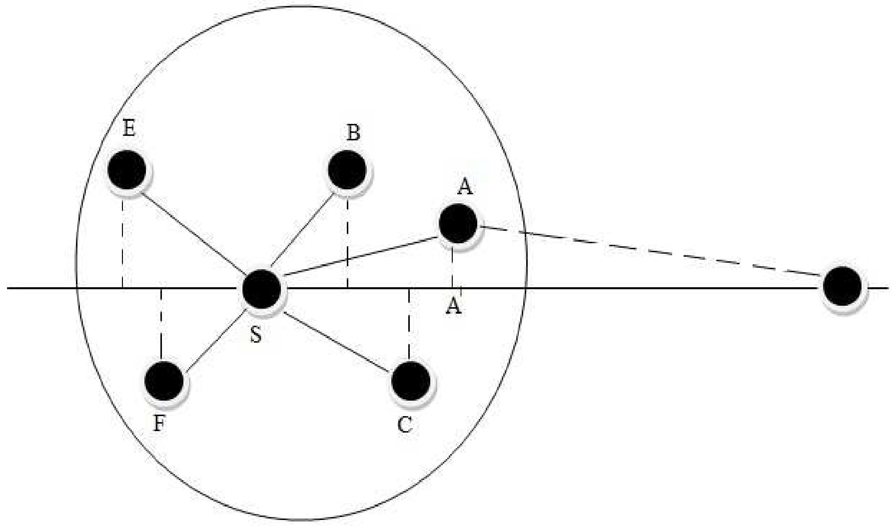

Figure 2.4 Position based Geographic Routing Scheme [15]

Position based routing protocols are very dynamic and very energy efficient as compared to the topology based routing protocols. The reason behind this is they do not share their routing table information at regular interval. This is resulting in increase in the lifetime of the network. Position based routing protocols formulate routing decisions based on the geographical location of the nodes. Different protocols pursue different criteria to forward packets based on the location information [15].

2.2 Optimized Link State Routing (OLSR)

OLSR is proactive routing protocol for adhoc networks. The protocol inhibits the stability of link state algorithm. Because of the proactive approach, this protocol has a benefit of having routes quickly available whenever required. In the pure link state protocol, all the nodes declare and broadcast their neighbour links in the whole network [16]. But in OLSR protocol is do optimization of pure link state for adhoc network.

OLSR provides following features:

- It reduces the size of control packets by declaring a node as a multi-point-relay (MPR) selector to each and every nodes of its neighbour.
- By using those MPRs which were selected, it reduces to scatter its messages to the whole network.

OLSR uses MPR through which it is able to reduce the whole network traffic and also reduce the flooding in the network which arise when every node transmit data to each other to sent the message to the exact destination. Hence, this routing protocol is best fit for large and dense networks because this procedure based in all the cases of large networks this routing works best [16].

2.2.1 Control Messages

Types of control messages in OLSR:

- **HELLO:** Each node have to broadcast their own address and the list of all the neighbour which are not responding to the messages that are broadcasted to them and also send the list of all neighbours which are confirmed to the message by a reply at a defined time interval [16]. And they have to send the list of all those nodes which are selected as MPR for the originator node. The nodes inter-change these messages among their neighbours. This is used for the selection of the MPR set.
- **TC:** These messages are also sent by nodes in the whole network after a time interval. These messages are used for scattering topological information to the whole network. Senders of TC message have to include the list of all the neighbours of a MPR, who have selected that node as a MPR, and also have to include a sequence number for included MPR selector set [16].

2.2.2 Protocol Functioning

- **Neighbour Sensing:** Each node has to detect the all neighbour nodes with which this node has direct and bidirectional link. The uncertainties among radio propagation may make some link unidirectional. Therefore, all links must be tested in both directions in order to be considered valid. To accomplish this, each node periodically broadcast HELLO message, containing information about its neighbours and their links status. These control messages are received by one-hop neighbour but not relayed to further nodes. The HELLO message allows each node to learn the knowledge of up to two hops. The neighbour table stores information about one hop neighbours, status of link with these neighbours and list of two hop neighbours [16].
- **MPR Flooding:** It is the process by which each and every router is able to broadcast information to the entire network. Each router selects a neighbour which is capable of transmission data in both the direction, that node is known

as a subset (MPR set) and when router transmit a message and that message relayed by the MPR should be received all its two hop neighbours. MPR selection is encoded in outgoing hello messages [17]. The willingness to select a node as a MPR by the routers may express, in this messages, on which basis consideration for the MPR calculation decision is accounted and which is useful for example when an OLSR routing network is “planned”.

- **Link State Advertisement:** It is the process by which routers get to know that which link state information is to publish throughout the entire network. Each and every router have to advertise, at least all the links between MPR selector set and itself, through which routers can calculate the shortest path. Such type of link state advertisements are transmit in TCs, broadcast through the whole network using the MPR flooding process which is already described. As a router selects only those MPRs which have confirmed through the reply of message from the list. And links advertised in topology control message are also bi-directional and the routing paths calculated by OLSR also contain only two way links [17]. Certain events might occur in random timeinterval topology control messages, however normally these control messages are sent periodically.

2.3 Destination Sequence Distance Vector (DSDV)

Destination sequence distance vector routing is a routing algorithm designed for adhoc networks using the concept of Bellman-Ford algorithm. DSDV is modified version of Distance Vector Routing. Distance Vector Routing maintains hope count for each destination node. The routing table consist of destination, distance and next hope as shown in Figure 2.5. Initially routing tables are empty. Each node sends its routing table to the neighbour nodes periodically [18]. Nodes re-compute their shortest distance and update their table. Main problems of Distance Vector Routing are count to infinity, slow convergence and looping. DSDV was designed to solve the problems of Distance Vector Routing. DSDV added two parameters (Sequence number, Damping). Sequence number was added to avoid looping issues and damping was included to avoid unnecessary updates.DSDV routing updates are done in two forms:

- **Periodic updates:** Periodic updates are sent after every 15 second. Entire routing table of each node is broadcasted.
- **Trigger Updates:** These are the updates that are sent in between periodic updates. These updates are sent when any update is received by any node.

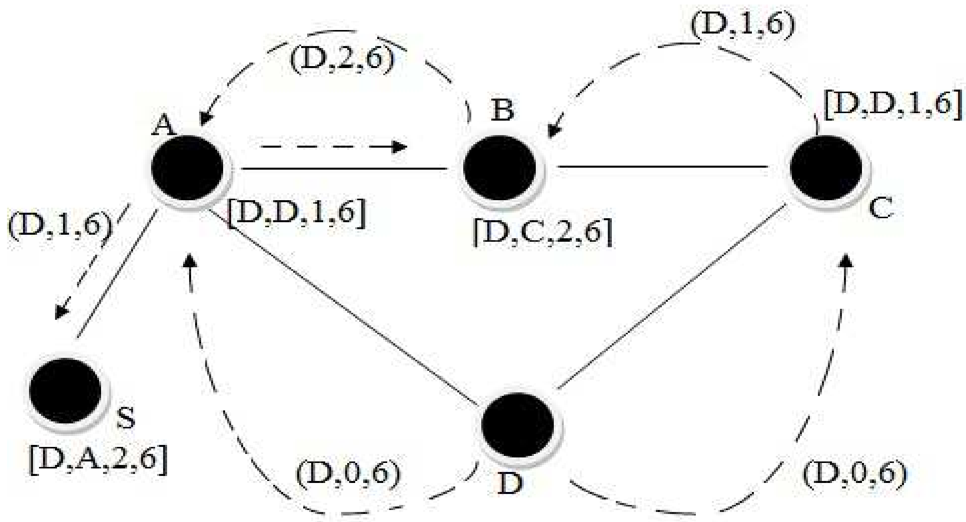

Figure 2.5 DSDV Message Exchange [18]

Figure 2.5 shows the exchange messages (destination, Distance, Sequence No.) and the routing table entries (Destination, NextHop, Distance, Sequence No.) related to nodes.

2.4 Adhoc On-Demand Distance Vector (AODV)

Adhoc On-Demand Distance Vector is a routing protocol that is designed for mobile nodes in adhoc networks. It is adaptive to dynamic link situation, memory overhead, less network utilization, low processing and find unicast routes to destinations in the ad hoc network [19]. This is an on demand protocol, which means it builds route only between those nodes which are desired by source node. Nodes need to keep the route until that is required by source node. AODV creates a tree of group members and nodes needed by members. AODV use sequence numbers to recognize new route updates [20]. This protocol is loop free, self-starting and used for large number of mobile nodes.

AODV use three types of control messages for route maintenance:

- **RREQ:** Route Request messages are used by a node that requires a route to node. Message contain broadcast id, destination ip, destination sequence number, source IP, source sequence number and hop count as shown in Figure 2.6.

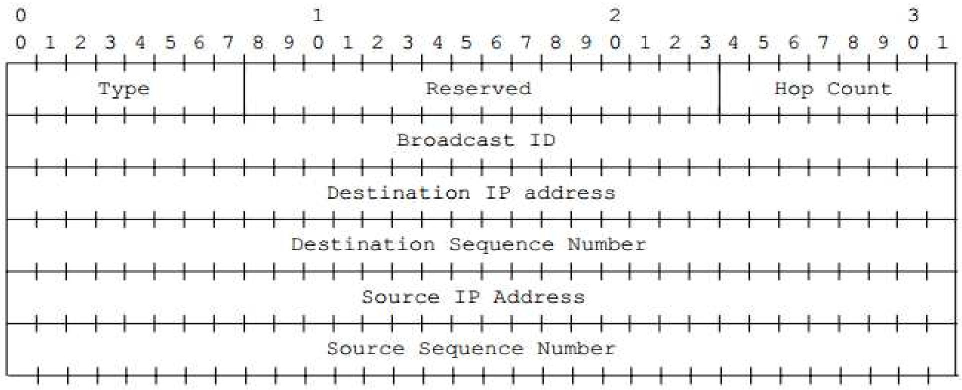

Figure 2.6 Request Message Format of AODV [20]

- **RREP:** Route reply messages are replied back to the request sender as shown in figure 2.7. The reason, one can unicast the message back, is that every route forwarding a RREQ caches a route back to the originator.
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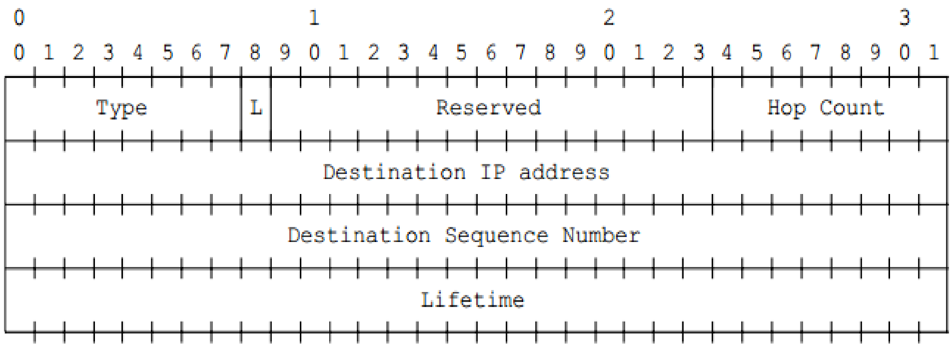

Figure 2.7 Reply Message Format of AODV [20]

- **RERR:** Route error messages are used to tell other nodes about loss of the link, link breakage in any active route.

2.5 Micro- Air Vehicles (MAVs)

Mobile adhoc network have become a major research domain in the last few years, this trend is mainly forced by the new technologies in microelectronic and wireless technology and not only new technology but also the requirement of the situations like disasters. Flying adhoc network uses a swarm of micro-air vehicle, who organised themselves to form a communication network. Micro Air Vehicle do not equip with GPS, radar and cameras [11]. Those sensors are very expensive to use which are dependent on the environment they are bigger in size and weight and use more energy and cost is very huge. GPS is not suitable to use for the disastrous areas. Because they use four satellites at the same time for getting the exact location there is necessary satellites required. The main aim of researchers is to use minimum platform which are less costly, safer, light-weight and can be easily deployable. MAVs form a communication network, so behaviour of MAVs play a crucial role to achieve a common goal through the individual act on their own. Some rules are proposed by Craig. W. Reynolds for enabling birdlike flocking within a group. The rules were derived from real bird-flocks and can be briefly summarized as: move with the same speed and direction as neighbours, avoid colliding with them and stay close [21]. MAVs communicate only with their immediate neighbour and form a tight chain, when MAVs try to find a user in search and rescue operation they use rough knowledge of direction and once a user has been found in the targeted area then a communication link has been established and maintained. To maintain the network, MAV should arrange them in the efficient manner [21]. This is the way how the packet delivery rate of the network will improve for the longer communication link. In 2012 Michael Muller has given two basic approaches to detecting and connecting a user.

2.6 Bird Flight-Inspired Routing Protocol

Many Routing Protocols have been developed to perform efficient and optimize routing for the Mobile Adhoc networks. In mobile adhoc network that how packet are transmitting between the mobile nodes is very important because this affect the data delivery, power consumption and time, security and node management. Two researchers from IIT Sudip Mishra and Gopidi Rajesh proposed an algorithm named “Bird Flight-Inspired Routing Protocol for Mobile Ad Hoc Networks”. The proposed protocol is inspired by the navigation of birds over long distances following the great circle arc, the shortest arc connecting two points on the surface of a sphere [22]. This sheds light on how birds save their energy while navigating over thousands of miles. Proposed protocol has high adaptability to rapid changes in the topology of the network. This is achieved by changing the period of the beacon broadcast in accordance with the mobility of the node. But this has the drawback of additional bandwidth utilization.

2.7 Great Circle Navigation by Birds

In Last few years, many researchers have been done on how birds navigate hundreds of miles and reach the same destination year after year. Recently, scientists have proposed a theory proving that how birds use a number of cues such as the magnetic field of the earth, the position of the stars during the night and the position of the sun during the day to steer long distances. Birds may use these cues in combination for better accuracy. Birds uses unlike combinations of cues end up travelling in different trajectories. Scientists have recorded the trajectories of birds using radar technology and compared them with the trajectories estimated using different combinations of cues [22]. The comparison disclosed the important cues used by the bird flocks for navigation over long distances. One of the important and most-used cues is the position of the sun.

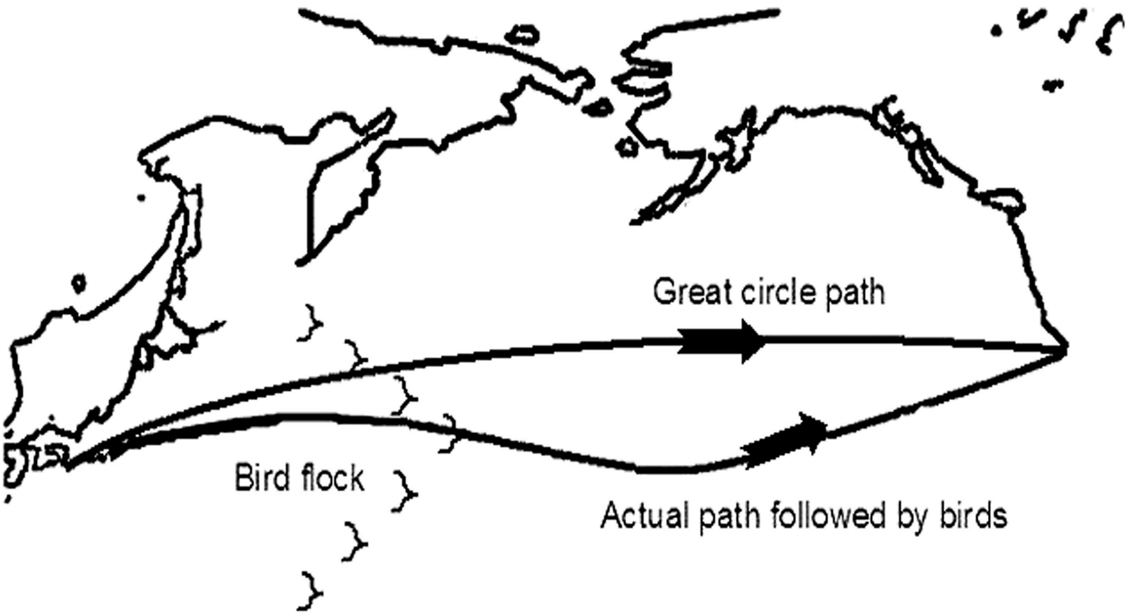

Figure 2.8 The Great Circle Path [22]

Alerstam pointed out that most of the birds navigate using the position of the sun without compensating for the fixed jet-lag and end up travelling along trajectories that approximated the great circle route on the globe as Figure 2.8. This is way through which birds save their energy while navigating thousands of miles [22]. Until we don't have any obstacles along the trajectory path, following the great circle does not make sure that we reach the destination in the minimum time period.

2.8 Mobility Models

Mobility models are designed to describe the different type mobility pattern of moving nodes and mobility model consider how their position is changing at a given time, velocity and acceleration changes with time. To finding and analyzing the performance of different protocols mobility models plays a remarkable role. It is expected from mobility models to emulate the movement pattern of nodes targeted life applications and scenario in a very efficient way [23]. Else it could leads to the wrong analysis and the conclusions done from the simulation. When evaluating MANET protocols, it is very important to select the proper mobility model. We have analyzed mobility models under two categories. Which are further sub-divided into different sub category as shown in Figure 2.9.

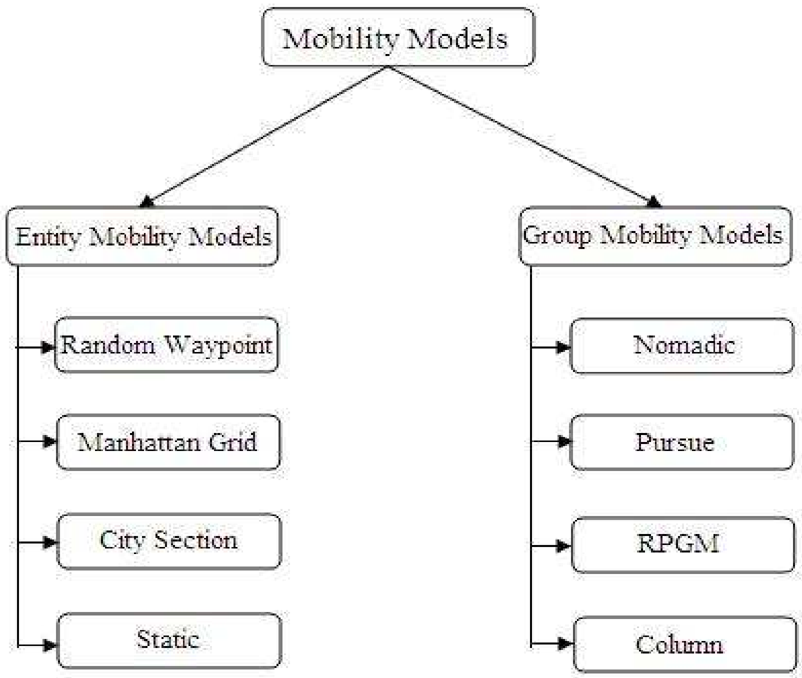

Figure 2.9 Classifications of Mobility Models [23]

2.8.1 Entity Mobility Models

- **Random Waypoint:** The Random Waypoint Model is the model which involves pause times before changes in speed and direction of the nodes. A mobile node starts transmission by staying in a particular location for some period of time means a pause time. Once this time period ends, the mobile nodes choose a random location in the defined simulation area and speed from the given range of maximum and minimum speed uniformly [23]. Then mobile nodes then travel toward the newly chosen location in the defined area at the selected speed shown in Figure 2.10. This process is repeated again and again but before that node takes a pause for short time period.

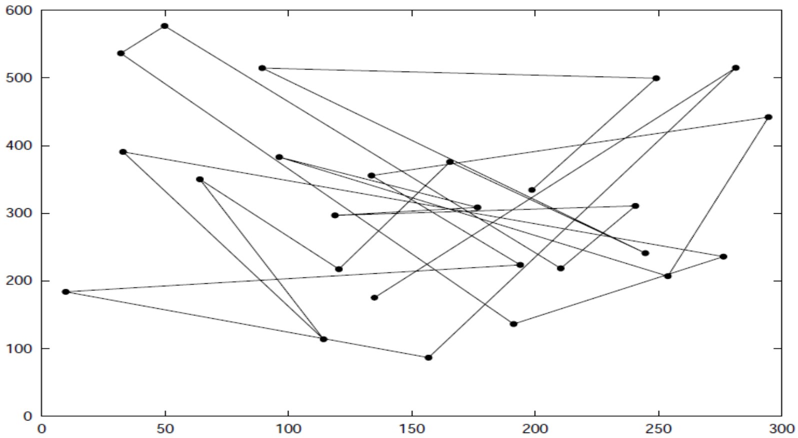

Figure 2.10 Travelling Pattern of an MN using the Random Waypoint Mobility Model [23]

- **Manhattan Grid:** The Manhattan Grid model is designed to provide a path in matrix form means in row and column points as presented in Figure 2.11. In this model, nodes move only on pre-specified paths. The –x and -y parameters set the number of blocks and the path between them.

  As an example, "\-v 3 -y 2" places the following paths on the simulation area:

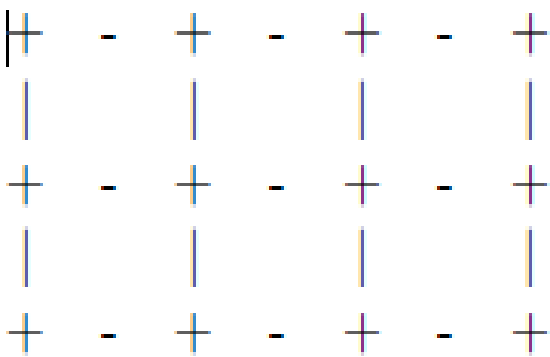

Figure 2.11 Manhattan Grid Mobile Node Travelling Pattern [23]

There are two more additional parameters that are supported by the Manhattan Grid. First it can decide or change the minimum speed of a mobile node. And second one is we can add the pause probability and the maximum pause time period of the mobile nodes.

- **City Mobility Model:** In this Mobility Model, the simulation area is defined by the street of a city which represents a section of a city where the ad hoc network has to create shown in Figure 2.12. The streets are based on the type of city being simulated, and the speed is dependent on the type of street. Figure 2.12 shows the mobility pattern of city section mobility model [24].

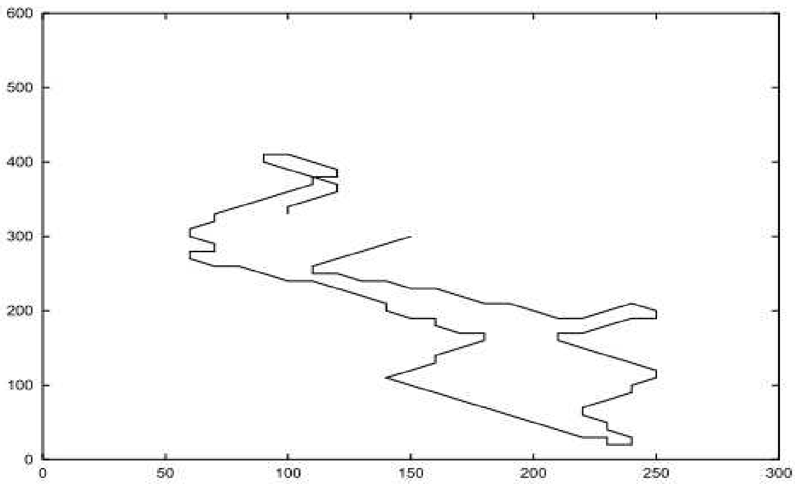

Figure 2.12 Travelling Pattern of an MN using City Section Model [24]

- **Static Mobility Model:** In the Static model, nodes distribution in the simulation area is homogenously distributed. For non-homogenous distribution, there are possibilities also through which we can define the non-homogenous distribution [24]. The attraction points can be defined with the “\-a" parameter. With the “\-l" parameter, the simulation area can be divided into several areas with different node densities along its x-axis.

2.8.2 Group Mobility Models

- **Reference Point Group Mobility Model (RPGM):** Reference Point Group Mobility shows movement of mobile nodes in group and as an individual. It also represents the random motion of nodes. Motion is dependent on logical centre of the group. This logical center is required for the calculation of group motion vector. Motion for group center specifies group movement, its speed and direction of movement. Apart from logical centre, each node decides its own reference point for random movement. The reference point moves from time t to t+1 and location of this is reported to the group's logical center. When reference points are updated, RP (t+1) is calculated each time and added to the random vector as shown in Figure 2.13.

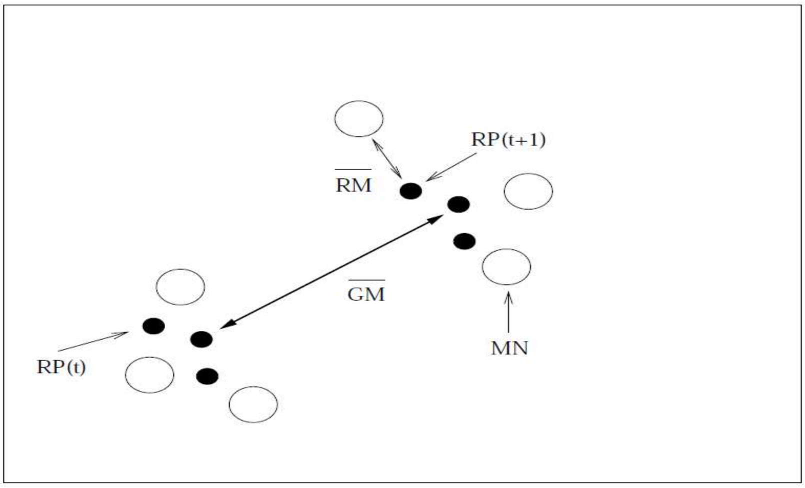

Figure 2.13 Movements of three MNs using the RPGM Model [24].

- **Nomadic Mobility Model:** As in old times, nomadic societies used to move from one location to another. This concept is used by nomadic mobility model. A group of mobile nodes is formed which moves collectively from one position to another. In this model, each individual node uses entity mobile model which is required for individual node movement across its own point of reference as shown in figure 2.14. When the point of reference changes, whole group moves to a new area and start wandering in that area [25].

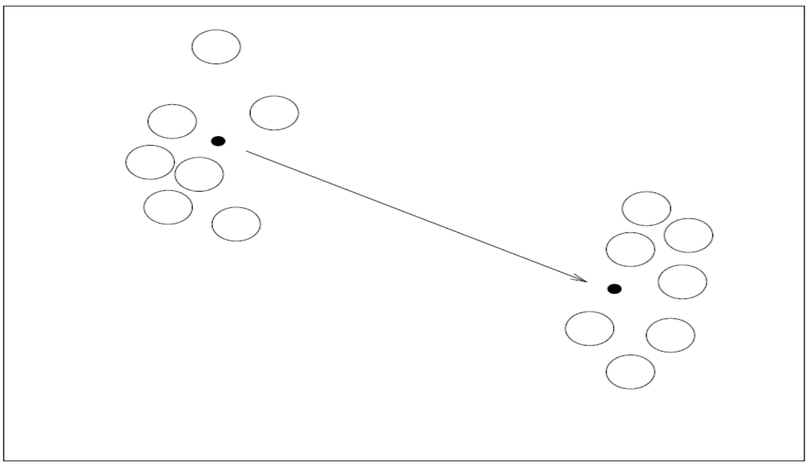

Figure 2.14 Movements of seven MNs in Nomadic Community Mobility Model [24]

- **Pursue Mobility Model:** In Pursue Mobility Model, the mobile nodes track a particular target. New position is calculated using the following equation for each mobile node:

  New position = old position + acceleration [target – old position] + random vector.

  Random vector is a offset for each mobile node and acceleration tells the how mobile nodes are pursuing towards target [26]. The degree of randomness of each node is limited to maintain tracking as shown in figure 2.15.

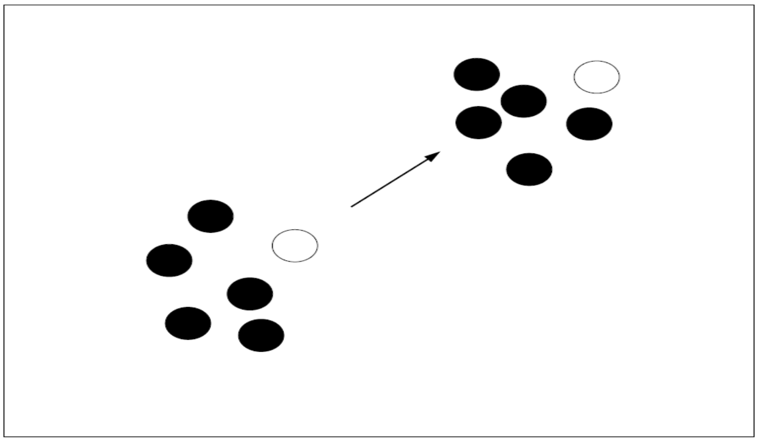

Figure 2.15 Movements of Six MNs using the Pursue Mobility Model [24]

- **Column Mobility Model:** This model is very useful for searching purposes. This model represents a set of mobile nodes that move around a given column, which moves in a forward direction like a group of children walking in a single-line to their classroom as shown in the figure 2.16.

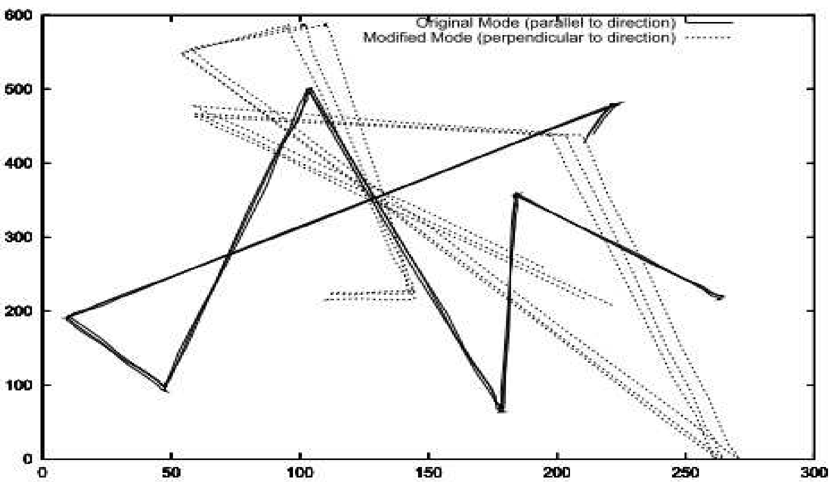

Figure 2.16 Travelling Pattern of MNs using the Column Mobility Model [24]

3. Problem Statement

3.1 Problem Statement

Because of many applications, flying adhoc network has fascinated many research institutes and automotive industries. Various types of challenges in flying adhoc network have been identified and addressed. Main issue of concern is implementation of an appropriate routing mechanism because of several issues. Routing protocol is an algorithm use to determine an appropriate path to destination along which message can be forwarded. Only routing is not important, but mobility pattern of a node in the adhoc network is also very important aspect. Adhoc routing protocols are classified into topology based and position based. It will be interesting to evaluate the performance of AODV (reactive routing), DSDV (proactive routing) and OLSR (proactive routing) for FANET. Analyzing these routing protocols will give clear and better understanding for selection of a better routing scheme for FANET. And it will also be very interesting to evaluate the performance of the selected routing protocol under the different mobility model for FANET. The performance of routing protocols can be evaluated using simulation tools, mainly Network Simulator and for mobility scenario Bonnmotion can be used.

3.2 Objective

The primary objective of this thesis is the simulation and analysis of AODV, DSDV and OLSR routing protocols for FANET. And find the better routing protocol and then simulates and analyze that protocol under different mobility models.

- To simulate AODV, DSDV and OLSR protocols for FANET.
- To compare and analyze their performance in terms of Packet Delivery Ratio, End to End Delay and Average Throughput.
- To analyze the results obtained in order to find best protocol among AODV, DSDV and OLSR.
- To simulate best routing protocol found with different mobility models.
- To find the best mobility model for best routing protocol found in FANET.
- To report and analyze the results obtained.

3.3 Methodology

- Simulation environment has been setup for AODV, DSDV and OLSR using NS-2.
- By using TCL scripts of AODV, DSDV and OLSR node speed has been varied. Five different set of node speed has been used to compare the performance of the said protocol.
- AWK scripts have been used to get the value from trace file and origin 9.1 is used to generate graphs.
- Selected protocol has been simulated with different mobility models by using NS-2.
- Results have been compared under various parameters like Packet Delivery Ratio, End to End Delay and Average Throughput.
- Simulation analysis has been done to obtain best suitable protocol with best mobility model for FANET.

4. Simulation and Implementation

4.1 Simulation

According to Shannon, simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of system and/or evaluating different strategies for system operation [28]. Developing a FANET in practical application is too costly therefore to test and to evaluate the protocols, simulators are used. Simulation of a protocol is the initial step of implementation of FANET protocols. Several communication network simulators already exist to provide a platform for testing and evaluating network protocols such as NS-2 [29], OPNET and Qualnet. Node mobility is the most important parameter in simulating ad-hoc network. It’s important to use real world mobility model so that the results from the simulation correctly reflect the real-world performance of a FANET.In this thesis, to generate real world mobility model for FANET simulation a tool BonnMotion has been used, which is developed in java.

4.2 System Environment

The system environment in which simulation has been carried out is given in the table 4.1

Table 4.1 System Environment

System	Sony Vaio
System Type	64 Bit
Ram	4gb
Hard disk	500gb
Operating System	Ubuntu 12.04
Processor	Intel Core™ I3
Mongodb	2.6.3

4.3 Network Simulator

NS-2 is application level simulator, which is developed in C++ and it uses OTCL interpreter as a front-end. C++ language is used for implementation of different protocols and for extension of network simulator libraries. OTCL is used to develop and control the environment of simulation. NS-2 supports both wireless as well as wireless networks and can simulate different types of network protocol like transmission control protocol, user datagram protocol and multiple routing protocols etc [30]. Recently, adhoc and satellite wireless network support has been added. NS-2 is developed at the University of Berkeley. It is consistently enhanced and modified by an active community of researchers. First we will discuss the basic installation mechanism and configuration of network simulator. Then later on, we will discuss how to create simulation environment under which we will analyze the working and performance OLSR routing protocols for flying ad hoc networks by using different mobility model based experiments.

4.4 Architecture of NS-2

Figure 4.1 shows the fundamental architecture of NS-2. NS-2 provides users with executable command ns which take an input argument, the name of a TCL simulation scripting file. Users are feeding the name of a TCL simulation script as an input argument of NS-2 executable command ns. NS-2 consists of two key languages C++ and Object oriented command language (OTCL). After simulation, NS-2 output either text-based or animation based simulation results. To interpret these results graphically and interactively, tools such as NAM (Network Animator) and XGraph are used.

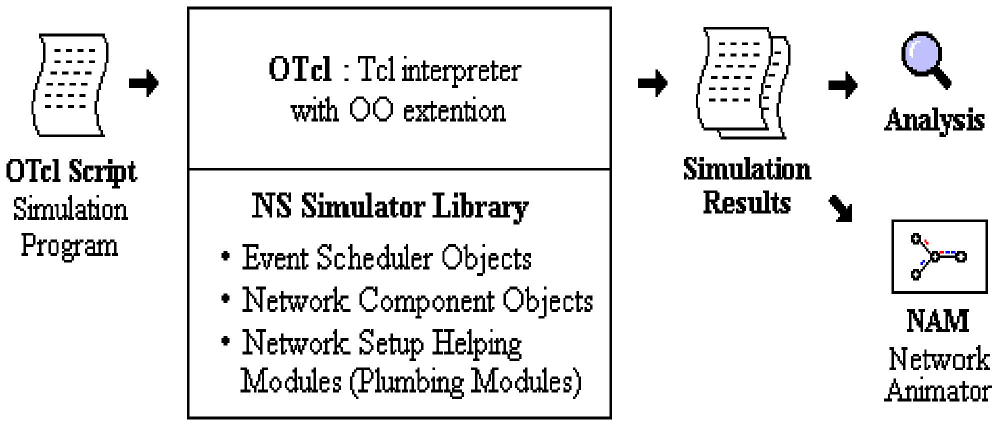

Figure 4.1 Architecture of NS

4.5 NAM (Network AniMator)

Nam provides a visual construal of the network topology created. The application was developed as part of the VNIT project. Figure 4.2 displays the NAM visualization.

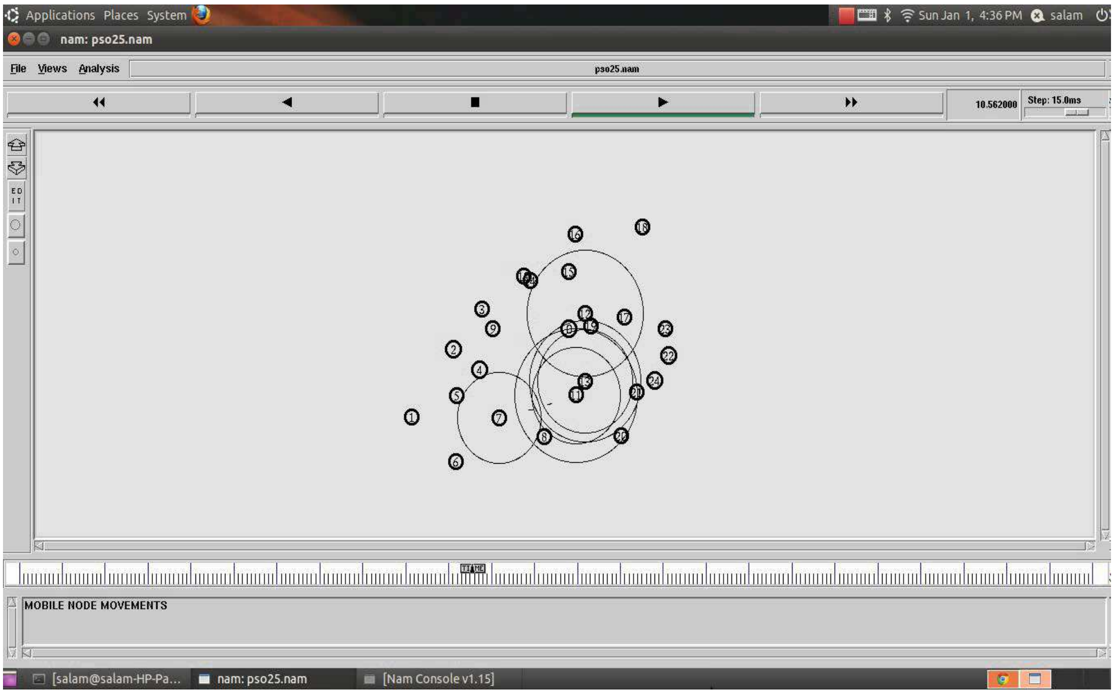

Figure 4.2 NAM Generated for 25 Nodes

4.6 Trace File Format

The trace file is an ASCII code files and the trace is organised in 12 fields as shown in Figure 4.3.

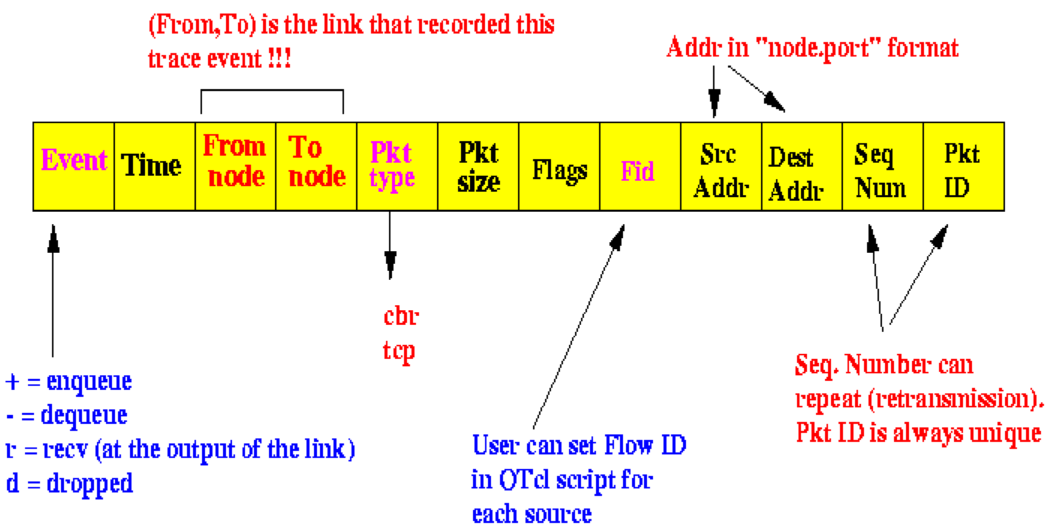

Figure 4.3 Trace File Format

The trace file data explanation is given below starting from the first field as number1.

1. Operation perform in the simulation, given by one of four available symbol r, +, - and d which correspond respectively receive, enqueued, dequeued and drooped.
2. Simulation time of event occurrence.
3. Input nodes of link at which the event takes place.
4. Output nodes of link at which the event takes place.
5. Packet type like CBR or TCP.
6. Packet size
7. Flags
8. IP flow identifier
9. Packet source node address
10. Sequence number
11. Unique packet identifier

Depending on the user's purpose for an OTCL simulation script, simulation results are stored as trace files, which can be loaded for analysis by the external applications or scripts.

4.7 Installation and Configuration

NS-2 is a free simulation tool. NS-2 is compatible with various platforms including Linux, windows and Mac systems. It is developed in Unix environment and because of this it has smoothest ride there and so does the installation. NS-2 source codes can be download in a single package named all-in-one. For beginners this is recommended.

Steps are given below for all-in-one suite installation.

4.7.1 Networks Simulator installation

To install network simulator, some steps are given as follow:

Step1: Download ns-2.35 from [online] http://www.isi.edu/nsnam/ns

Step2: Save the downloaded folder to home directory and unpack **"tar -xzvfns-allinone-2.35.tar.gz".**

Step3: Open terminal use command" **Sudo apt-get update"** and then use command **"sudo apt-get install build-essential autoconfautomakelibxmu-dev"**

Step4: cd ns-allinone-2.35and then run command ./install

Step5: Run the following command to install xgraph **"Sudo apt-get install xgraph".**

Step6: Setup the environment variables "**gedit ~/.bashrc**".

Step7: Run the following command "**source ~/.bashrc**".

Step8: Type ns on terminal, % symbol shows successful installation of ns-2.\

4.7.2 OLSR Patch

Step1: Download OLSR patch from http://masimum.inf.um.es/fjrm/ development/um-olsr/

Step2: Change the directory "**cd ns-allinone-2.35/ns-2.35/"**

Step3: Unpack um-olsr-0.8.8.tgz **" tarzxvf um-olsr-0.8.8.tgz"**

Step4: Create symbolic link **" ln -s ./um-olsr-0.8.8. /olsr"**

Step5: Run this command to patch OLSR **"patch -p1<olsr/um-olsr_ns-2.35_v0.8.8.patch".**

Step6: Run the configuration file and make file **". /configure"** and **make**.

4.7.3 BonnMotion

BonnMotion is developed in Java. Which is used to create and analyzes mobility scenarios for different mobility patterns, and this tool is used by the most of the researchers to analyze and investigate to the characteristic of the mobile adhoc networks [31]. The scenarios generated by bonnmotion can be used with different simulation and analysis tools like NS-2, NS-3 and MiXiM.

BonnMotion is being jointly developed by the Communication Systems group at the University of Bonn, Germany, the Toilers group at the Colorado School of Mines, Golden, CO, USA, and the Distributed Systems group at the University of Osnabruck, Germany [31].

Installation

BonnMotion requires Java Run Time Engine (JRE) and java development Kit (JDK).

Step1: Install jre and jdk**"sudo apt-get install openjdk-7-jre openjdk-7-jdk**"

Step2: download and extract bonnmotion-2.0 **"unzip bonnmotion-2.0.zip"**

Step3: change directory **"cd bonnmotion-2.0"**

Step4: edit install file and run **". /install"**

Now it will ask for java path:

Please enter your java binary path [/usr/bin]: Press Enter

The message will appear on terminal: Bonnmotion successfully installed.

Running Bonnmotion

Bonnmotion have a wrapper script "\bm" which is required for all the applications to run [31]. This wrapper can be run using

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

The application can be a mobility model used to analyse scenario characteristics. Starting the script without command line parameters display help options.

Scenario Generation

The scenario generator writes all parameters used to create a certain scenario to a file. In this way, settings are saved and particular scenario parameters can be varied without the need to re-enter all other parameters. Important parameters used with all models are the following:

- [-n] number of nodes
- [-d] scenario duration (in seconds)
- [-i] to skip the additional seconds at the beginning of the scenario.
- [-x] width of simulation area set (in meters)
- [-y] height of simulation area set (in meters)

Example: ./bm -f scenario1 Nomadic -n 100 -d 900 -i 3600

This creates a Nomadic scenario with 100 nodes and duration of 900 seconds. An initial phase of 3600 seconds is cut off. A scenario is saved in two files: the first file with suffix "name.params" contains the complete set of parameters used for simulation and second file with suffix "name.movements.gz" contains the node movement data.

5. Results and Analysis

5.1 Simulation Parameters

In this chapter, simulation is done in three parts and on different parameters, so table 5.1, 5.2 and 5.3 shows first, second and third set of parameters respectively. Results are shown in the same sequence as the parameter set table given.

5.1.1 Simulation Parameter Set1

In simulation parameter set1, routing protocols considered are AODV, DSDV and OLSR for 20 nodes. Speed of nodes varies from 5 m/sec to 50 m/sec. The duration of simulation is 900 seconds, data payload of 512 bytes/packet and traffic type considered is CBR.

Table 5.1 Simulation Parameters Set1

Parameter	**Value**
Simulator	NS-2(Version-2.35)
Channel Type	Channel/Wireless Channel
Routing Protocol	AODV, DSDV, OLSR
Simulation Duration	900s
Number of Nodes Per Simulation	20
MAC Layer Protocol	802.11
Traffic Type	CBR
Data Payload	512 bytes/packet
Max of CBR Connections	200
Node Speed	5,10,20,30,40,50 (m/sec)

5.1.2 Simulation Parameter Set2

In simulation parameter set2, OLSR routing protocol is considered with Random Waypoint, Manhattan Grid, RPGM and Pursue mobility models with 20 nodes. Speed of nodes varies from 5 m/sec to 50 m/sec. The duration of simulation is 900 seconds, data payload of 512 bytes/packet and traffic type considered is CBR.

Table 5.2 Simulation Parameters Set2

Parameter	Value
Simulator	NS-2(Version-2.35)
Channel Type	Channel/Wireless Channel
Routing Protocol	OLSR
Mobility Models	Random Waypoint, Manhattan Grid , RPGM, Pursue
Simulation Duration	900s
Number of Nodes per Simulation	20
MAC Layer Protocol	802.11
Traffic Type	CBR
Data Payload	512 bytes/packet
Max of CBR Connections	200
Node Speed	5,10,20,30,40,50 (m/sec)

5.1.3 Simulation Parameter Set3

In simulation parameter set3, OLSR routing protocol is considered with Random Waypoint, Manhattan Grid, RPGM and Pursue mobility models. The node group of 10,20,40,70 and 100 are taken. Speed of nodes varies from 5 m/sec to 25 m/sec. The duration of simulation is 900 seconds, data payload of 512 bytes/packet and traffic type considered is CBR.

Table 5.3 Simulation Parameters Set3

Parameter	Value
Simulator	Network Simulator -2 (Version 2.35)
Channel Type	Channel/Wireless Channel
Protocol	OLSR
Simulation Duration	900s
Nodes Groups	10,20,40,70,100
Mobility Models	Random Waypoint, Manhattan Grid , RPGM, Pursue
MAC Layer Protocol	802.11
Traffic Type	CBR
Data Payload	512 bytes/packet
Max of CBR Connections	100,200,400,700,1000
Speed	(5-25)m/sec

5.2 Performance Parameters

Here we have taken three performance parameters for analyzing the different mobility model for OLSR:

- **Packet Delivery Ratio:** Packet delivery ratio tells that how many packets were sent and how many actually delivered to the destination.

  Packet delivery ratio= Total number of packet sent/ Total number of packet received
- **End to End Delay:** End to End tells that the average time taken by a packet to arrive at the destination, it also involves delay in queue and delay caused by the route discovery.End to End delay= (arrive time –send time)/ number of connections [27].
- **Throughput:** Throughput shows the bandwidth of the protocol. Below are the results obtained from the trace file used along with the AWK scripts.

5.3 Simulation Results of Routing Protocols AODV, DSDV and OLSR (with Parameter Set1)

5.3.1 Node Speed vs Packet Delivery Ratio: Table 5.4 shows the variation of packet delivery ratio of different routing protocols OLSR, AODV and DSDV with the change in speed of node.

Table 5.4 Node Speed vs. Packet Delivery Ratio

Routing Protocol	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR	1	1	.996	1	.997	1
AODV	0.998	1	0.991	0.987	0.953	0.927
DSDV	0.996	0.994	0.986	0.949	0.931	0.916

The graph obtained by variation of packet delivery ratio with the change of speed of node is shown in Figure 5.1.

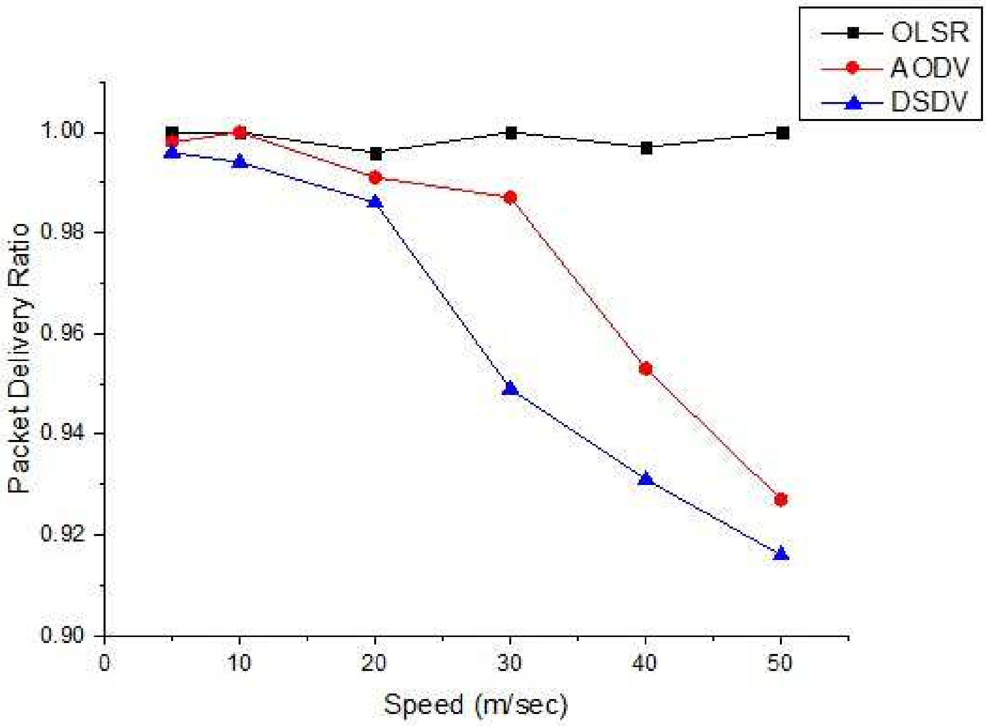

Figure 5.1 Node Speed vs Packet Delivery Ratio

5.3.2 Node Speed vs End to End Delay: Table 5.5 shows the variation in end to end delay of different routing protocols OLSR, AODV and DSDV with the change in speed of node.

Table 5.5 Node Speed vs. End to End Delay

Routing Protocol	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR	6.234	6.233	6.234	6.233	6.333	6.533
AODV	6.201	6.131	6.931	7.246	7.789	8.346
DSDV	6.011	5.931	6.493	6.972	6.993	7.293

The graph obtained by variation of end to end delay with the change of speed of node is shown in Figure 5.2.

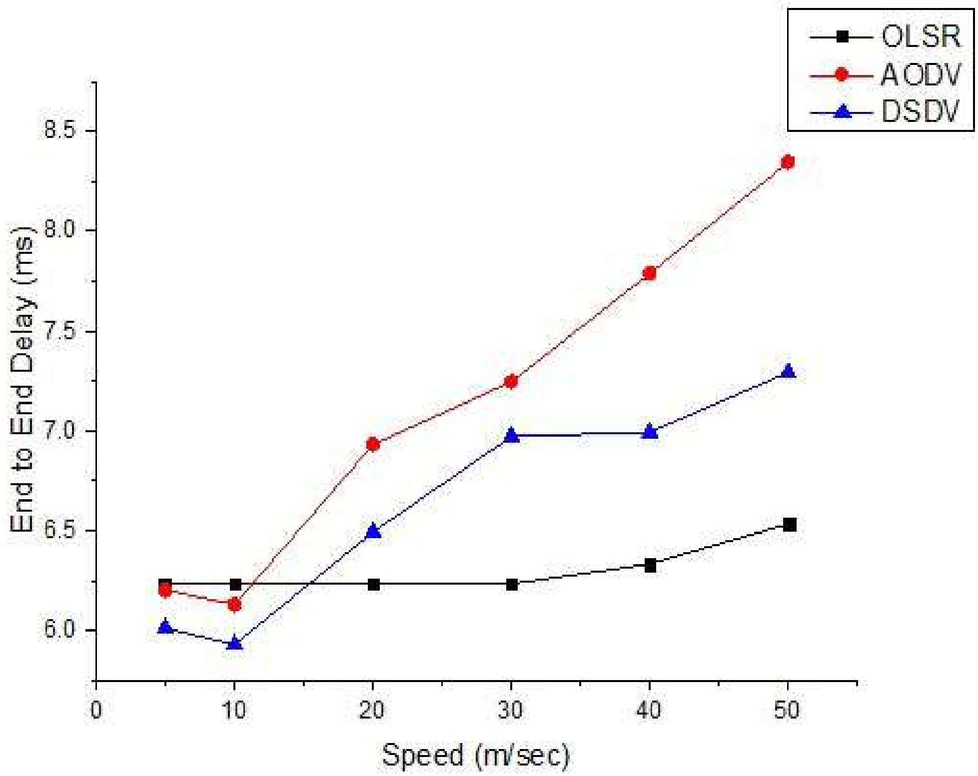

Figure 5.2 Node Speed vs End to End Delay

5.3.3 Node Speed vs Average Throughput: Table 5.6 shows the change of average throughput of different routing protocols OLSR, AODV and DSDV with the change in speed of node.

Table 5.6 Node Speed vs. Average Throughput

Routing Protocol	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR	64.61	64.61	64.61	64.61	64.61	64.61
AODV	62.13	63.69	65.71	61.32	59.16	58.13
DSDV	60.91	62.77	60.93	62.11	62.27	61.93

The graph obtained by change in average throughput with the change of speed of node is shown in Figure 5.3.

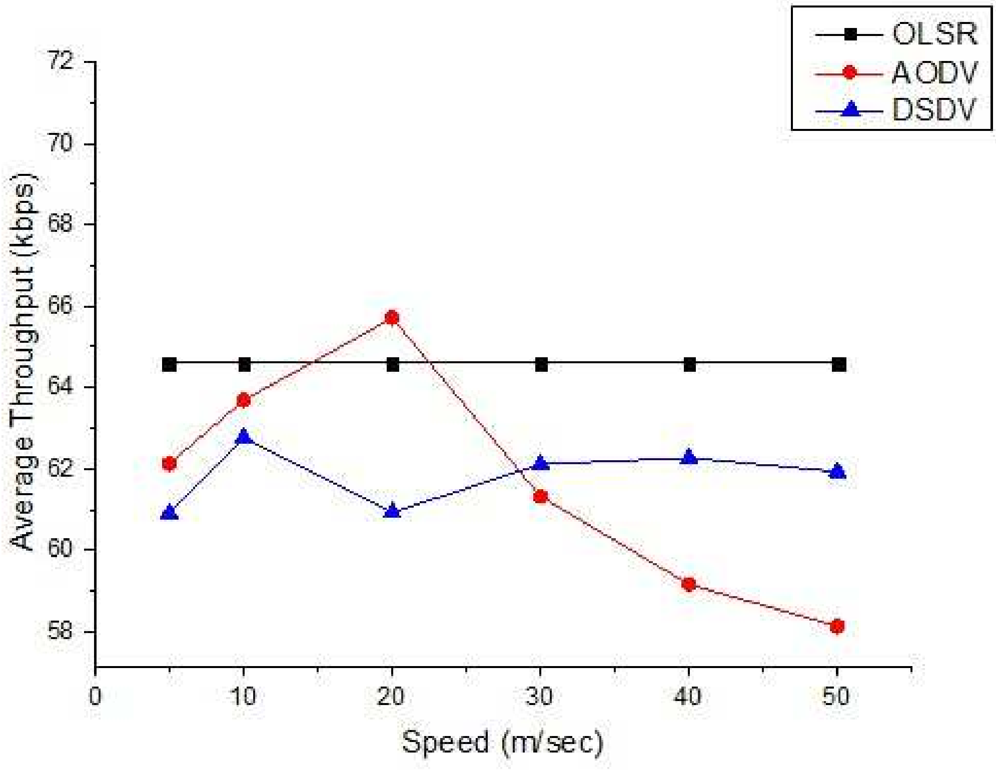

Figure 5.3 Node Speed vs Average Throughput

5.4 Simulation Results of OLSR Routing Protocols with different Mobility Models (with Parameter Set2)

5.4.1 Node Speed vs Packet Delivery Ratio: Table 5.7 shows the variation of packet delivery ratio of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the change in speed of node.

Table 5.7 Speed vs. Packet Delivery Ratio

Mobility Models	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR with Random Waypoint	0.998	0.995	0.988	0.986	0.983	0.901
OLSR with Manhattan Grid	0.992	0.991	0.989	0.998	0.991	0.987
OLSR with RPGM	0.997	0.961	0.927	0.946	0.897	0.995
OLSR with Pursue	1	1	0.996	1	0.997	1

The graph obtained by change in packet delivery ratio with the change of speed of node is shown in Figure 5.4.

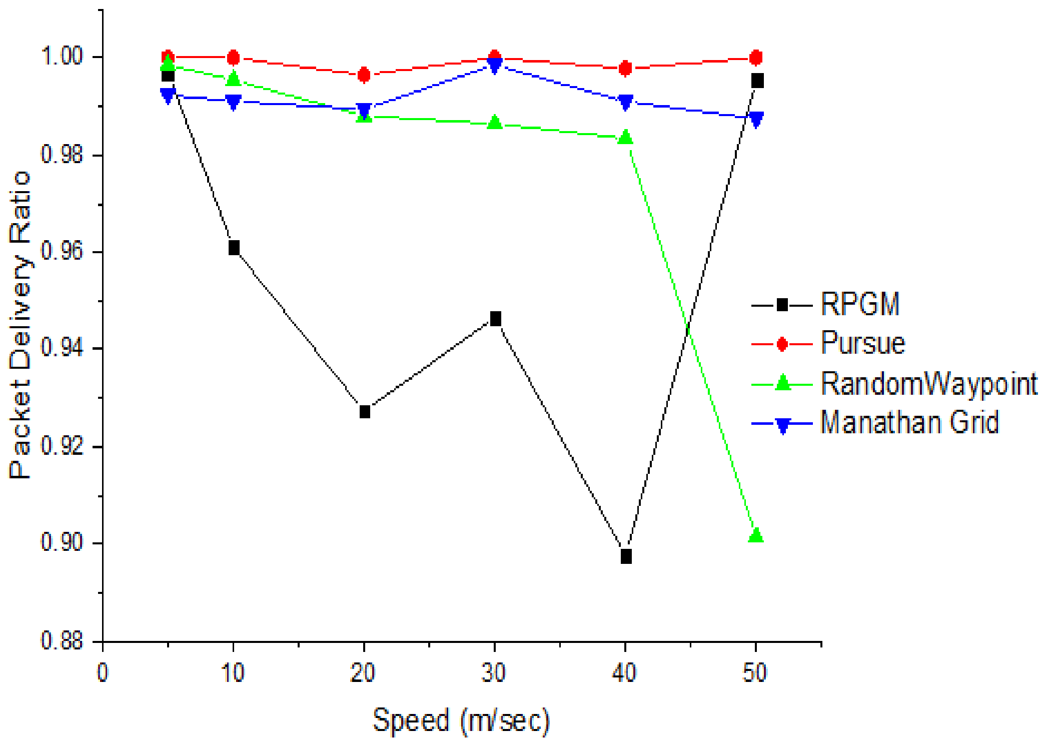

Figure 5.4 Speed vs. Packet Delivery Ratio

5.4.2 Node Speed vs End to End Delay: Table 5.8 shows the change in end to end delay of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the change in speed of node.

Table 5.8 Speed vs. End to End Delay

Mobility Models	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR with Random Waypoint	8.920	8.989	7.322	11.571	11.911	10.614
OLSR with Manhattan Grid	12.897	8.921	17.494	10.657	12.300	12.411
OLSR with RPGM	9.953	6.713	6.093	8.236	6.624	7.563
OLSR with Pursue	6.234	6.233	6.234	6.233	6.333	6.533

The graph obtained by change in end to end delay with the change of speed of node is shown in Figure 5.5.

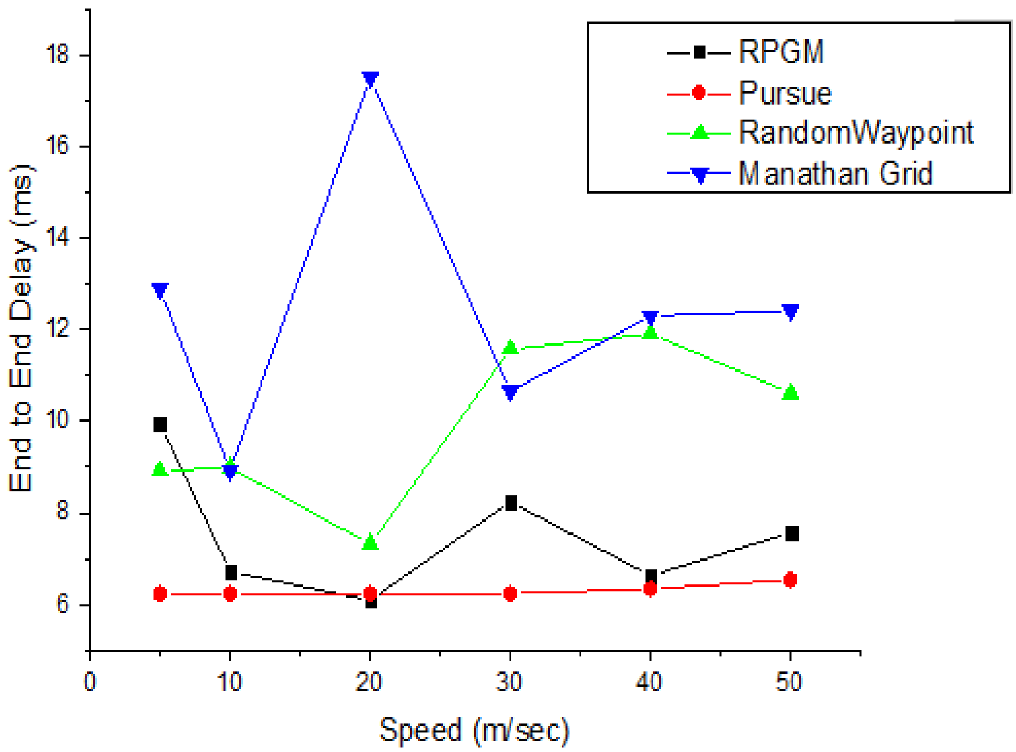

Figure 5.5 Speed vs. End to End Delay

5.4.3 Node Speed vs End to End Delay: Table 5.9 shows the change in average throughput of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the change in speed of node.

Table 5.9 Speed vs. Average Throughput

Mobility Models	Speed(m/sec)					
	5	*10*	*20*	*30*	*40*	*50*
OLSR with Random Waypoint	64.03	63.6	63.54	63.42	62.95	57.44
OLSR with Manhattan Grid	63.03	63.93	63.23	63.42	63.54	63.51
OLSR with RPGM	64.04	61.04	59.44	61.49	57.62	63.57
OLSR with Pursue	64.61	64.61	64.61	64.61	64.61	64.61

The graph obtained by change in average throughput with the change of speed of node is shown in Figure 5.6.

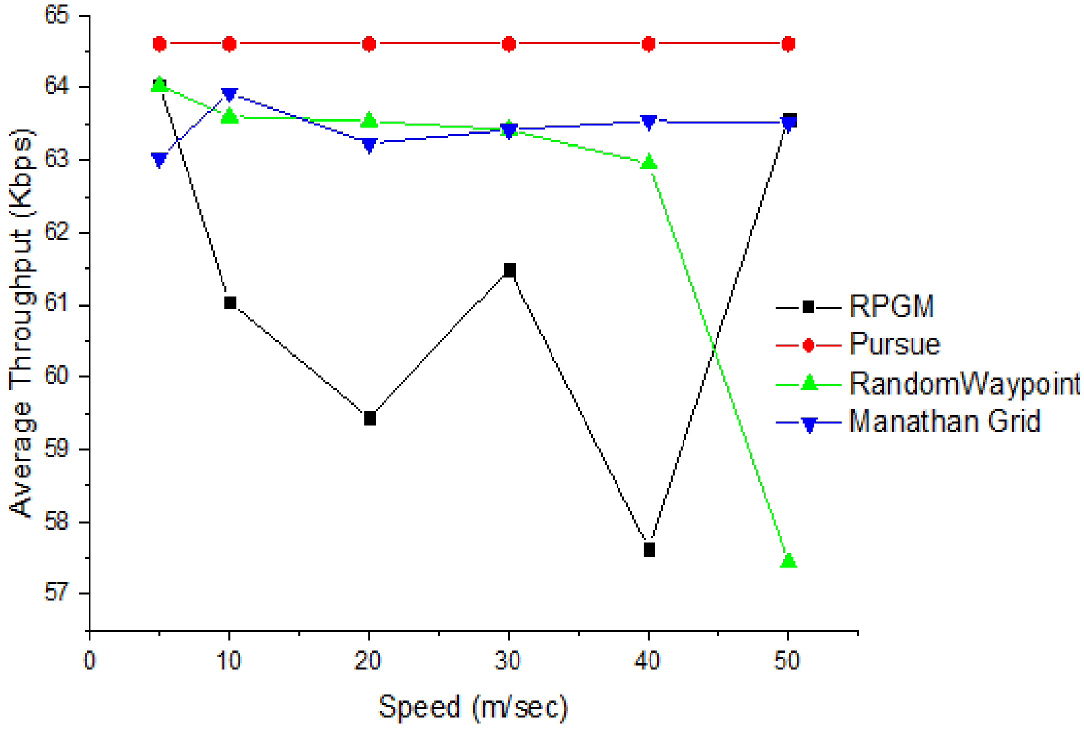

Figure 5.6 Speed vs. Average Throughput

5.5 Simulation Results of OLSR Routing Protocols with different mobility models (with Parameter Set3)

5.5.1 Node Speed vs Packet Delivery Ratio: Table 5.10 shows the variation of packet delivery ratio of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the different number of nodes.

Table 5.10 Number of Nodes vs Packet Delivery Ratio

Mobility Models	**Node Group**				
	10	*20*	*40*	*70*	*100*
OLSR with Random Waypoint	0.9971	0.9841	0.9844	0.9726	0.9731
OLSR with Manhattan Grid	0.9358	0.9671	0.9592	0.9472	0.9584
OLSR with RPGM	0.9976	0.9951	0.9864	0.9706	0.97
OLSR with Pursue	0.9983	0.9946	0.9876	0.9793	0.974

The graph obtained by change in packet delivery ratio with the different number of nodes is shown in Figure 5.7.

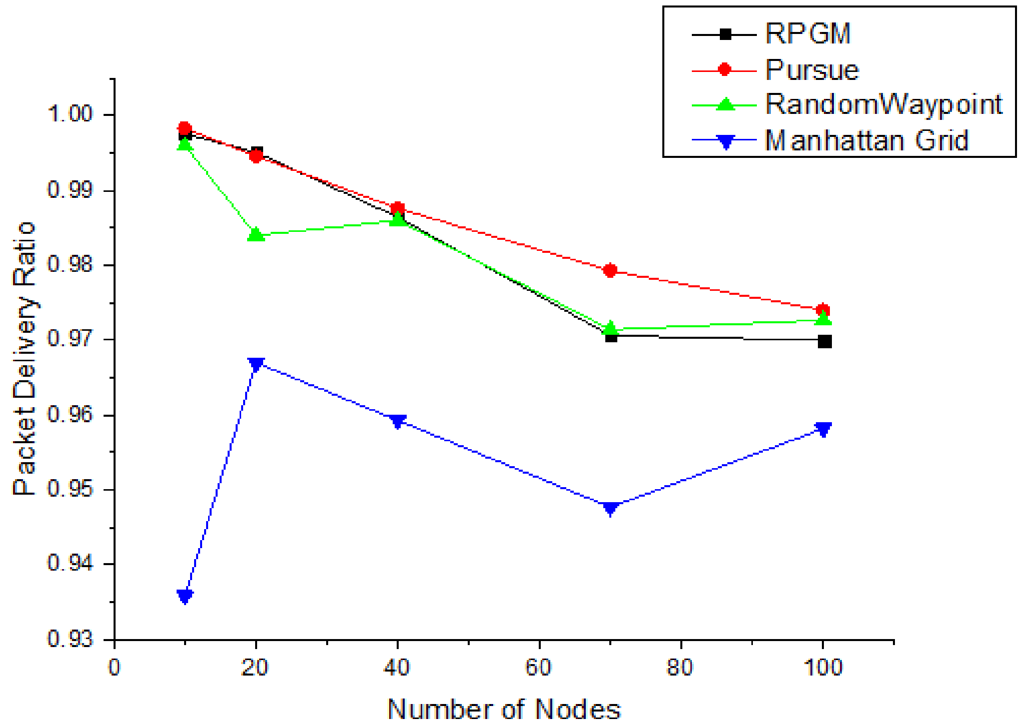

Figure 5.7 Number of Nodes vs. Packet Delivery Ratio

5.5.2 Node Speed vs End to End Delay: Table 5.11 shows the variation of end to end delay of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the different number of nodes.

Table 5.11 Number of Nodes vs End to End Delay

Mobility Models	**Node Group**				
	10	*20*	*40*	*70*	*100*
OLSR with Random Waypoint	8.004	9.662	10.819	9.334	9.311
OLSR with Manhattan Grid	16.31	11.678	12.162	13.259	11.342
OLSR with RPGM	6.982	6.228	8.385	9.0258	9.238
OLSR with Pursue	6.039	6.349	8.443	8.9351	8.217

The graph obtained by change in end to end delay with the different number of nodes is shown in Figure 5.8.

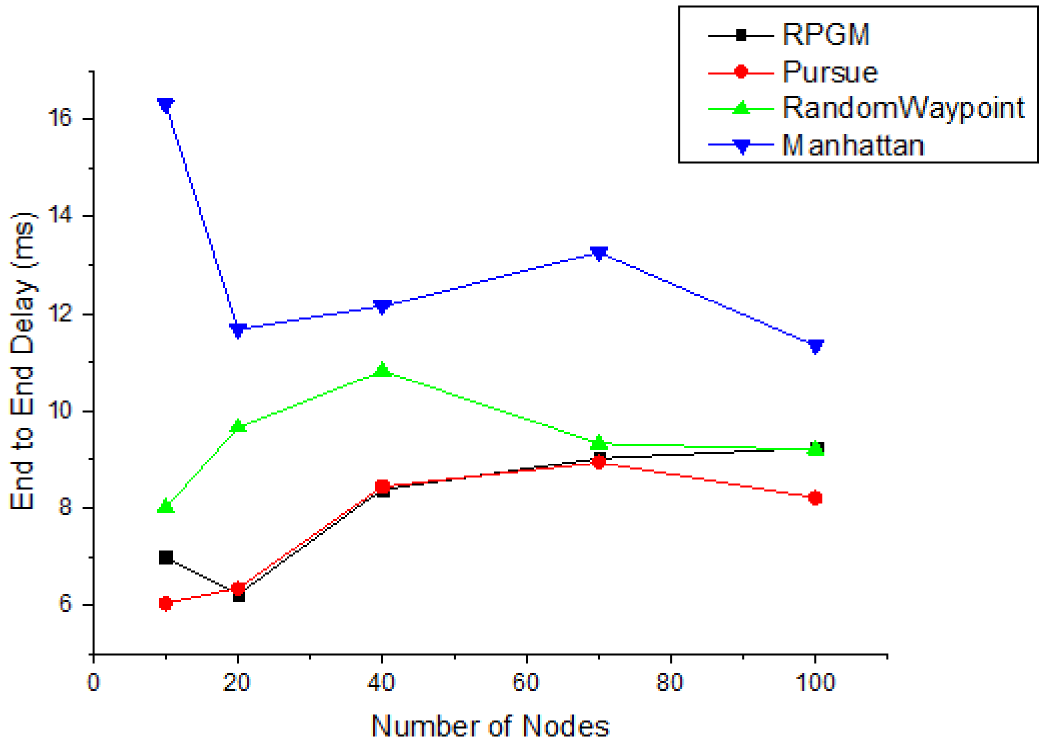

Figure 5.8 Number of Nodes vs. End to End Delay

5.5.2 Node Speed vs Average Throughput: Table 5.12 shows the variation of average throughput of OLSR routing protocol with different mobility models (Random Waypoint, Manhattan Grid, RPGM and Pursue) with the different number of nodes.

Table 5.12 Number of Nodes vs Average Throughput

Mobility Models	**Node Group**				
	10	*20*	*40*	*70*	*100*
OLSR with Random Waypoint	46.52	53.92	60	61.35	57.89
OLSR with Manhattan Grid	45.76	54.58	56.33	60.84	54.49
OLSR with RPGM	45.64	53.21	59.37	62.66	60.7
OLSR with Pursue	46.67	55.46	60.01	63.9	62.14

The graph obtained by change in average throughput with the different number of nodes is shown in Figure 5.9.

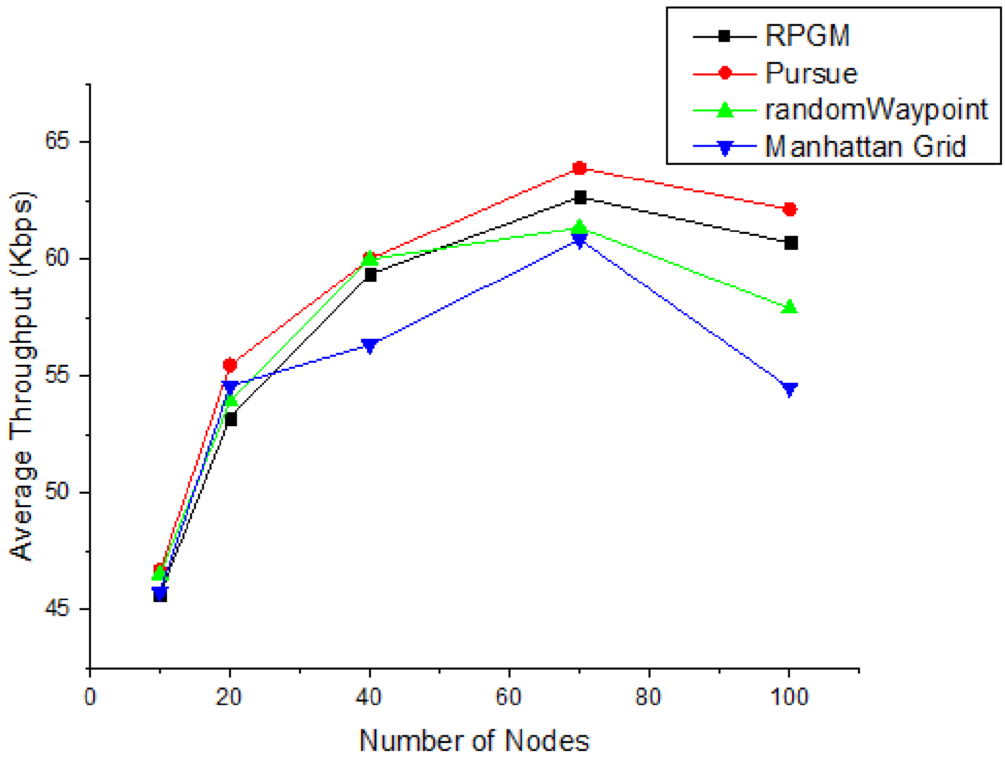

Figure 5.9 Number of Nodes vs. Average Throughput

5.6 Simulation Analysis

The simulation is done with three different parameter sets. With parameter set1, simulation of OLSR, AODV and DSDV routing protocols have been performed and results obtained from simulation is shown in table (5.4, 5.5 and 5.6) and on the base of results graphs are drawn. From the Figure 5.1, it is observed that the packet delivery ratio of OLSR is consistent and almost near to hundred percent whereas packet delivery ratio of AODV and DSDV decreases when the node speed increase. And from Figure 5.2, it can be clearly seen that at low node speed end to end delay of OLSR is more than the AODV and DSDV but as the speed of node increases the end to end delay time of AODV and DSDV routing increases. Whereas OLSR end to end delay time increase little. So in case of end to end delay OLSR perform better than other two (AODV and DSDV) routing protocol. Figure 5.3 shows; the average throughput of OLSR is consistent even when the node speed increase, but average throughput of AODV and DSDV is getting down with the high speed nodes. So from the first part of results it can be seen that OLSR perform better than AODV and DSDV in FANET.

With the parameter set2, OLSR protocol has been applied under different mobility models (Random Waypoint, Manhattan-Grid, RPGM and Pursue) in FANET. Under parameter set2, same type of traffic and number of nodes (20) has been used. In this simulation, different speed groups (5, 10, 20, 30, 40 and 50) are used to check the performance of protocol under a fix simulation area 400X600.

As shown in Figure 5.4, it is observed that OLSR with Pursue mobility model performs better in terms of packet delivery ratio. Pursue mobility models provide almost 100 percent packet delivery ratio (PDF) even at a high speed of nodes, whereas PDF of other mobility models vary from 90 to 99 percent. Figure 5.5 shows that, End to End delay of OLSR with pursue mobility models is low and it is almost the consistent, whereas the other mobility models (random waypoint, Manhattan grid and RPGM) have high End to End delay, Which leads to the poor performance of OLSR for FANET. From Figure 5.6, it can be clearly observed that speed of node in the FANET does not affect the throughput of OLSR under Pursue mobility model, and which is better than the other three mobility models.

With parameter set3, same type of traffic and different number of nodes (10, 20, 40, 70, 100) has been used. In this simulation, node speed varies from 5m/s to 25m/s are used to check the performance of protocol under a fix simulation area 400X600.

As shown in Figure 5.7, it is observed that OLSR with Pursue mobility model performs better in terms of packet delivery ratio. Pursue mobility models provide high percentage of packet delivery ratio (PDF) even at a high speed of nodes, whereas PDF of other mobility models is comparatively low. Figure 5.8 shows that, End to End delay of OLSR with pursue mobility models is low, whereas the other mobility models (random waypoint, Manhattan grid and RPGM) have high End to End delay, Which leads to the poor performance of OLSR for FANET.

From Figure 5.9, OLSR with pursue mobility model gives better performance in terms of throughput whereas OLSR with other mobility models (random waypoint, Manhattan grid and RPGM) throughput is low.

5.7 Summary

AODV, DSDV and OLSR routing protocols are simulated using NS-2. OLSR routing protocol is simulated with various mobility models Random Waypoint, Manhattan grid, Pursue and RPGM. The performance analysis is done by considering parameters like end to end delay, packet delivery ratio and average throughput for FANET. Simulation analysis results show that among three protocols OLSR routing protocol with Pursue mobility model works better. So OLSR routing protocol with Pursue mobility can be used for optimized performance of FANET.

6. Conclusion and Future Scope

6.1 Conclusion

In this thesis, performance of AODV, DSDV and OLSR routing protocols have been analyzed in terms of Packet Delivery Ratio, End to End Delay and Average Throughput. The evaluation made on these protocols brings out some important behavior and characteristic of these protocols when they are used in FANET. It has been observed that OLSR routing protocols works better than other protocols. Comparison is made in terms of Packet Delivery Ratio, End to End Delay and Average Throughput for AODV, DSDV and OLSR. The comparison resulted that, OLSR perform better for Packet Delivery Ratio, End to End Delay and Average Throughput.

After selecting OLSR routing protocol as suitable protocol for FANET, different mobility models are simulated and analyzed for average end to end delay and packet delivery ratio with variation in speed of node. Simulation results show that performance of OLSR varies depending on the variation in speed of node and mobility models. Under the pursue mobility model OLSR performs better for FANET, in comparison of Manhattan, Random Waypoint and RPGM.

OLSR routing protocol is again simulated and analyzed using different mobility model with variation in number of nodes. Simulation results show that performance of OLSR under the pursue mobility model is better for FANET, in comparison of Manhattan, Random Waypoint and RPGM. So OLSR routing protocol with pursue mobility model can be used to optimized the performance of FANET.

6.2 Future Scope

There are certain limitations of flying agents due to characteristic of mobile adhoc network like- dynamically topology management, security and bandwidth and node management. Another issue is Swarm behavior, because they work together to form a network so how they interacts to each other also have importance in communication. This work can be enhanced by implementing OLSR with Purse mobility model based on requirement in the FANET.

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List of Publication

- K. Singh and A.K. Verma, “Applying OLSR Routing in FANETs” *IEEE International Conference on Advance Communication, Control and Computing Technologies (ICACCCT’14),* Syed Ammal Engineering College, Ramanathapuram, Tamilnadu, India, May 2014. **[Accepted and Presented]**
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