Chaining Mobility Models for AOMDV and DSDV protocols in FANETs

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

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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, "***Chaining Mobility Models for AOMDV and DSDV protocols in FANETs***", 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. Ashima Singh*** 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 the 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

Flying Ad-hoc Networks are the subtype of MANETs where the collection of Unmanned Aerial Vehicles (UAV) communicates with each other for sharing the information. The mobility models are designed to represent the movement of nodes. The major role of mobility model is to create a realistic simulation environment and evaluate the performance of different routing protocols. The performance of routing protocols varies according to the mobility models. The main purpose of this research is to propose a new chain mobility model integrating existing Random Waypoint Mobility Model and Gauss-Markov Mobility Model. These protocols are analyzed for using purpose mobility chain in terms of different Quality of Service parameters such as Packet Delivery Ratio, End-To-End Delay, and Throughput.

The main objective of this thesis is to analyze the performance of two routing protocols of FANETs are AOMDV (reactive) and DSDV (proactive) under the different mobility models. The performance of AOMDV and DSDV routing protocols are analyzed under the Random Waypoint, Gauss-Markov, and the proposed Chain Mobility Model. The simulation can be done by using an NS-2 simulator. The results show that AOMDV protocol performed better in terms of PDR but the DSDV performed better in End-To-End Delay when the number of nodes increases under the proposed Chain Mobility Model rather than the Random Waypoint and Gauss-Markov Mobility Model.

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List of Abbreviations

UAV	Unmanned Aerial Vehicle
WANET	Wireless Ad-hoc Network
VANET	Vehicular Ad-hoc Network
FANET	Flying Ad-hoc Network
OLSR	Optimized Link State Routing Protocol
AODV	Ad-hoc On-demand Distance Vector Routing
AOMDV	Ad-hoc On-demand Multipath Distance Vector Routing
PDR	Packet Delivery Ratio
DSDV	Destination Sequenced Distance Vector Routing Protocol
RPGM	Reference Point Group Mobility Model
DSR	Dynamic Source Routing
RWPM	Random Waypoint Mobility Model
GMM	Gauss-Markov Mobility Model

Chapter 1

Introduction

This Chapter discusses the brief introduction about the wireless network, different types of wireless network, wireless ad-hoc networks, MANETs, VANETs, and FANETs with its characteristics and the working of AOMDV and DSDV routing protocols are discussed.

1.1 Wireless Network

In Wireless networks, two or more devices communicate with each other using radio channels. It avoids the cables which are very costly to build a connection between various devices or computers. In the past, they believed that wireless networks are less secure rather than wired networks and continuously some improvements come in wireless networking standards. Also, the security and speed differences have comes in technologies [1]. Figure 1.1 shows that how the devices access the Wi-Fi connection.

Figure 1.1 Wireless Network

1.1.1 Benefits of Wireless Networks

There are various benefits for wireless networks are mentioned below:

- **Easy to move around**: In the network connectivity, it is very easy for the hardware to relocate in wireless networks. If the desired location range is out from the wireless network, the range is easily increased by using additional hardware quickly.

- **No Messy Wires**: The major benefit is not to use lots of cables to connect servers, workstations and some other devices. It reduces the network cost. The maintenance cost of wireless networks is cheaper than the wired networks because there is no need to replace or repair the cables.
- **Provide access to visitors**: It can provide free Wi-Fi access to the large number of visitors at cafes, coffee shops, and restaurants. There is no need to worry about the security. Internet access can be offered by bu1sinesses to the visiting clients and enable the more effective meetings with them.
- **Mobile Connectivity**: It provides connectivity to the devices in wireless network otherwise some devices in the wired network are unable to connect like smart phones and tablets.

Over the wired network, many benefits are offered by a wireless network like scalability and also reduces the maintenance and installation cost [2].

1.2 Types of Wireless Network

Wireless Networks are divided into two categories: Infrastructure Based and Infrastructure-less Based. Wireless Ad-hoc Networks is the type of Infrastructure-less Based Wireless Network. The below Figure 1.2 shows the hierarchy of wireless network:

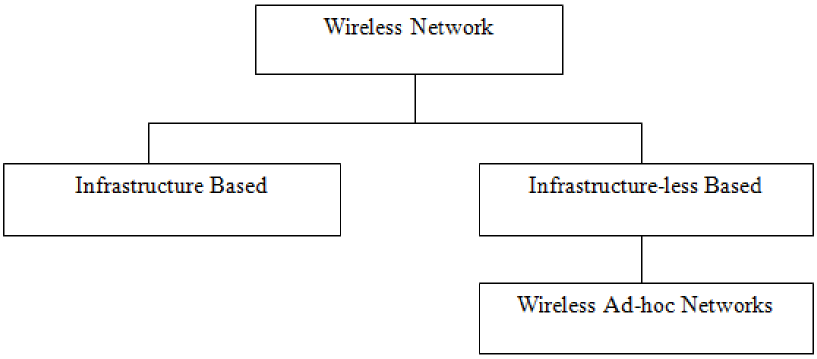


Figure 1.2 Types of Wireless Network

1.2.1 Infrastructure Based Wireless Network

In this network, there is an access point like a router or a base station. The base stations act as infrastructure which is responsible for communicating the mobile nodes. In Infrastructure mode, there is a need for at least one access point.

1.2.2 Infrastructure-less Based Wireless Network

In Infrastructure-less Wireless Network, there is no need for any infrastructure. All the moving nodes are communicating with each other through a radio signals but not use of any base stations. For example, the mobile-to-mobile communication, vehicle-to-vehicle communication, Unmanned Aerial Vehicles communications etc.

1.3 Wireless Ad-hoc Networks

In this network, there is no pre-existing infrastructure which is responsible for the communication between the devices. All the moving nodes share the information between each other without any existing infrastructure. WANET are divided into three categories: Wireless Mesh Network, Mobile Ad-hoc Network (MANET) and Wireless Sensor Network are shows in below Figure 1.3.

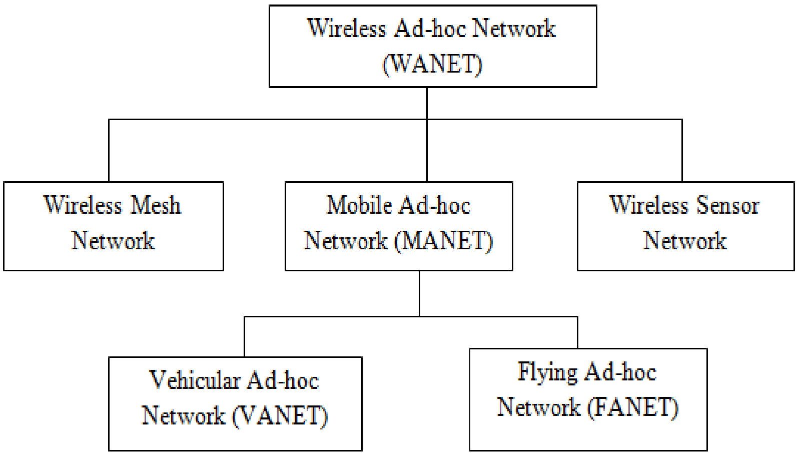


Figure 1.3 Wireless Ad-hoc Networks (WANET)

1.3.1 Wireless Mesh Network

In this network, all the nodes are arranged in a mesh structure. In this network, a topology of the network is more static because the mobility of nodes is very low. It takes lots of time to update the routes if the nodes are moved very frequently. Mesh network consists of gateways, mesh routers, and mesh clients such as cell phones, laptops etc. Mesh networks are more reliable because all nodes communicate with each other if one of them fails.

1.3.2 Wireless Sensor Network

In this network, to monitor the environmental conditions such as weather, temperature etc, various autonomous wireless sensors are available. On one sensor, there is thousands number of nodes are connected to it. There are various parts of wireless sensor network such as radio transceiver, antennas, microcontroller etc.

1.3.3 Mobile Ad-hoc Network (MANET)

A Mobile Ad-hoc Network (MANETs) is a type of ad-hoc network where each device moves freely in any direction and links are changed very frequently with other devices. Mobile ad-hoc networks where mobile nodes communicate with each other without any infrastructure. The Figure 1.4 shows the communication between the devices.

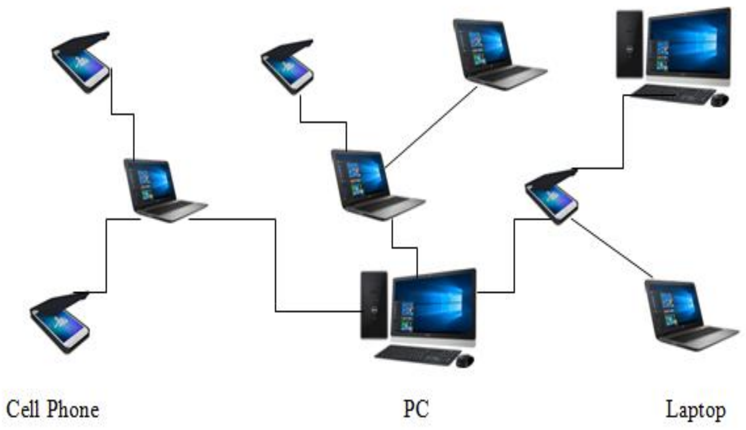


Figure 1.4 Mobile Ad-hoc Network

The most challenging issue is routing in MANETs. The existing routing protocols can be categorized into reactive and pro-active protocols in the wireless ad-hoc network. In all environments, most of the known protocols do not perform well [3]. The rapid expansion comes due to widely available wireless devices or inexpensive under the field of MANETs. In MANETs, an autonomous collection of smart phones, sensors, laptops sharing the information between the nodes under wireless links and in the absence of fixed infrastructure, it provides necessary network functionality [4]. MANETs are the super class of VANETs and FANETs. In VANETs, the vehicles communicate with each other and in FANETs, the Unmanned Aerial Vehicles (UAV) communicating with each other. The main two types of MANETs are VANETs and FANETs. The characteristics of MANETs are described below:

- Dynamic topology: In MANET, the nodes move randomly which make network topology dynamic in nature.
- Distributed operation: In MANET, the network is controlled by all the distributed nodes as there is no one network that control the network operation.
- Multi hop routing: When a source node sends data to the node out of radio range, then the message is send through other nodes.
- Autonomous behavior: In MANET, the mobile nodes can behave as a host and in addition a router.

1.3.3.1 VANETs

VANETs are the type of mobile ad-hoc network they formed a wireless communication between the vehicle-to-vehicle, vehicle-to-infrastructure, and infrastructure-to-infrastructure by using the IEEE standard 802.11p. Many people are killed during the accidents. So the safety is most important when we design a routing protocol. Through a wireless connection, all the mobile nodes share the information between each other having some properties like rapid changing topology, variable network density, predictable mobility and high computational ability. V2I share the information between the nodes which act as vehicles and the roadside units (RSUs) to avoid the vehicle collisions. In Vehicle-to-Vehicle (V2V), through a radio communication range two or more vehicles communicate with each other in the ad-hoc wireless network [5]. Figure 1.5 shows the communication between the vehicles to vehicles, and vehicles to infrastructure, and infrastructure to infrastructure. The various characteristics of VANETs over the MANETs are described below:

- High mobility: In VANET, the nodes move at high speed in a network as compared to nodes in MANET.
- Unbounded network size: VANET can be formed for a city, many cities or a country which make VANET geographically unbounded.
- Communication environment: In VANET, the communication between vehicles is done for both city and highway scenarios.

- Mobility pattern: The nature of mobile nodes is affected by traffic, construction of roads, location and moving speed of vehicle and driving nature of driver.
- Frequent disconnection: As the topology changes dynamically in VANET, the vehicles are disconnected frequently.

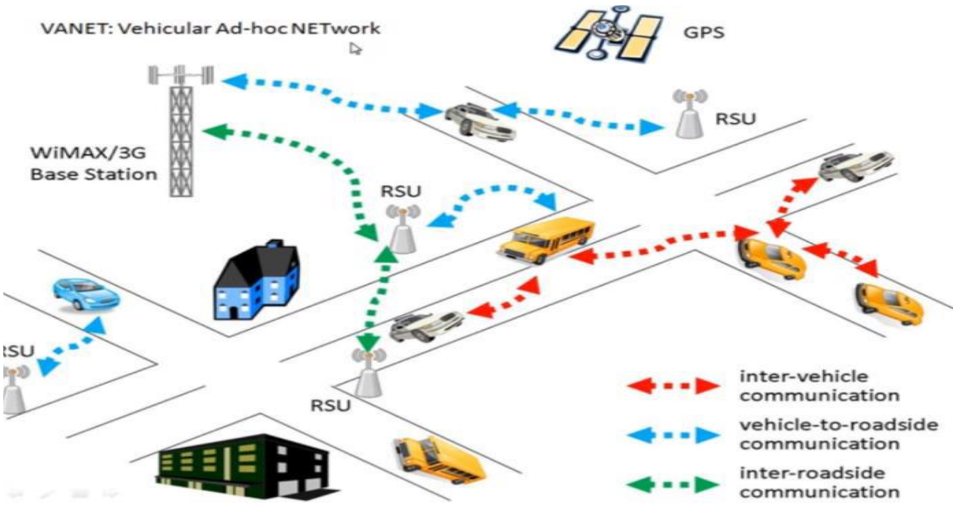


Figure 1.5 Vehicular Ad-hoc Network (VANETs) [5]

1.3.3.2 Flying Ad-hoc Networks (FANETs)

FANETs are the subtype of MANETs where the Unmanned Aerial Vehicles (UAV) communicates with each other for sharing the information. There are two types of communication in FANETs: UAV-to-Infrastructure and UAV-to-UAV. In the Infrastructure based network or UAV-to-Infrastructure, all the Unmanned Aerial Vehicles are connected to the satellite or a ground base station directly. The below Figure 1.6 shows the communication between the UAVs and also the communication between base station and UAV:

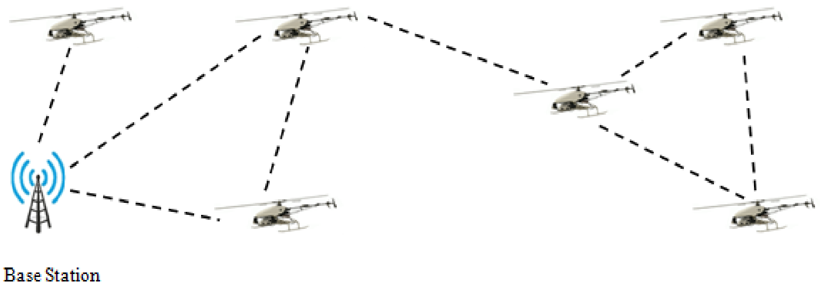


Figure 1.6 Flying Ad-hoc Network

If the UAVs are connected with each other without any need of infrastructure are called as Infrastructure-less Networks or UAV-to-UAV communication. Flying ad-hoc networks work in three dimensions such as x-axis, y-axis, and z-axis. The topology of flying ad-hoc networks are changing very frequently than the MANETs and the VANETs because the speed is very fast. There are various routing protocols are available to analyze the performance.

There are various advantages of having multi-UAV system are described as follow:

- Cost: The cost of small UAV is very less rather than the large UAV and also the cost to maintain the small UAVs is less.
- Scalability: By using multiple UAVs the scalability of the operation is extended compared to one large UAV.
- Speed: Using multiple number of UAVs complete the mission fast as compared to single UAV.
- Survivability: Only one UAV does not proceed to complete the mission if it fails but in case of multiple UAVs, the mission will be extended by the using of other UAVs.

1.3.3.2.1 Applications of FANETs

The advantages of FANET like more flexibility, less operating cost makes it useful for various applications described as follow:

- Disaster monitoring: FANET is used in transferring the data collected from the disaster-affected area to the base station for monitoring.
- Wind estimation: Unmanned Aerial Vehicles are used to estimate the speed and direction of the wind.
- Border surveillance: Unmanned Aerial Vehicles are equipped with cameras at border areas for detecting, tracking and recognizing unauthorized intruders.
- Managing wildfire: Unmanned Aerial Vehicles captures the images of the burned area and forward this information to the base station.
- Search and Rescue operations: Unmanned Aerial Vehicles has the ability to carry resources for search and rescue operation.

1.4 Comparison between the MANET, VANET, and FANET:

The Table 1.1 shows the comparison of these three wireless ad-hoc networks.

Table 1.1Comparison among MANET, VANET, and FANET [6]:

Ad-hoc Network Types / **Parameters**	**MANET**	**VANET**	**FANET**
Node Mobility	Low Compactness	Medium Compactness	High Compactness
Mobility Model	Random	Regular	Regular for predetermined paths
Node Density	Low	Very High	Very low
Topology Change	Slow	Fast	Fast
Radio Propagation Model	Close to ground	Close to ground	High above the ground
Power Consumption	Energy efficient Protocols	Not needed	Energy efficiency for mini UAVs, but not needed for small UAVs
Computational Power	Limited	High	High
Localization	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU

1.5 Routing Protocols

Routing protocols defined a route for sending the data packets from the source to the destination. The main aim of routing is to optimize the path where packets delay is very less and more packet delivery ratio. The two routing protocols are describes below:

1.5.1 Working of Ad-hoc On-Demand Multipath Distance Vector Routing Protocol (AOMDV)

AOMDV is the improvement of AODV routing protocol used to calculate multiple link-disjoint and loop-free paths. AOMDV uses the route construction process of basic AODV routing protocol. For each destination node, they hold a routing table having a routing entry includes the list of next hopes with its related number of hopes. Every next hope contains the same sequence number for keeping the track of routes. “Advertised hop count” maintained by destination node which called as maximum hop count for all the possible routes. The advantage of AOMDV routing protocol is permitted to answer to route request (RREQs) by intermediate nodes during the selection of disjoint paths. The more message overhead comes because of the selection of multiple paths and the destination node has to reply to the multiple route requests (RREQs) [7].

1.5.2 Working of Destination Sequenced Distance Vector Routing Protocol (DSDV)

DSDV protocol is a Table-Driven Routing protocol. The Bellman-Ford algorithm is used in the DSDV protocol and also it is the modified version of Distance Vector Routing. Each node having a routing table that contains the information of the possible destination nodes and hop count to each destination within the ad-hoc wireless network. Initially, the routing table is empty at each node. Periodically, a node sends its routing table to the neighboring nodes. The node calculates the shortest distance and updates the value in the routing table. The limitation of DSDV protocol are count goes to infinity. All the issues of Distance Vector are solved by DSDV. The two different parameters are added in DSDV <Sequence no, Damping> where Sequence no was added to avoid looping and to avoid unnecessary updates Damping is used. The updates of this routing protocol are performed in two ways:

- Periodic Updates: After every 15 sec periodic updates are sent. The whole table is broadcast from each node.
- Trigger Updates: In between the periodic updates, the updates are sent when an update is received by any node [11].

1.6 Organization of Thesis

The rest of the structure of this thesis is:

Chapter 2 describes the types of routing protocols and the mobility models in FANETs and also discusses the review work on the routing protocols and mobility models.

Chapter 3 divided into four sections. In the first section, the research gaps are explained. In the second section, the problem statement is defined. Third section presents the objectives of this research and the last section briefs in present work.

Chapter 4 discuss about the proposed model.

Chapter 5 discuss about the implementation work of thesis and discuss about the NS-2 simulator, installation steps of NS-2, trace file, and AWK file and brief introduction about the Bonnmotion tool and also describe how to generate a mobility model scenario helps us to create a test bed for the proposed model.

Chapter 6 shows the results of one reactive protocol AOMDV and one proactive protocol DSDV under the different mobility models and the proposed chain model. The routing protocols performance is measured under the two different mobility models and one proposed chain model.

Chapter 7 discuss the conclusion of the proposed chain mobility model and also discuss the limitations of research. The future scope of the proposed model was also discussed.

1.7 Summary

This chapter gave the overview of the wireless ad-hoc network and the types of ad-hoc networks and also discussed about the mobile ad-hoc network, vehicular ad-hoc networks, and flying ad-hoc network with its characteristics. The comparison of MANETs, VANETs, and FANETs are shown in table for clearly differentiate between the three wireless ad-hoc networks. The working of AOMDV and DSDV protocols are also explained. The organization of the thesis gave the overall structure of the thesis.

Chapter 2

Literature Survey

This chapter describes the types of routing protocols and the mobility models in FANETs and also discusses the review work on the routing protocols and mobility models.

2.1 Routing Protocols in FANETs

The mechanism is to establish and select a specific path for data sending from source to destination, there is a need for various protocols of routing. So the various protocols are available for the wireless ad-hoc network. The classification of routing protocols is divided into five categories i.e. Topology based, Position based, Cluster based, Geo-cast based, Broad-cast based protocols. The hierarchy of routing protocols shown below in Figure 2.1:

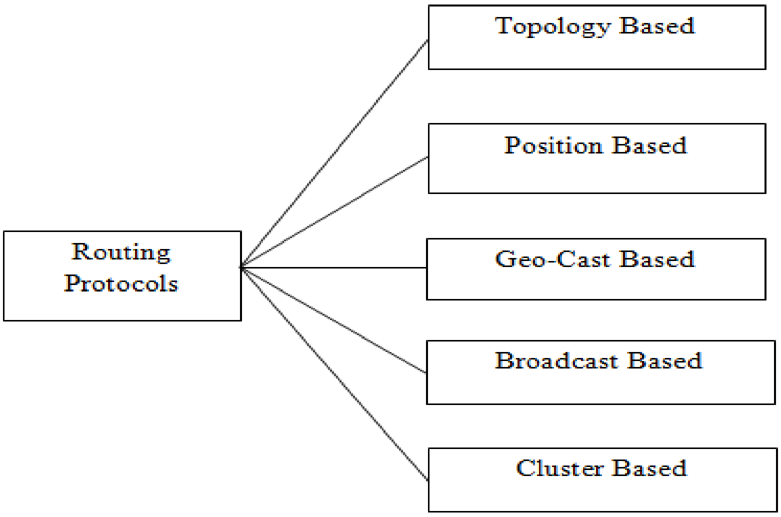


Figure 2.1 Flowchart of Routing Protocols

2.1.1 Topology-Based

In this routing, the links data is used to sending the data from one node to another node within a network. Data packets are forwarded by using the information of the links. The two types of topology-based routing protocols are Reactive based and Proactive based routing protocols.

2.1.1.1 Reactive Based Routing

Reactive based routing is the On-Demand routing protocols. In reactive routing, when the node wants to share the data with another node all the routes are open. This routing protocol maintains only those paths which are presently used. The results of reactive routing, the burden of the network is reduced. Reactive routing protocols having a route discovery phase where they flooded the query packets into the network for searching the path and when the route is found, this phase was completed [9]. The examples of reactive protocols are AODV, AOMDV, DSR, and TORA.

2.1.1.2 Proactive Based Routing

Proactive based routing protocols are the Table-Driven based routing protocols. In the proactive, the information at every node has maintained in the table and also the table share with another node for sending the information from one point to the other point. The information in the table is consistent and up-to-date on the routing is stored at every point. The different types of proactive routing protocols are DSDV, OLSR, and FSR.

2.1.2 Position Based Routing

The data for vehicles is the position which is very important for vehicles. All the vehicles want to know its neighbor vehicle’s position as well as its own vehicle position. The position of vehicles may be gathered from the GPS (Geographical Position System). The routing protocol which uses the information of position called as a position-based routing protocol. The position of the vehicles can be obtained when the vehicles transmitted beacons or control messages directly to the neighbors. Through a location service, the sender can request for the position of the receiver. When the route is traced there is no overhead comes because the protocols are not used the routing tables.

The route is composed of the source to the destination vehicle by the communication links between the several pairs of vehicles are connected with each other. We find the position of the vehicle in the future by predicting links between the two vehicles if we know the position of the current vehicle [10]. There position based protocol like GPSR etc.

2.1.3 Geo Cast Based

This routing protocol called as geographic based protocols. The main purpose when one vehicle share the data to the other vehicle within a geographic region i.e. ZOR. The nodes called as vehicles which do not come under the geographical region, the information is not provided to that node by the geo-cast routing protocols. A forwarding zone which was defined by a geo-cast routing protocol is to overcome the overhead of messages and congestion in the network which is simply created by the flooding of packets everywhere. The different routing protocols are Inter-Vehicle Geo-Cast Routing (IVG), Robust Vehicular Routing (ROVER). The disadvantage of geo-cast based routing is contention, high latency period, and collision problems. The advantage of the geo-cast routing is to reduce the overhead problem of data packets during the transmission.

2.1.4 Broadcast-Based Routing

Broadcast routing protocols called as flooded based routing protocols for sharing information between the vehicles. When the event or accident occurs, they transmit the data to the possible maximum number of nodes. The reason to use the broadcast based protocols for analyze the weather conditions, information about the traffic on the roads, road conditions, emergency conditions, announcements, and delivering advertisements. Almost in all the safety applications, broadcast-based protocols play a big role. Within the range, the data is broadcast to all the mobile nodes with the use of multi-hop transmission. For the broadcast applications, the conventional protocols like DSR and AODV are not appropriate for VANETs. The disadvantages of the broadcast routing protocols are the big chances of collision of transmitted messages and hidden node problem. The broadcast routing protocols are Distributed Vehicular Broadcast Protocol (DV-CAST), BROADCOMM.

2.1.5 Cluster Based Routing

Cluster based routing protocols create clusters between the vehicles. The group of vehicles which are having a same intension called as cluster. In the cluster, there is a one cluster head which is responsible for giving the information to all the nodes within the cluster. The head of the cluster is responsible for the communication of inter and intra-clusters. There is a direct link between the vehicles to communicate within a cluster and for the communication between the inter cluster, that is possible through a designated cluster heads. The data packets are broadcast to all the vehicles within the cluster by a cluster-head. The result of cluster-based routing protocols is, it improves the scalability when the no of nodes is very large. The different cluster-based protocols are CBDRP, CBLR.

K. Singh and A. K. Verma [11] experimented on the performance of AODV, DSDV, and OLSR protocols for the different parameters named as PDR, Throughput, and E-To-E delay at the different speeds of the node in flying ad-hoc networks. The results show that OLSR protocol performed better in all the parameters than the AODV and DSDV.

M. A. Mahdi and T. Wan [12] discussed the performance of single-path and multi-path routing protocols CBRP, AODV, and AOMDV for the sparse and dense network. The authors analyzed that the AOMDV performed better in terms of delay rather than the CBRP and AODV for both dense and sparse networks but in PDR, AODV performed better than the CBRP and AOMDV in sparse topology.

T. K. Araghi et al. [13] experimented on the performance of reactive based protocols in terms of PDR, E-To-E Delay, and throughput. The authors observed that if the total number of nodes is 20 in the network, then PDR and Throughput of DSR and AOMDV performed better rather than the AODV and the E-To-E delay is also very less in AOMDV than the AODV and DSR.

S. K. Nalam et al. [14] experimented on the behavior of three protocols AOMDV, DSR, and OLSR using UDP agents. Authors determined the routing protocol which performed better in PDR, E-To-E Delay, Throughput, packet loss, and energy consumption. According to the results, OLSR shows better results in all the parameters. AOMDV shows better results in PDR and Throughput rather than DSR.

2.2 Mobility models in FANETs

Mobility Models represents the scenario of nodes mobility and provides the information about the velocity, acceleration, and location that can change according to time. Mobility models generate a simulation environment in realistic. There are various mobility models available for the wireless network. With the help of mobility models, we can analyze the routing protocols performance. They also compared the different well-known ad-hoc routing protocols under the Mobility Models. The four different types of Mobility Models which mainly exist in FANETs are shown below in Figure 2.2 [15]:

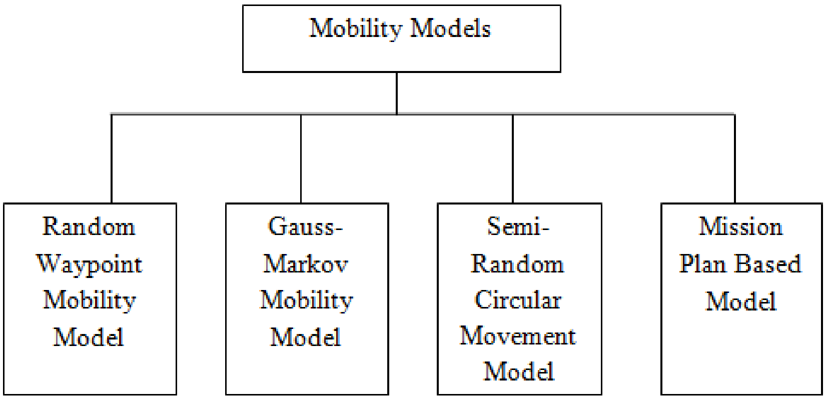


Figure 2.2 Mobility Models

2.2.1 Random Waypoint Mobility Model

In Random Waypoint, every node selects the destination point randomly and moving toward it with random velocity chosen from the range of [0-Vmax] shown in below Figure 2.3.

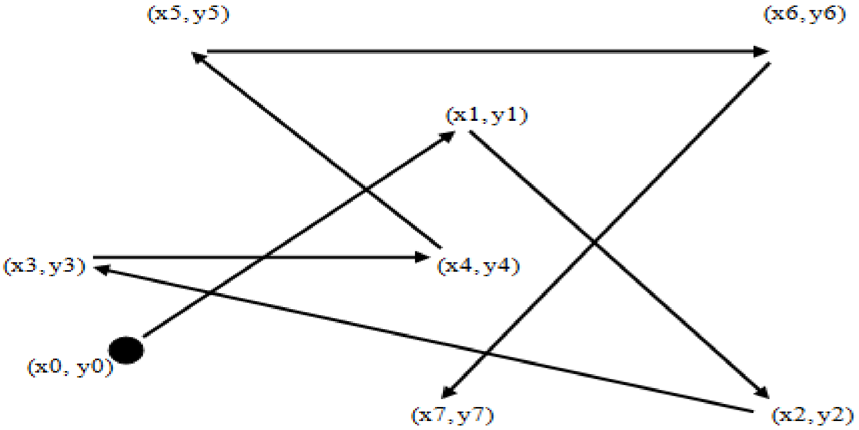


Figure 2.3 Random Waypoint model [31]

If goal achieved, for some interval of time node stops and that interval is defined by the parameter named as “pause time”. After this interval of time, the node chooses the destination point randomly again. The entire procedure repeats again till the whole simulation time gets over [16].

K. Singh and A. K. Verma [17] discussed the effect of different mobility models on the OLSR routing protocol performance in FANETs. The Mobility Models like Pursue, Random Waypoint Mobility Model, RPGM, and Manhattan Grid Mobility Model are used for the analysis. Authors analyzed the performance on different parameters named as PDR, Average Throughput, and E-To-E delay at the different nodes speed. The authors conclude that performance is varied according to the mobility models and the speed of node. OLSR performed better results under the Pursue as compared to the Random Waypoint, RPGM, and Manhattan Grid Mobility Model for FANETs.

B. Singh et al. [18] analyzed the MANETs AOMDV routing protocol performance under different mobility models such as Random Waypoint, RPGM, Column, Manhattan, Pursue, and Nomadic in terms of PDR, E-To-E delay, and Throughput. The results of AOMDV compared with the AODV routing protocol. The authors proved that AOMDV protocol performed better under all the mobility models rather than the AODV routing protocol.

B. Divecha et al. [19] compared the effect of different mobility models on one reactive DSR and one proactive DSDV routing protocols performance in flying ad-hoc networks. Authors used four different mobility models such as Freeway, Random Waypoint, Manhattan, and Group Mobility Model. The authors analyzed that the performance of protocols varies according to node density, Mobility Models, and data paths length. The results show that DSR performed better when the mobility of nodes is very high rather than DSDV. The new route was discovered faster when the old route was broken in DSR but in DSDV, a mechanism for route repair is not available.

P. Sharma and I. Yadav [20] proposed an improved RGR routing protocol which is geographical routing protocol and analyzed the impact on existing RGR protocol in flying ad-hoc network. After the authors analyzed the performance of improved RGR protocol under Random Waypoint for different QoS parameter values such as PDR, Throughput, and E-To-E delay. The results proved that the new enhancements in the RGR protocol gave less overhead and higher PDR rather than the original AODV and the RGR protocol.

A. Aggarwal et al. [21] discussed the three protocols AODV, DSR, and DSDV performance in MANETs for Random Waypoint. The performance analysis parameters are the average delay, Throughput, PDF, and NRL. The authors analyzed the performance under three different densities of nodes such as low, medium, and high. The results proved that AODV performs better rather than the DSR and DSDV.

G. Jayakumar and G. Ganapathi [22] analyzed the two reactive routing protocols DSR and AODV performance under the two mobility models Random Waypoint and RPGM Model. The performance was analyzed for different QoS parameters such as PDR, NRL, Normalized MAC load, Average Delay by varying the different node densities, network loading and the variations in mobility for the two different mobility models. Authors observed that the high throughput and least overhead comes in AODV and DSR when compared with RPGP Mobility Model.

M. Amnai et al. [23] discussed the impact of different densities of nodes and mobility models on different QoS parameters such as PDR, Delay, and Throughput. Authors compared the performance of OLSR protocol on two different scenarios one is real-time VBR and another is CBR Traffic. Random Waypoint, Mobgen steady state, and Random Direction Mobility models are considered for the evaluation of OLSR protocol. The results proved that according to change of the traffic and the mobility model, performance of OLSR routing protocol changes.

D. Singh et al. [24] discussed the performance of four well-known MANET routing protocols such as LANMAR, DYMO, LAR1, and ZRP under the Random Waypoint Mobility Model. The metrics named as average jitter, PDR, average E-To-E delay, and throughput used for the analysis. The authors proved that LANMAR performed better in average E-To-E delay and average jitter but in PDR and throughput LAR1 gave better results. DYMO and ZRP both show worst results in average jitter and PDR respectively.

2.2.2 Gauss-Markov Mobility Model

Gauss-Markov Model is used to simulate the behavior of Unmanned Aerial Vehicle and the simulated area size is variable. In this model, every node is pre-defined by direction and speed. At fixed interval of time, movement occurs by updating the direction and speed of every node. The value of direction and speed at the nth point of time is calculated by the value of direction and speed of the previous point i.e. n-1th.

The below Figure 2.4 shows the movement of the node according to the previous node position [15]:

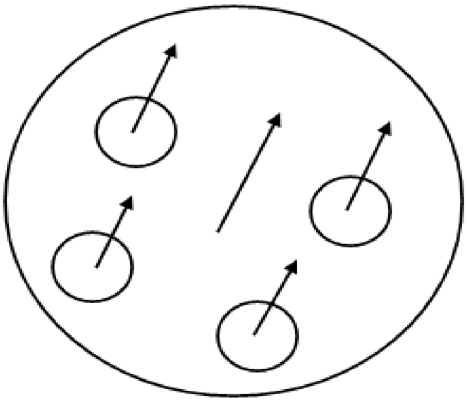


Figure 2.4 Gauss-Markov Mobility Model [15]

M. Alenazi and C. Sahin [25] proposed some enhancements in the existing ns-3 implementation of 3-D Gauss-Markov Model. The authors followed the approach that all the mobile nodes are moving at the center of the simulation area with some random angle. The new implementation proved that the nodes which are mobile are moving smoothly within the simulation boundaries area and there is no bounce off.

A. Jain et al. [26] discussed the TAODV routing protocol which is trust based protocol. TAODV protocol used to modify the black hole attacks in the MANETs. The performance is analyzed under the Gauss-Markov Model for three different traffic scenarios such as Pareto, Exponential, and CBR. The authors analyzed that for the PDR and Throughput Gauss-Markov and Random Waypoint Model gives better results.

B. S. Gouda et al. [27] proposed a new reactive protocol ORSRP which gives an optimal route for sending the data packets to the destination and gives lower overhead in communication. It is based on the route discovery approach. ORSRP is based on the reactive routing which calculates an RREQ, RREP, RCAC, and RRER in reverse route for find the best optimal path. The authors show that the proposed protocol performed better results rather than the existing routing protocols in MANETs in terms of Packet loss, packet delivery percentage, routing packet overhead, Throughput, and average E-to-E delay under the Gauss-Markov Mobility Model.

D. Chenghao [28] proposed enhancements in the existing reactive protocol DSR for the improvements of the link between nodes. The authors proposed a Gauss-Markov to reduce the random movements of the nodes. The improved protocol may increase the number of hops rather than the original DSR protocol having minimum no of hopes in data transmission which makes a more stable network. The authors analyzed that the improved DSR routing protocol gives better results rather than the original DSR protocols in PDR, received throughput, average E-To-E delay, and average jitter.

S. LAQTIB et al. [29] evaluated the different mobility models effect on the OLSR routing protocol performance. The different mobility models named as Random Waypoint, Random Walk, Random Direction, and Gauss-Markov Mobility Models are used for analysis. The results show that Random Waypoint performed well in the parameters of QoS like PDR, E-To-E delay, and Throughput when the number of nodes varies.

A. Macintosh et al. [30] discussed the effect of speed on the performance of position based protocol under the mobility model. The OPNET simulator is used for simulation. The authors proposed a different protocol in the Internet Engineering Task Force (IETF). The proposed protocols are evaluated under the various mobility models. The position based protocols GPSR, GRP, and LANDY are analyzed in terms of PDR, Routing Overhead, and throughput at the different speed of nodes. In another case, authors compared the four mobility models named as Random Waypoint, Gauss-Markov, Manhattan, and RPGM at the different node speeds. The authors show that the performance of protocols varies according to the mobility models.

Dr. K. Sumathi et al. [31] analyzed the performance of QSEAAR protocol under the various mobility models in MANETs. Authors conclude that only Random Waypoint model is not sufficient for the analysis of QSEAAR protocol. The Random Waypoint, Manhattan Grid, RPGM, and Gauss-Markov Mobility Model used to analyze the performance of QOS based stable energy aware ad-hoc routing protocol (QSEAAR) in terms of PDF and average delay. The authors conclude that protocols performance varies according to different mobility model.

A. M. Qureshi and B. M. Khan [32] analyzed the routing performance of protocols for the different mobility models. Authors got the overall network throughput by varying the speed of nodes. The authors gave a better routing protocol on the basis of throughput of different routing protocols. The simulation can be done in ns-3 simulator which is more suitable to optimize the parameter values without any overhead. The authors conclude that AODV performed much better than the OLSR and DSDV routing protocol. OLSR performed better in Random Waypoint Mobility Model and the Gauss-Markov Mobility Model when node speed is very less.

S. Singla and S. Jain [33] compared the performance of AODV, OLSR, and DSDV protocols under the Gauss-Markov Mobility Models in real world scenarios. The authors conclude that OLSR performed well in PDR rather than the AODV. OLSR also performed better in average delay and throughput rather than DSDV.

2.2.3 Semi-Random Circular Movement Model

Semi-Random Circular Mobility Model is applicable for gathering some information by turning around a specific position for simulating UAV's and this model is designed for the curved movement scenarios. In this model, the route is hexagon rather than Random Waypoint Mobility Model where the plan of flight is not predetermined. In this model, aircraft are placed at different locations wherein a square area it selects the desired object as shown in the below Figure 2.5 [15]:

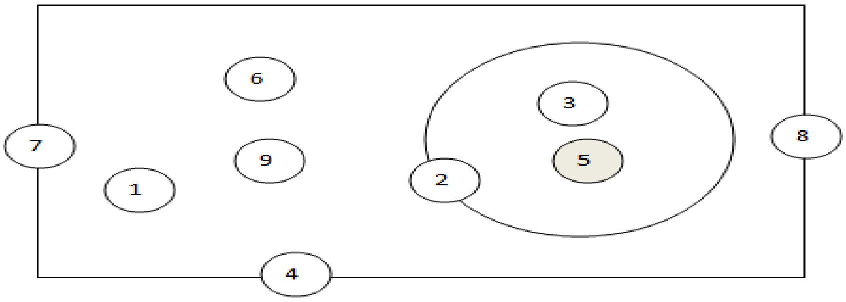


Figure 2.5 Semi-Random Circular Mobility Model [15]

2.2.4 Mission Plan Based Model

In Mission Plan Based Model, the whole information of trajectory already knows by the aircraft which are planned in advance. This means that on the predefined path all the aircraft travel along with them consistently. This MPB Model creates a mobility files which is updated after some period of time. In mission plan based model, the starting and the ending points are selected randomly for each aircraft and they move towards or away from the destination. The flight time and the velocity of flight are given. Each aircraft changes its direction to the starting point when they reach the destination point before when flight time is over. Below Figure 2.6 shows that the aircraft reaches the mission area and the information of location is available [15].

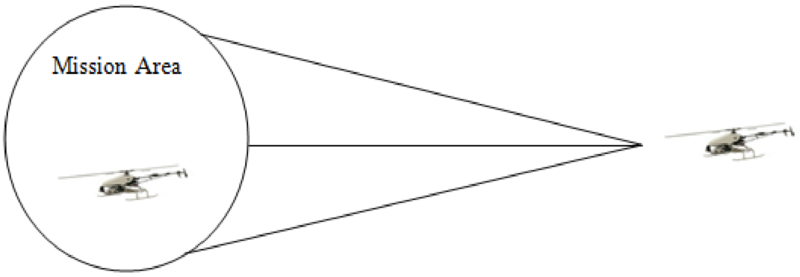


Figure 2.6 Mission Plan Based Mobility Model [15]

2.3 Chain Model

Chain model is basically a concatenation of various mobility models (Random Waypoint, Reference Point Group Mobility model, Manhattan Grid, Gauss-Markov). In this model, the position of the first node in the n-1th scenario is connected with the first position of nth scenario. Chain model is used to model a real scenario. The chain model is used by various research fellows as discussed below:

A. Bhasin and D. Kumar [34] compared the performance of DSR and AODV reactive routing protocols using chain mobility model. The simulation is done with NS-2 simulator using throughput, packet delivery ratio and end-to-end delay performance parameters. AODV and DSR give equal throughput using chaintest random and chain campus model. In chaintest random model, DSR protocol results in more end to end delay as compared to AODV. AODV give steady packet delivery ratio using chain campus model and packet delivery ratio of DSR is reduced with varying number of nodes.

A. K. Shukla and C.K.Jha [35] compared chain mobility model (Random Waypoint and Manhattan Grid) with Random Waypoint model. The different performance parameters like throughput, end to end delay and packet delivery ratio are evaluated for DSR routing protocol. The simulation is done using NS-2 simulator for varying number of nodes. The results show that chain model gives better performance compared to Random Waypoint mobility model.

Y. Huan et al. [36] compared the performance of Random Waypoint, Reference point group mobility model, Manhattan and Freeway mobility models in a sparse network. From the results, it is concluded that these four mobility models are not relevant for sparse ad hoc network. The authors proposed a chain mobility model for efficient communication between nodes in sparse Ad hoc network. The simulation results show that chain model gives better performance for the sparse network.

2.4 Summary

This chapter properly discussed the different types of routing protocols and also gave a quick summary on the working of routing protocols. The different mobility models of FANETs are also discussed. The review work concludes that the protocol OLSR performed better in all the parameters of quality of service. The authors also concluded that AOMDV performed better in PDR and throughput rather than the AODV when the different protocols are compared. The performance of protocols also analyzed under the different mobility models individually. The authors also analyzed the performance of protocols on the chain mobility models.

Chapter 3

Problem Statement and Objective

This chapter is divided into four sections. In the first section, the research gaps are explained. In the second section, the problem statement is defined. Third section presents the objectives of this research and the last section briefs in present work.

3.1 Research Gaps

The list of research gaps which are identified during the survey of the FANETs are:

i. In wireless ad-hoc networks, the chain mobility model is mainly formed by integrating Random waypoint model and Manhattan Grid mobility model [34, 35]. The other existing mobility models are not considered for integration for the said purpose.

ii. In FANETs, the QoS performance parameters are mostly evaluated by using Random waypoint model [19, 21] and Gauss-Markov mobility model [23, 24] for routing protocols. In FANETs, the chain mobility model is not used for evaluating parameters.

3.2 Problem Statement

The different challenges have been identified and addressed in flying ad-hoc networks. The major problem in FANETs is routing. The appropriate routing is achieved only when the routing protocols satisfy the quality of service parameters. Only the routing is not important but the mobility pattern of nodes in FANETs are also important as the mobility models enhance the performance of routing protocols. The performance of AOMDV (reactive based) and DSDV (proactive based) protocols under the different mobility models and the proposed chain model to be evaluated for FANETs.

3.3 Objective

The objectives of this thesis are discussed below:

1. To study the flying ad-hoc networks and the different routing protocols for wireless ad-hoc network.
2. To study the existing mobility models for FANETs.
3. To simulate selected routing protocol under the different mobility models and proposed chain mobility model for FANETs.
4. To compare and validate proposed model for performance of QoS parameters PDR, End-To-End Delay, and throughput with the existing selected mobility models performance.

3.4 Methodology

The purpose of this research is to improve and compare the performance of routing protocols in terms of different quality of service parameters at different no of nodes under the different models of mobility. The goal is achieved by using the proposed mobility model which is explained in the next chapter. The methodology of this research work is shown below in Figure 3.1 and the steps are explained here:

1. Firstly, simulation environment has been set up for AOMDV and DSDV protocols in NS-2 using TCL script.
2. The mobility scenarios of Random Waypoint model, Gauss Markov model and are generated in Bonnmotion tool.
3. In the proposed work, create a chain of RWPM and GMM. In FANET, at starting the movement of UAVs will be modeled according to Random Waypoint model and when the UAVs are near their destination, the movement is modeled by Gauss-Markov model.
4. The mobility scenario files are simulated on the NS-2 simulator. This network simulator generates trace file and the network animator (NAM) file. Then creates AWK script to read the trace files and get the values of quality of service parameter such as packet delivery ratio, end-to-end delay, and throughput.
5. To view the topology of the network, network animator (NAM) file is used.
6. Then creates a graph of obtained values to analyze the performance of AOMDV and DSDV protocols.

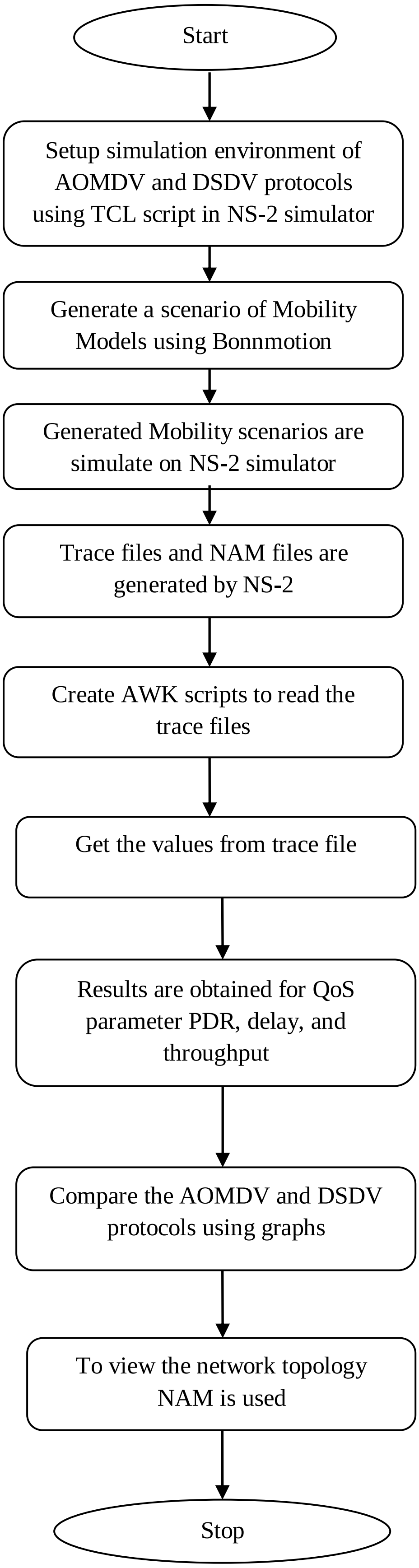


Figure 3.1 Flowchart of Methodology

3.5 Summary

This chapter concludes the different major routing problems which are faced in the FANETs. The major concern in the routing protocols is to satisfying the parameters of quality of service for the improvement of performance. The mobility model improves the performance of routing protocols. The chain of Random Waypoint and Gauss-Markov mobility models are proposed in this thesis and we analyzed the AOMDV and DSDV protocols under the proposed model and compare with existing mobility models performance.

Chapter 4

Proposed Model

This chapter discuss about the components of proposed chain model, Random Waypoint model, Gauss-Markov model with their algorithms.

4.1 Components of Proposed Chain mobility model

The chain mobility model is the combination of RWPM and GMM is proposed in this thesis work. In FANET, at starting the movement of UAVs will be modeled according to RWPM and when the UAVs are near their destination, the movement is modeled by Gauss-Markov model. In the review work, the RWPM [17, 18] and GMM [25, 26] are mainly used in the existing research. The algorithms of Random Waypoint and Gauss-Markov are explained below:

4.1.1 Random Waypoint Model

In Random Waypoint, every node selects the destination point randomly and moving toward it with random velocity chosen from the range of [0-Vmax]. When the goal is achieved, for some interval of time node stops and that interval is defined by the parameter named as “pause time”. After this interval of time, the node chooses the destination point randomly again. The entire procedure repeats again till the whole simulation time gets over. The algorithm of Random Waypoint model [39] is explained below:

Algorithm for Random Waypoint Model

Step 1: Define the parameters i denoting the movement duration of node and j which identifies the particular node.

Step 2: The random waypoint for each node is represented as vector ${P_i}^{(j)}$

Step 3: The movement trace of a node in Random waypoint model is as given below:

$$\left\{{P_i}^{(j)}\right\}_{i\epsilon N_0} = {P_0}^{(j)}, {P_1}^{(j)}, {P_2}^{(j)}, {P_3}^{(j)}, \ldots\ldots\ldots\ldots \text{ [39]} \tag{4.1}$$

Step 4: If the node chooses random speed V_i from P_{i-1} to P_i and choose pause time $T_{p,i}$ at P_i. The complete movement of node is as given below:

$$\{(P_i\,, V_i\,, T_{p,i})\}_{i\epsilon\,N} = (P_1\,, V_1, T_{p,1})\,, (P_2\,, V_2, T_{p,2})\,, (P_3\,, V_3, T_{p,3})\,, \ldots. \quad [39]\ (4.2)$$

4.1.2 Gauss-Markov Model

In this model, every node is pre-defined by direction and speed. At fixed interval of time, movement occurs by updating the direction and speed of every node. The value of direction and speed at the nth point of time is calculated by the value of direction and speed of the previous point i.e. n-1th. The algorithm of Gauss-Markov model [26] is explained below.

Algorithm for Gauss-Markov Model

Assumptions:
// all the nodes are located at the random locations
// S_n is node new speed and D_n is node new direction at time of interval (t).
//$\bar{S}$ is mean speed and $\bar{D}$ is mean direction.
// α is the degree of randomness lies between (0 < α <1). $\alpha = 0$ is for linear motions and α=1 for random values.
//$S_{x_{t-1}}$and $D_{x_{t-1}}$ are the random Gaussian distribution with mean=0 and standard deviation is 1.

Step 1: Assign a current speed and current direction for the movement to the each node.

Step 2: At the constant interval of time, the speed and direction is to update for the movement of nodes.

Step 3: The direction and speed are calculated from the previous direction and speed for a period of time (t):

$$S_t \;=\; \alpha s_{t-1} + (1-\;\alpha)\bar{S} + \sqrt{(1-\alpha^2)S_{x_{t-1}}} \qquad [26] \qquad (4.3)$$

$$D_n \;=\; \alpha d_{t-1} + (1-\;\alpha)\bar{D} + \sqrt{(1-\alpha^2)D_{x_{t-1}}} \qquad [26] \qquad (4.4)$$

Step 4: The next location is calculated from the current speed and direction at each interval of time (t):

$$X_t = X_{t-1} + S_{t-1} \cos D_{t-1} \qquad [26] \tag{4.5}$$

$$Y_t = Y_{t-1} + S_{t-1} \sin D_{t-1} \qquad [26] \tag{4.6}$$

Where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the coordinates of node position of X and Y respectively at time interval t and (t-1). S_{t-1} and D_{t-1} are speed and direction of node.

4.2 Proposed Chain Mobility Models

The chain model is formed by connecting final position of n-1th scenario with first position of nth scenario. The proposed chain model is formed by combining the RWPM and GMM in a chain. The algorithm of proposed model is explained below:

Algorithm for Proposed Chain Model

```
Assumptions:
// where $n_1$ and $n_2$ is number of nodes for Random Waypoint and Gauss-Markov respectively.
// $d_1$ and $d_2$ is the simulation duration for Random Waypoint and Gauss-Markov respectively.
// x, y, and z are the coordinates.
Step 1: Create a scenario of Random Waypoint model by initializing values to the $n_1$, x, y, z, and $d_1$.
Step 2: Create a scenario of Gauss-Markov model by initializing values to the $n_2$, x, y, z, and $d_2$.
Step 3: If $n_1 = = n_2$
                Chain scenario generated
        Else
                Chain scenario fails
Step 4: Exit
```

The proposed algorithm of chain mobility model is represented with the help of Flow Chart as shown below in Figure 4.1:

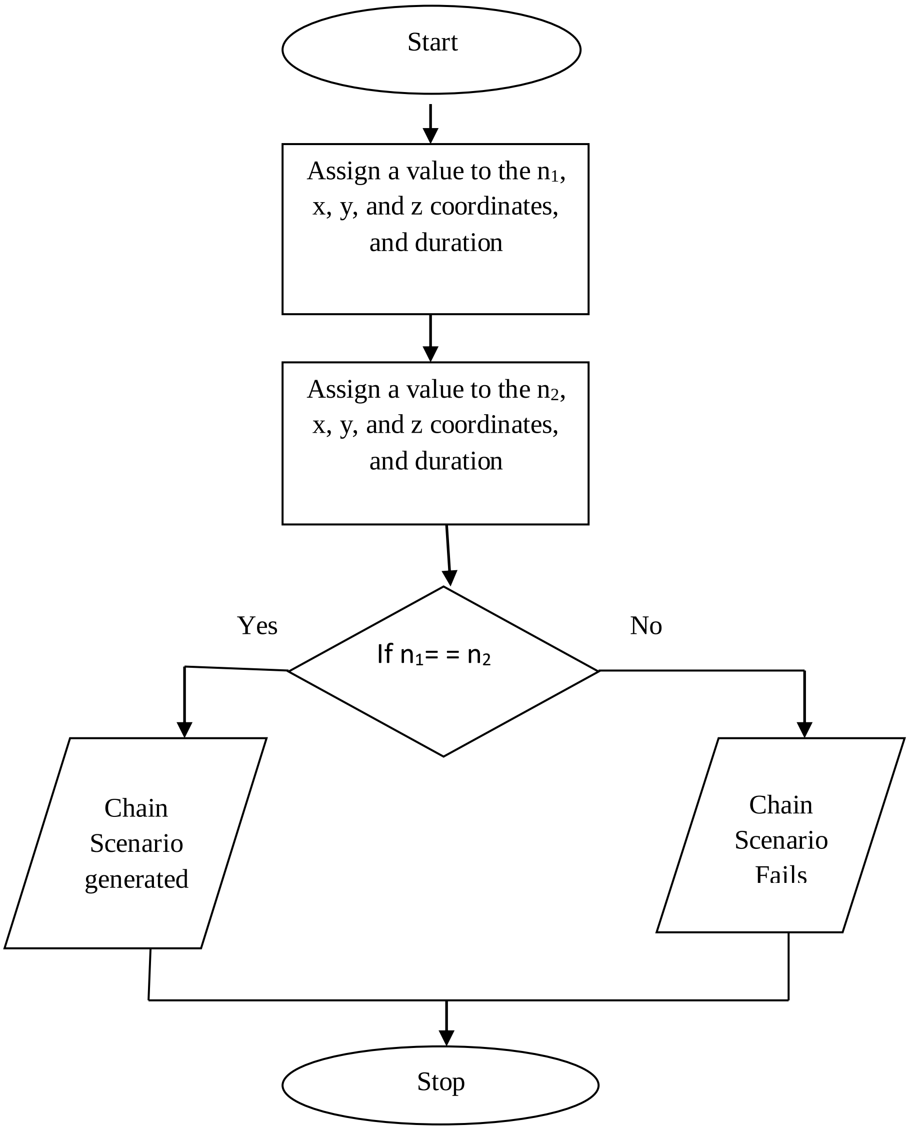


Figure 4.1 Flowchart of Proposed Chain Model

In the proposed model, if n_1 is equal to n_2, it generate a chain of both the models having duration is equal to the sum of both the durations and the nodes is equal to n_1 or n_2 otherwise chain scenario generation fails.

4.3 Summary

In this chapter, the RWPM and GMM explained in brief with the help of algorithms. The chain mobility model is the combination of RWPM and GMM is proposed in this chapter and explained with algorithm and flowchart.

Chapter 5

Simulation and Implementation

This chapter discussed about the implementation work of thesis and discuss about the NS-2 simulator, installation steps of NS-2, trace file, and AWK file and brief introduction about the Bonnmotion tool and also describe how to generate a mobility model scenario helps us to create a test bed for the proposed model.

5.1 Simulation

The generation of FANETs is very costly. So to evaluate the routing protocols performance, different network simulators are used. Simulation is the first step of the implementation of different routing protocols. There are various network simulators which provide a platform for testing and evaluating the performance of routing protocols like OPNET, NS-2, NS-3, Qualnet etc. In FANETs, the mobility scenario generator tool such as Bonnmotion is used to generate the mobility scenarios of unmanned aerial vehicles. The most important parameter for simulating the ad-hoc network is node mobility because, in FANETs, the mobility of the nodes is very higher than the VANETs and the MANETs.

The brief introduction of the simulators which has been used in thesis work has shown below:

5.2 NS-2 simulator

NS-2 widely called as network simulator version 2. NS-2 uses the two languages, one is coded in C++, and the second one is coded in Object-oriented Tool Command Language (OTCL). For the networking research, NS-2 is a discrete event simulator. NS-2 simulates the list of protocols like UDP, TCP, HTTP, DSR, and FTP. It simulates the both wireless and the wired network. NS-2 uses the TCL script language for creating the different number of nodes [37].

5.2.1 NS-2 Basic Architecture

NS-2 having two key languages: one is C++ and another one is OTCL. ns-allinone is the main directory of network simulator version 2 and it also has a various subdirectories or features which are used to run the Tcl scripts. The back-end of the network simulator is C++ and all the routing protocols are coded in this language and also the main scripting was written in Tcl language for the environment. Both the languages are linked with each other using a TCLCL. The whole working of network simulator is shown below in the Figure 5.1. Firstly, the script is written in OTCL language with the extension of (.tcl). In the terminal, run the .tcl file by using the command (ns filename.tcl) which generates two files: a trace file having an extension with .tr and network animator file having an extension with .nam. We read the trace file for extracting the QoS parameters values such as Packet Delivery Ratio, Generated Packets, Received Packets, Throughput, End-To-End Delay etc by the AWK files, Perl Files etc. Then we plot a graph for clearly identifying the performance of routing protocols.

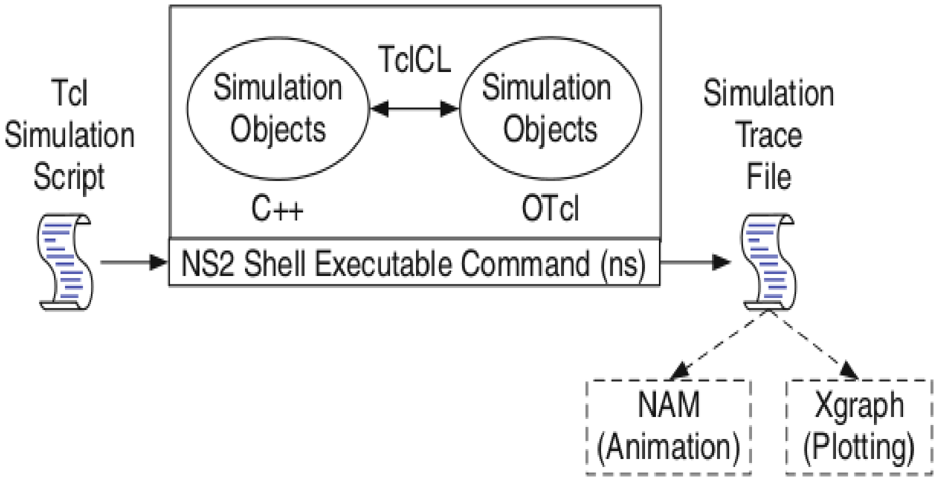


Figure 5.1 Basic Architecture of Network Simulator [38]

5.2.2 NAM

NAM basically stands for Network Animator which is used for viewing the network in real and analyzing that how the data packets move to the destination from the source node. NAM is a Tcl script based animator tool. It also shows that how packets are dropped during sending. Network animator visualization has shown below in the Figure 5.2.

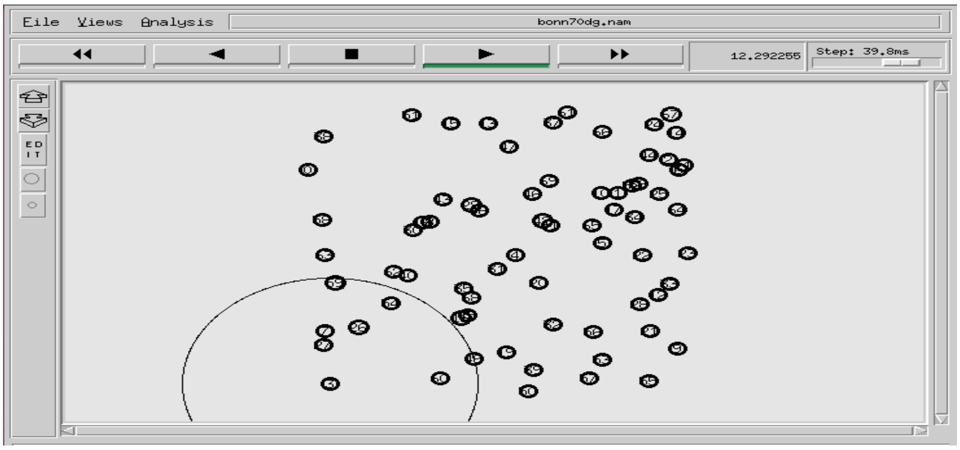


Figure 5.2 Network Animator of 70 nodes

5.2.3 Installation and Configuration of NS-2

NS-2 is an open source simulator. The package of ns-2 downloaded from [10]. NS-2 runs on various different platforms such as LINUX, Windows etc. To run the network simulator on Windows, there is a need to install a package called as Cygwin and the package ns-allinone is needed to run the network simulator on LINUX. There are various different versions of ns-allinone are available. It is the collection of all the packages which are needed to run the network simulator. There are few steps to install ns-2 on LINUX:

Step 1: Download the package: **"ns-allinone-2.35.tar.gz".**

Step 2: Unzip that package and place it on a home directory in LINUX.

Step 3: Open the terminal and type a command "**sudo apt-get update**" and then "**sudo apt-get install build-essential autoconf automake libxmu-dev".**

Step 4: Go to the home directory where the package is placed by typing a command on terminal: "**cd ns-allinone-2.35**".

Step 5: Type a command: **"./install".**

Step 6: Install the network animator by using a command: **"sudo apt-get install nam".**

Step 7: The environment variables set by: **"gedit ./bashrc".**

Step 8: Then type **"ns"** on terminal, % shows a successful installation of ns-2.

Configuration of NS-2

After the successful installation of ns-2 in LINUX, this platform is used to run the Tcl files. The command "ns filename.tcl" is used to run the Tcl file by typing a command on terminal. To run the nam file “nam filename.nam” command is used to run the network animator. After running the Tcl file on NS-2 simulator, it creates a trace file with the file extension .tr. Then to read the trace file for getting the useful information like PDR, throughput, End-To-End Delay, we need AWK file scripts. Results are obtained from the AWK file scripts and stored into the table and create a graph of obtained results. The graphs may be created in Microsoft Excel, Matlab etc.

5.3 Trace File

The file which contains the information of the overall network called as a trace file. Trace file can be generated by running the TCL script. There are 12 fields in the trace file format [40]. The format of trace file has shown below in Figure 5.3:

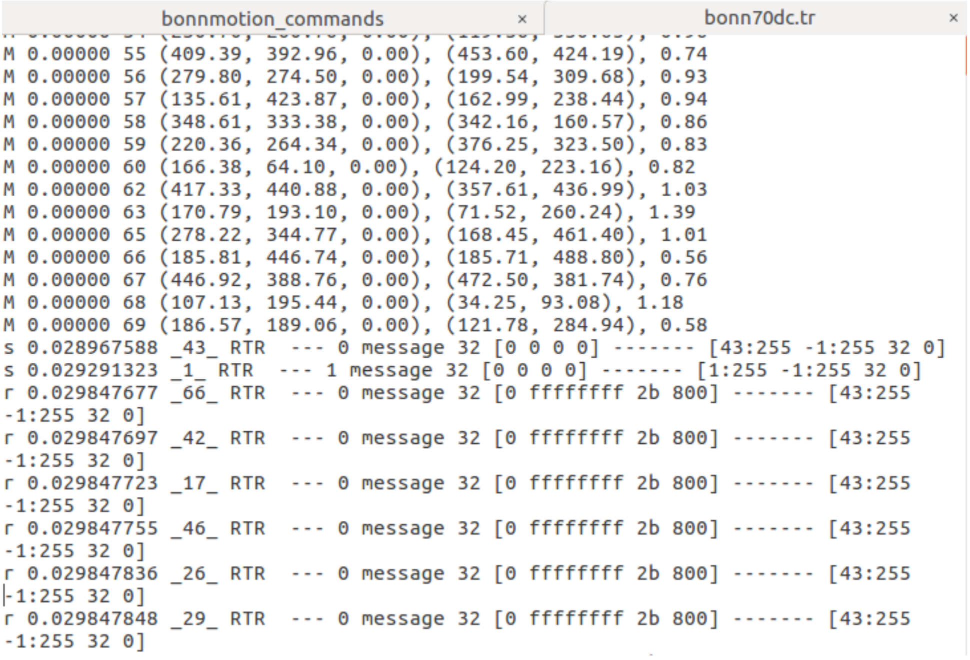
Event	Time	From node	To node	Pkt type	Pkt size	Flags	Fid	Src Addr	Dst addr	Seq Num	Pkt id

Figure 5.3 Trace File Format

The brief description of trace file format can be explained below:

1. **Event:** It contains a list of different events such as + for packet enque, - for deque the packet, s indicates the source event, r indicates the receiver event, d for dropped packets, c indicates for the collision of packets.
2. **Time:** The time when the simulation starts.
3. **From node:** It is the starting node which sends the data packets.
4. **To node:** It is the ending node where they received the data packets.
5. **Pkt type:** It defines the type of packet. It may be a cbr or tcp.
6. **Pkt size:** It defines the size of the packet which is created by the sender.
7. **Flags:** It defines the flag according to the event.
8. **Fid:** It is the flag id.
9. **Src addr:** It is the source address where the packet is created.
10. **Dst addr:** It is the destination address where the source delivered the data packets.
11. **Seq Num:** It is the sequence number which is given to the data packets.
12. **Pkt id:** At the source node, it gives a unique id to each packet when they transmit to another node.

An example of Trace File Format of DSDV protocol shown below in Figure 5.4:



```
M 0.00000 55 (409.39, 392.96, 0.00), (453.60, 424.19), 0.74
M 0.00000 56 (279.80, 274.50, 0.00), (199.54, 309.68), 0.93
M 0.00000 57 (135.61, 423.87, 0.00), (162.99, 238.44), 0.94
M 0.00000 58 (348.61, 333.38, 0.00), (342.16, 160.57), 0.86
M 0.00000 59 (220.36, 264.34, 0.00), (376.25, 323.50), 0.83
M 0.00000 60 (166.38, 64.10, 0.00), (124.20, 223.16), 0.82
M 0.00000 62 (417.33, 440.88, 0.00), (357.61, 436.99), 1.03
M 0.00000 63 (170.79, 193.10, 0.00), (71.52, 260.24), 1.39
M 0.00000 65 (278.22, 344.77, 0.00), (168.45, 461.40), 1.01
M 0.00000 66 (185.81, 446.74, 0.00), (185.71, 488.80), 0.56
M 0.00000 67 (446.92, 388.76, 0.00), (472.50, 381.74), 0.76
M 0.00000 68 (107.13, 195.44, 0.00), (34.25, 93.08), 1.18
M 0.00000 69 (186.57, 189.06, 0.00), (121.78, 284.94), 0.58
s 0.028967588 _43_ RTR  --- 0 message 32 [0 0 0 0] ------- [43:255 -1:255 32 0]
s 0.029291323 _1_ RTR  --- 1 message 32 [0 0 0 0] ------- [1:255 -1:255 32 0]
r 0.029847677 _66_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
r 0.029847697 _42_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
r 0.029847723 _17_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
r 0.029847755 _46_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
r 0.029847836 _26_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
r 0.029847848 _29_ RTR  --- 0 message 32 [0 ffffffff 2b 800] ------- [43:255
-1:255 32 0]
```

Figure 5.4 Trace File of DSDV

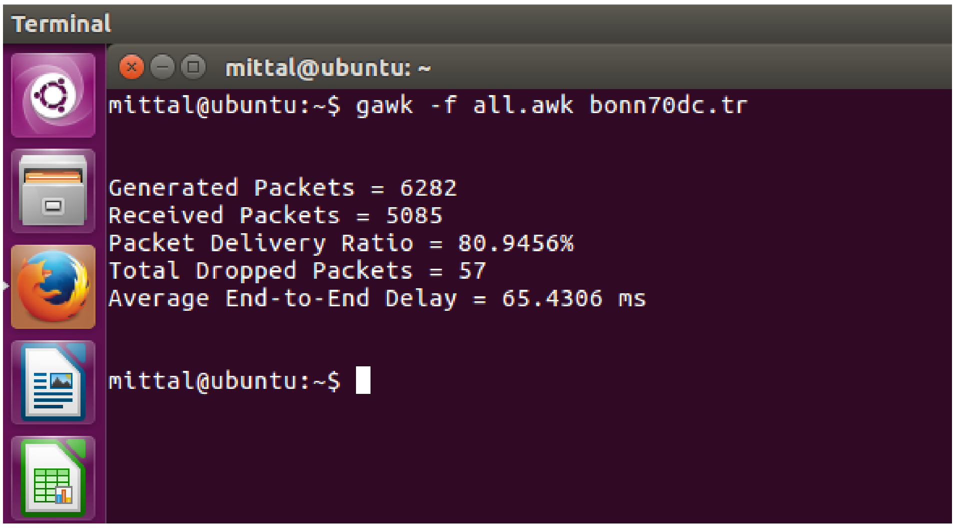
5.4 AWK File

AWK files are the scripting files which are used to read the trace files for extracting the useful information such as PDR, Delay, Throughput, Generated and Received Packets, Dropped Packets etc are shown below in Figure 5.5. It reads the trace file in column wise and processing it. The description of a particular column has been described below:

- $1 represents the ACTION
- $2 represents Time
- $3 represents Node Id
- $4 represents Layer
- $5 represents Flag
- $6 represents Sequence No
- $7 represents Type
- $8 represents Size
- $14 represents Energy (for Energy Model)

The command to read the AWK files by:

```
gawk –f filename.awk filename.tr
```



```
mittal@ubuntu:~$ gawk -f all.awk bonn70dc.tr


Generated Packets = 6282
Received Packets = 5085
Packet Delivery Ratio = 80.9456%
Total Dropped Packets = 57
Average End-to-End Delay = 65.4306 ms


mittal@ubuntu:~$
```

Figure 5.5 Parameters of trace file read by AWK file

5.5 BonnMotion

BonnMotion is a scenario generator tool. It is Java based software. It generates scenarios of different mobility models. That generated scenarios are simulated on different provided network simulators. The different network simulators are ns-2, ns-3, Qualnet etc. There are various mobility models which are easily created in BonnMotion. The list of mobility models are shown below [41]:

- The Random Waypoint
- The Gauss-Markov
- The Manhattan Grid
- The Random Walk
- The Random Street l
- The Reference Point Group
- The Disaster Area and more.

5.5.1 Installation of BonnMotion

BonnMotion is an open source simulator which generates scenarios of mobility model. There are various mobility models generated by Bonnmotion. There are very few steps to install the software into the ns-2 simulator. Steps are listed below [42]:

Step 1: Download the package of BonnMotion tool.

Step 2: Unzip the package and place into the home directory in the LINUX.
Step 3: Install the JRE and JDK by using a command "**sudo apt-get install openjdk-7-jre openjdk-7-jdk".**
Step 4: Go to the home directory where package placed by "**cd bonnmotion-2.0".**
Step 5: Then type **"./install".**

It successfully installed a bonnmotion tool in ns-2. In a bonnmotion tool, we generate a various mobility models scenarios.

5.5.2 Scenario Generation

In the scenario generation, there is a list of different parameters which are used to generate a mobility scenario of nodes. The list of the parameters that used with all the models shown below:

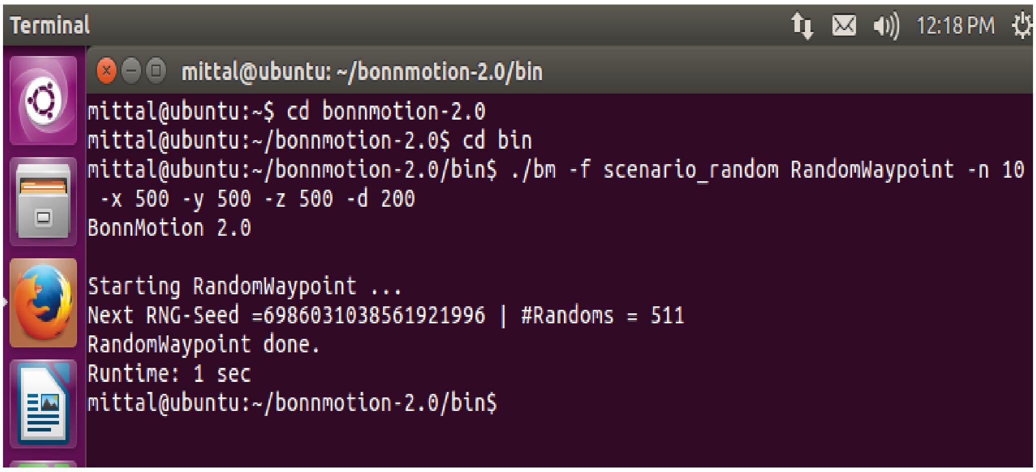
- [-n] represents the number of nodes
- [-d] represents duration of scenario (in seconds)
- [-x] represents the width of simulation area (in meters)
- [-y] represents the height of simulation area (in meters)
- [-z] represents the depth of simulation area (in meters)

5.5.2.1 Scenario generation of Random Waypoint

The below command is used to generate a mobility scenario of RWPM:

```
./bm –f file1 RandomWaypoint –n 10  -x 500 –y 500 –z 500 –d 200
```

This above command creates a scenario of the file named as file1 with 10 nodes in x, y, z-axis. The whole mobility scenario is stored in two files: one file having a suffix is "file1.params" which contains parameters values and the second file having a suffix is "file1.movements" which contains the mobility generated by 10 nodes shown below in the Figure 5.6.



```
mittal@ubuntu:~$ cd bonnmotion-2.0
mittal@ubuntu:~/bonnmotion-2.0$ cd bin
mittal@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f scenario_random RandomWaypoint -n 10
 -x 500 -y 500 -z 500 -d 200
BonnMotion 2.0

Starting RandomWaypoint ...
Next RNG-Seed =6986031038561921996 | #Randoms = 511
RandomWaypoint done.
Runtime: 1 sec
mittal@ubuntu:~/bonnmotion-2.0/bin$
```

Figure 5.6 Random Waypoint Mobility Model Scenario

The command used to convert the scenario files into the NS files by:

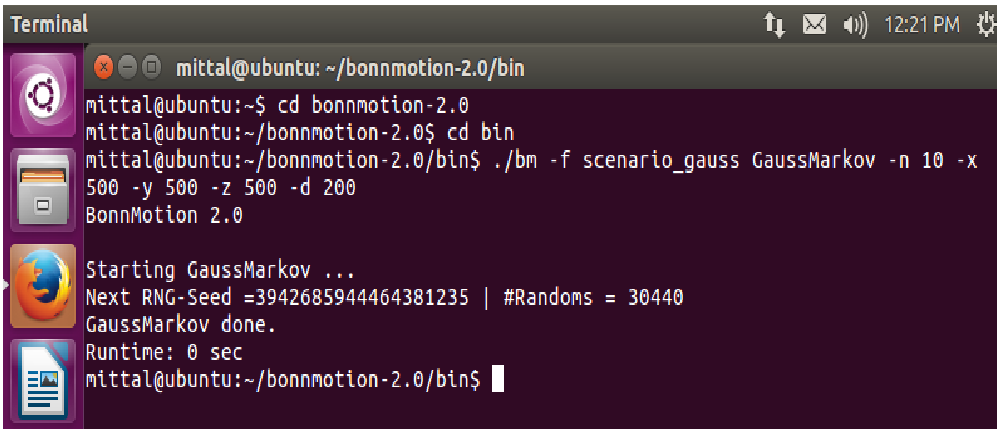
./bm NSFile –f scenario_random

5.5.2.2 Scenario generation of Gauss-Markov

The below command used to generate a scenario of Gauss-Markov Mobility Model:

./bm –f file2_gauss GaussMarkov –n 10 -x 500 –y 500 –z 500 –d 200

This command creates a file2_gauss scenario with 10 nodes in x, y, and z-axis. The whole mobility scenario is stored in two files: one file having a suffix is “file2_gauss.params” which contains parameter values and the second file having a suffix is “file2.movements” which contains the mobility generated by 10 nodes shown below in Figure 5.7.



```
mittal@ubuntu:~$ cd bonnmotion-2.0
mittal@ubuntu:~/bonnmotion-2.0$ cd bin
mittal@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f scenario_gauss GaussMarkov -n 10 -x
500 -y 500 -z 500 -d 200
BonnMotion 2.0

Starting GaussMarkov ...
Next RNG-Seed =3942685944464381235 | #Randoms = 30440
GaussMarkov done.
Runtime: 0 sec
mittal@ubuntu:~/bonnmotion-2.0/bin$ 
```

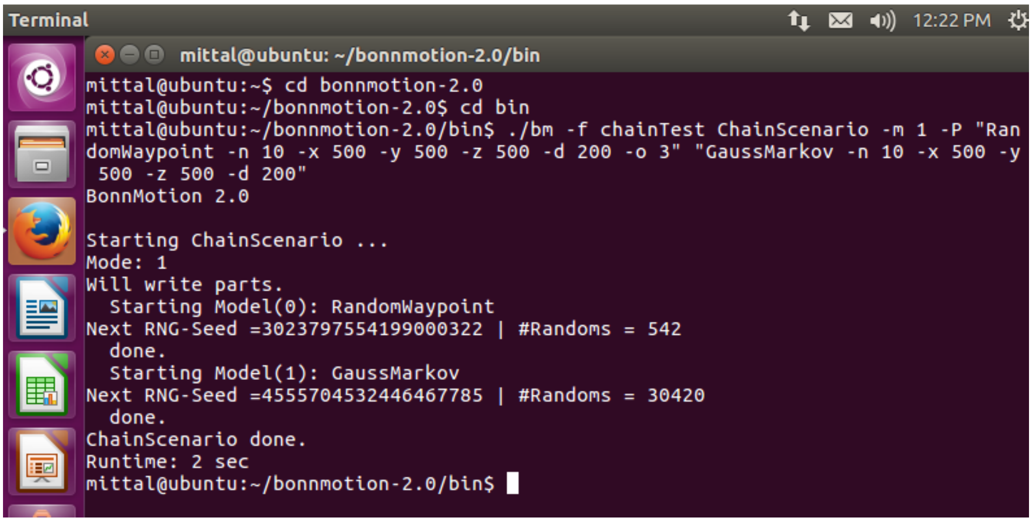
Figure 5.7 Gauss-Markov Mobility Model Scenario

5.5.2.3 Scenario generation of Chain

The below command creates a Chain scenario of combined Random Waypoint and Gauss-Markov Mobility Model:

./bm –f file3 ChainScenario –m 1 –p “RandomWaypoint –d 200 –n 10 –x 500 –y 500 –z 500 –d 200 –o 3” “GuassMarkov –d 200 –n 10 –x 500 –y 500 –z 500 –d 200”.

This command creates a file3 scenario with 10 nodes in x, y, and z-axis. The whole mobility scenario is stored in two files: one file having a suffix is “file3-ALL.params” which contains all the parameters values of both the models and the second file having a suffix is “file3-ALL.movements” which contains the mobility of both the models generated by 10 nodes shown below in Figure 5.8.



```
mittal@ubuntu:~$ cd bonnmotion-2.0
mittal@ubuntu:~/bonnmotion-2.0$ cd bin
mittal@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f chainTest ChainScenario -m 1 -P "Ran
domWaypoint -n 10 -x 500 -y 500 -z 500 -d 200 -o 3" "GaussMarkov -n 10 -x 500 -y
 500 -z 500 -d 200"
BonnMotion 2.0

Starting ChainScenario ...
Mode: 1
Will write parts.
  Starting Model(0): RandomWaypoint
Next RNG-Seed =3023797554199000322 | #Randoms = 542
  done.
  Starting Model(1): GaussMarkov
Next RNG-Seed =4555704532446467785 | #Randoms = 30420
  done.
ChainScenario done.
Runtime: 2 sec
mittal@ubuntu:~/bonnmotion-2.0/bin$ 
```

Figure 5.8 Mobility Scenario of Chain Model

5.6 Summary

This chapter discussed about the NS-2 simulator tool, the basic architecture, Installation steps of NS-2. This chapter also discussed about the different mobility models in FANETs. The Bonnmotion tool is used to generate mobility scenarios of models. The Random Waypoint, Gauss-Markov, and Chain mobility model scenarios are generated in this work. The generated scenario is saved in two file: one file having a suffix is “filename_params” which contains the values of parameters and the second file having a suffix is “filename_movements” which contains the mobility of nodes. Then convert the scenario files into the TCL files for running onto the NS-2 simulator. The simulator generates a trace file having extension “.tr” and network animator file having extension “.nam”. Then AWK scripts are used to read the trace files for getting the Quality of service parameter values. The NAM is used to view the network in real of network animator file.

Chapter 6

Results and Analysis

This chapter shows the results of one reactive protocol AOMDV and one proactive protocol DSDV under the different mobility models and the proposed chain model. The routing protocols performance is measured under the two different mobility models and one proposed chain model.

- the RandomWaypoint
- the GaussMarkov
- the Chain of RandomWaypoint and GaussMarkov.

Simulation is done under the different number of nodes:

- low (10 nodes)
- medium (40 nodes)
- high (70 nodes)

6.1 Simulation Parameters

In the below Table 6.1, the AOMDV and DSDV routing protocols are considered for Random Waypoint, Gauss-Markov, and chain of both the models with 10, 40 and 70 number of nodes. The transport layer protocol i.e. TCP is used for traffic type and duration of simulation is 200s.

Table 6.1 Parameters of Simulation

Parameter	**Value**
Simulator	NS-2 (Version 2.35)
Channel Type	Channel/Wireless Channel
Routing Protocol	AOMDV, DSDV
Mobility Model	Random Waypoint, Gauss-Markov, Chain
Simulation Duration	200s
No of Nodes	10, 40, 70

MAC Layer Protocol	802.11
Traffic Type	TCP

6.2 Performance Parameters

Here we have taken three QoS parameters for the performance analysis of AOMDV and DSDV routing protocols under different mobility models.

1. **Packet Delivery Ratio (PDR):** PDR tells that how many packets are sent by the sender and how many packets are actually received by the receiver.
   PDR = total sent packets/ total received packets.
2. **End-To-End Delay:** E-To-E Delay tells that the average time is taken by a packet from the source to reach the Destination. It also includes that the delay comes during the route discovery.
   E-To-E Delay= (Arrival Time-Sent Time)/ Number of Connections.
3. **Throughput:** It defines that the number of packets which are successfully delivered from the sender to the destination.

6.3 Simulation Results of AOMDV and DSDV routing protocols with the Random Waypoint Mobility Model

The results of simulation are obtained from the generated trace files using AWK scripts are shown below:

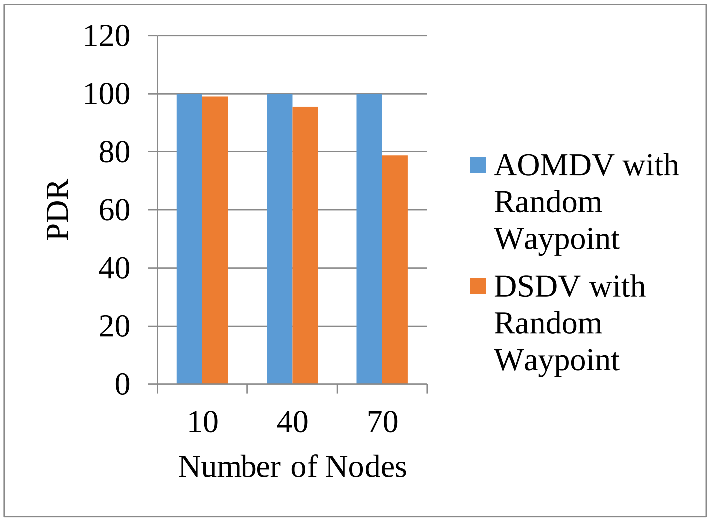
6.3.1 Number of nodes vs Packet Delivery Ratio

Table 6.2 shows the variation of PDR of AOMDV and DSDV protocols with RWPM with different node density.

Table 6.2 Number of nodes vs PDR for Random Waypoint

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Random Waypoint	99.8615%	99.8568%	99.8530%
DSDV with Random Waypoint	98.9993%	95.4558%	78.6603%

The below Figure 6.1 shows that the PDR of AOMDV is almost same when number of nodes increases but in the DSDV when the number of nodes increases PDR decreases.



. Figure 6.1 Number of nodes vs PDR for Random Waypoint

6.3.2 Number of nodes vs End-To-End Delay

Table 6.3 shows the variation of End-To-End Delay of AOMDV and DSDV protocols with RWPM with different number of nodes.

Table 6.3 Number of nodes vs End-To-End Delay for Random Waypoint

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Random Waypoint	63.6236	77.7087	53.5448
DSDV with Random Waypoint	64.8764	57.6399	82.7467

The Figure 6.2 shows that when the no of nodes is very less, then the delay in AOMDV is less than the DSDV. When the no of nodes is 40, the delay of DSDV protocol decreases but when the no of nodes is 70, delay of DSDV is very high than the AOMDV routing protocol.

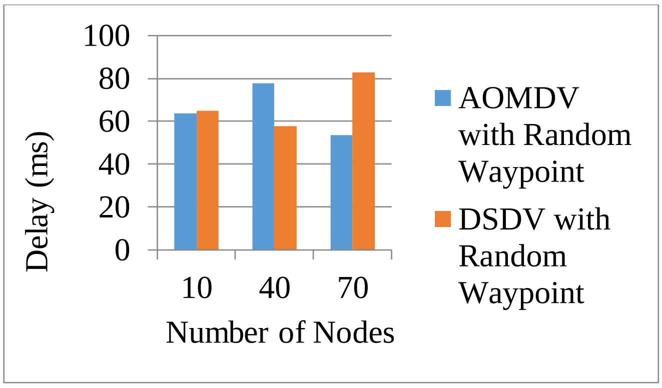


Figure 6.2 Number of nodes vs End-To-End Delay for Random Waypoint

6.3.3 Number of nodes vs Throughput

Table 6.4 shows the variation of Throughput of AOMDV and DSDV protocols with RWPM with different no of nodes.

Table 6.4 Number of nodes vs Throughput for Random Waypoint

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Random Waypoint	657.42	636.90	623.22
DSDV with Random Waypoint	663.54	656.74	477.64

The Figure 6.3 clearly shows the throughput of both the protocols AOMDV and DSDV. When the no of nodes increases, the throughput of AOMDV remains same but in the case of DSDV, throughput decreases when the no of nodes increases.

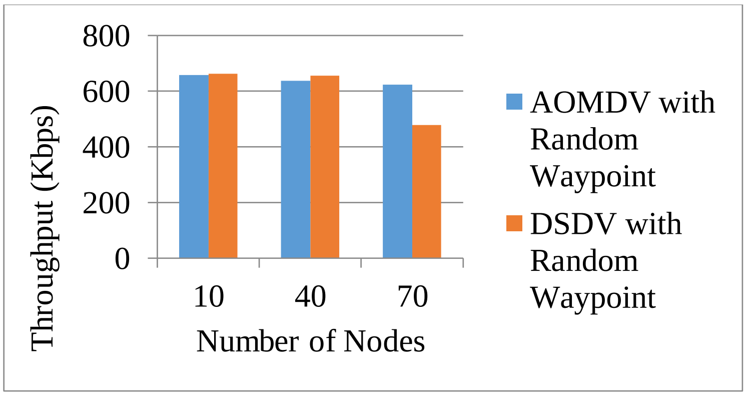


Figure 6.3 Number of nodes vs Throughput for Random Waypoint

6.4 Simulation Results of AOMDV and DSDV routing protocols with the Gauss-Markov Mobility Model

The results of simulation are obtained from the generated trace files using AWK scripts are shown below:

6.4.1 Number of nodes vs Packet Delivery Ratio

Table 6.5 shows the variation of PDR of AOMDV and DSDV routing protocol with Gauss-Markov Model with different no of nodes.

Table 6.5 Number of nodes vs PDR for Gauss-Markov Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Gauss-Markov	99.724%	99.8574%	99.8534%
DSDV with Gauss-Markov	98.8719%	95.3247%	78.0116%

Figure 6.4 shown below clearly shows that the PDR of AOMDV is almost same when the no of nodes increases but in the DSDV, the PDR decreases.

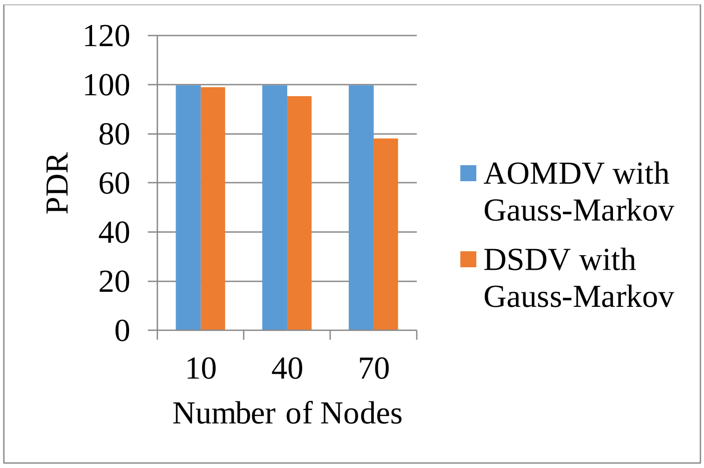


Figure 6.4 Number of nodes vs PDR for Gauss-Markov Model

6.4.2 Number of nodes vs End-To-End Delay

Table 6.6 shows the variation of End-To-End delay of AOMDV and DSDV routing protocol with Gauss-Markov Model with different no of nodes.

Table 6.6 Number of nodes vs End-To-End Delay for Gauss-Markov Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Gauss-Markov	129.249	87.231	64.703
DSDV with Gauss-Markov	66.008	70.9865	99.311

The below Figure 6.5 clearly shows that the delay of AOMDV protocol is decreased when the no of nodes increases but in the case of DSDV, delay increases.

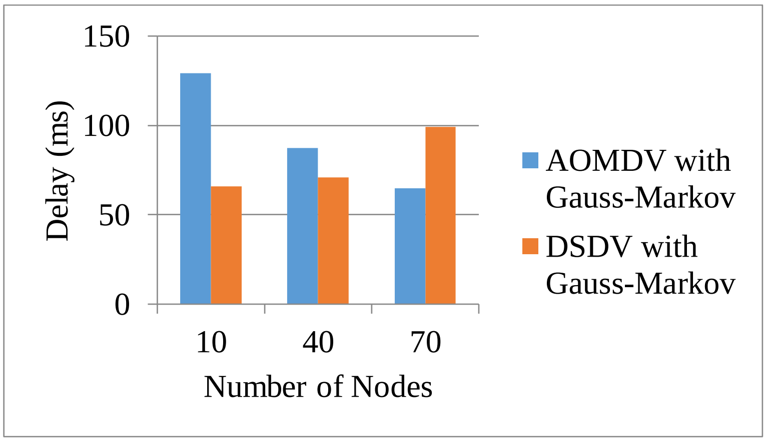


Figure 6.5 Number of nodes vs End-To-End Delay for Gauss-Markov Model

6.4.3 Number of nodes vs Throughput

Table 6.7 shows the variation of Throughput of AOMDV and DSDV routing protocol with Gauss-Markov Mobility with the different no of nodes.

Table 6.7 Number of nodes vs Throughput for Gauss-Markov Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Gauss-Markov	660.45	640.18	622.15
DSDV with Gauss-Markov	663.21	652.89	769.38

Figure 6.6 shown below clearly shows that when the no of nodes is very less, the throughput of both the protocols is same. When the no of nodes increases, throughput of DSDV increases than the AOMDV routing protocol.

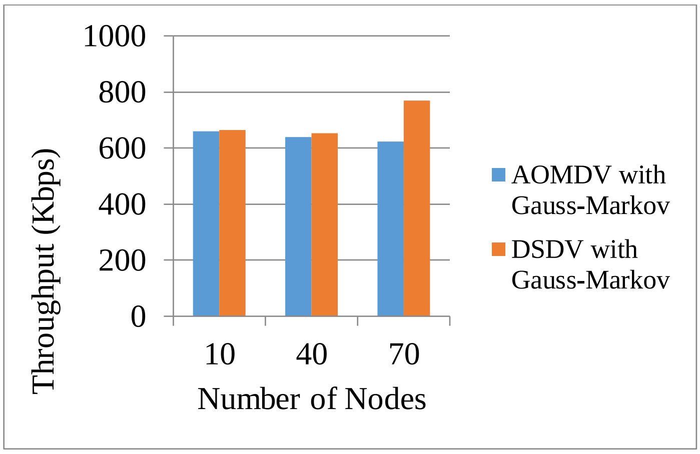


Figure 6.6 Number of nodes vs Throughput for Gauss-Markov Model

6.5 Simulation Results of AOMDV and DSDV routing protocols with the Chain Mobility Model

The results of simulation are obtained from the generated trace files using AWK scripts are shown below:

6.5.1 Number of nodes vs Packet Delivery Ratio

Table 6.8 shows the variation of PDR of AOMDV and DSDV routing protocol with Chain model with the different no of nodes.

Table 6.8 Number of nodes vs PDR for Chain Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Chain	99.8623%	99.8577%	99.8426%
DSDV with Chain	99.039%	95.556%	80.9456%

Figure 6.7 shown below clearly shows that the PDR of AOMDV is almost same when the no of nodes increases but in the case of DSDV, PDR decreases.

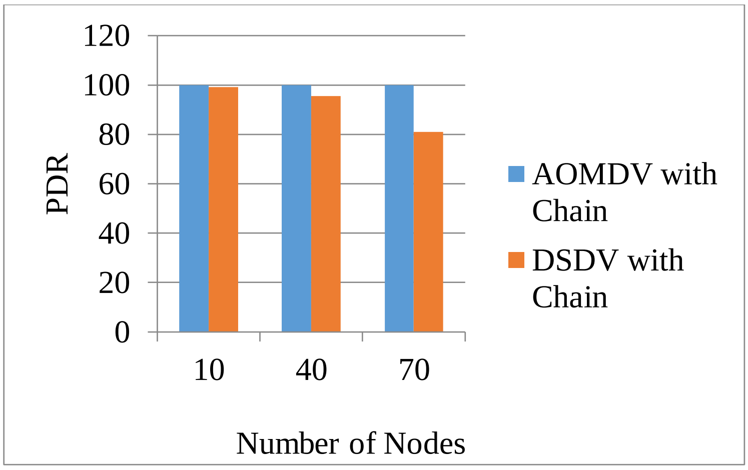


Figure 6.7 Number of nodes vs PDR for Chain Model

6.5.2 Number of nodes vs End-To-End Delay

Table 6.9 shows the variation of End-To-End delay of AOMDV and DSDV routing protocol with Chain Model with the different no of nodes.

Table 6.9 Number of nodes vs End-To-End Delay for Chain Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Chain	54.7235	53.7748	69.9840
DSDV with Chain	70.4525	66.9123	65.4306

The below Figure 6.8 shows that when the no of nodes increases, the End-To-End delay of DSDV decreases rather than the AOMDV protocol because, in AOMDV, the delay increases when the nodes increases.

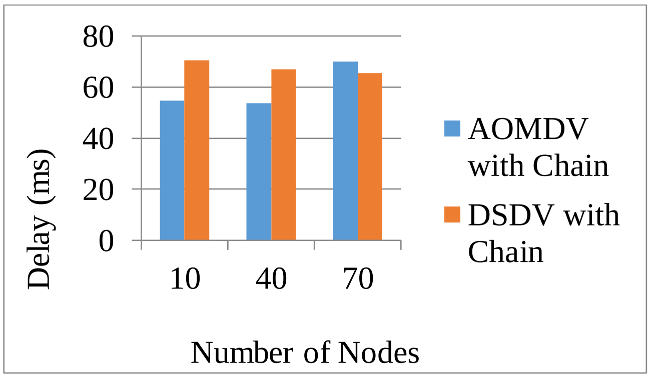


Figure 6.8 Number of nodes vs End-To-End Delay for Chain Model

6.5.3 Number of nodes vs Throughput

Table 6.10 shows the variation of Throughput of AOMDV and DSDV routing protocol with Chain Model with the different no of nodes.

Table 6.10 Number of nodes vs Throughput for Chain Model

Mobility Model	**Number of nodes**		
	10	**40**	**70**
AOMDV with Chain	661.94	640.90	627.09
DSDV with Chain	662.76	654.81	822.48

The Figure 6.9 shows that when the no of nodes increases, throughput of AOMDV remains same. In the case of DSDV, throughput increases when the no of nodes increases.

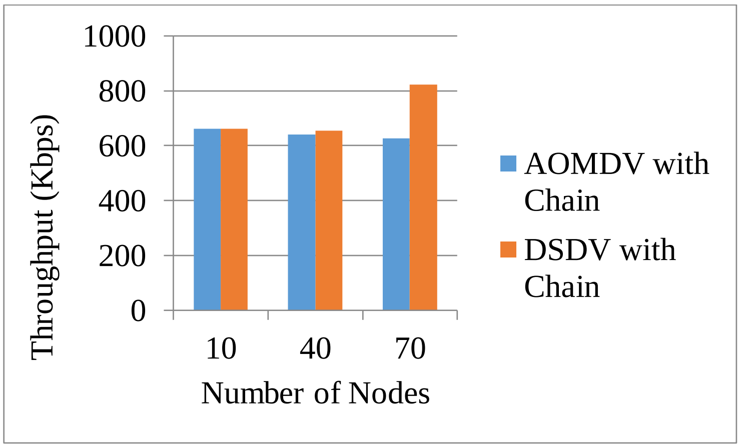


Figure 6.9 Number of nodes vs Throughput for Chain Model

6.6 Validation

The performance analysis of two routing protocols AOMDV (reactive) and DSDV (proactive) for the different quality of service parameter Paket Delivery Ratio, End-To-End Delay, and Throughput under the Random Waypoint model, Gauss-Markov model, and the proposed Chain mobility model are evaluated. The performance can be evaluated for the three different no of nodes (10, 40, and 70). From the below Figure

6.10 shows that the delay in chain model is decreases when the no of increases but in the case of RWPM and GMM delay increases when the no of nodes increases.

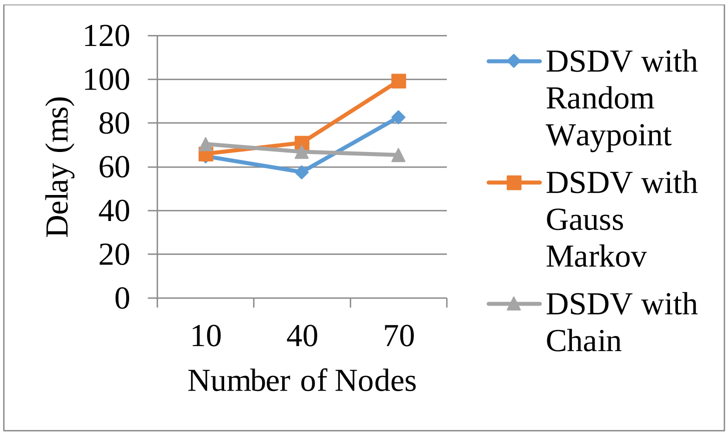


Figure 6.10 Comparison of delay

6.7 Simulation Analysis

The simulation results of AOMDV and DSDV routing protocols are obtained from the generated trace files and read the files by the AWK scripts. The obtained results are shown in tables (6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10) and the graphs are drawn for easy to understand the increasing and decreasing the performance of protocols when the no of nodes increases. The results are obtained for the various quality of service parameters such as PDR, End-To-End delay, and throughput under the Random Waypoint mobility model, Gauss-Markov mobility model, and the proposed chain mobility model. The number of nodes are 10, 40, and 70 are used for the simulation. The simulation analysis for the different mobility models are conclude below

6.7.1 Random Waypoint model

From Figure 6.1, it is clearly observed the PDR of DSDV and AOMDV protocols under the RWPM, when number of nodes increases AOMDV is almost same but in the DSDV when the number of nodes increases PDR decreases**.**

From Figure 6.2, it is observed the delay of protocols under the RWPM, when the no of nodes is very less, the delay of AOMDV is also less than the DSDV. When the no of nodes is 40, the delay of DSDV protocol decreases but when the no of nodes is 70, delay of DSDV is very high than the AOMDV routing protocol.

From Figure 6.3, it is clearly observed the throughput of both the protocols AOMDV and DSDV under the RWPM, if nodes increases, the throughput of AOMDV remains same but in the case of DSDV, throughput decreases when the no of nodes increases.

6.7.2 Gauss-Markov model

From Figure 6.4, it is observed the PDR of both the protocols under the Gauss-Markov model, the PDR of AOMDV is almost same when the no of nodes increases but in the DSDV, the PDR decreases.

From Figure 6.5, it is observed the End-To-End delay of AOMDV and DSDV protocols under the Gauss-Markov model, the delay of AOMDV protocol is decreased when the no of nodes increases but in the case of DSDV, delay increases.

From Figure 6.6, clearly observed the throughput of both the protocols under the GMM, if nodes are less, then the throughput of both the protocols is same. When the no of nodes increases, throughput of DSDV increases than the AOMDV routing protocol.

6.7.3 Proposed Chain model

From Figure 6.7, clearly observed the PDR of AOMDV and DSDV protocols under the Chain model, the PDR of AOMDV is almost same when the no of nodes increases but in the case of DSDV, PDR decreases.

From Figure 6.8, it is observed the End-To-End delay of protocols under the Chain model, when the no of nodes increases, the End-To-End delay of DSDV decreases rather than the AOMDV protocol because, in AOMDV, the delay increases when the nodes increases.

From Figure 6.9, it is observed the throughput of AOMDV and DSDV protocols under the Chain model, when the no of nodes increases, throughput of AOMDV remains same. In the case of DSDV, throughput increases when the no of nodes increases.

6.8 Summary

In the proposed Chain mobility model, we clearly conclude that the packet delivery ratio of AOMDV protocol is better than the DSDV protocol. Under the case of delay, it decreases when nodes increases in the chain model rather than the delay of RWPM and GMM. When DSDV throughput increases when nodes increases rather than the AOMDV protocol.

Chapter 7

Conclusion and Future Work

This chapter discuss the conclusion of the proposed chain mobility model and also discuss the limitations of research. The future scope of the proposed model was also discussed.

7.1 Conclusion

In this thesis, Chain mobility model is proposed using a combination of Random Waypoint mobility model and Gauss-Markov mobility model for FANETs. The different mobility scenarios are created by varying number of nodes i.e. 10, 40, and 70. The routing protocols AOMDV (reactive) and DSDV (proactive) are experimentally analyzed for various performance parameters i.e. PDR, End-to-End delay and throughput by using the mobility scenarios of proposed chain mobility model. From the simulation results, it is observed that AOMDV performed better in terms of PDR when the number of nodes increases but in DSDV protocol delay decreases continuously when the nodes increases under chain mobility model rather than the delay of Random Waypoint and Gauss-Markov mobility model. So, it is concluded that chain mobility model optimize the delay of DSDV protocol than RWPM and GMM.

7.2 Limitations

There are some limitations which we suffer during the thesis work are listed below:

1. The availability of tools are very less for the simulation because the scope of FANETs increases day by day.
2. The 3D view of UAVs not properly viewed in NS-2 simulator. So we cannot analyze that how the UAVs are communicating with each other in FANETs.
3. The availability of mobility models is very limited in FANETs.

7.3 Future Work

In this research, chain mobility model is applied only to evaluate the performance of reactive and proactive routing protocols. In future, the chain model can be varied by using a combination of some different existing mobility models to get better results of routing protocols. Also, evaluate the performance of reactive, proactive, and position-based routing protocols using this proposed chain mobility model. We have used only two routing protocols, so in future three or more routing protocols will use to check the protocols performance under the proposed model.

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Publications

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