

Chaining Mobility Models for AODV and DSR protocols in FANETs

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

Master of Engineering
in
Software Engineering

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 AODV and DSR protocols in FANETs*", in partial fulfilment of the requirements for the award of degree of Master of Engineering in *Software 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.

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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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Flying Ad hoc Networks (FANETs) is a collection of unmanned aerial vehicles that communicate without any predefined infrastructure. FANETs being the most searched and researched topic nowadays is finding its scope in flying objects like Drones used for military applications like border surveillance and for civil applications like disaster management, traffic monitoring. Mobility models are designed to represent the movement pattern of nodes. A realistic simulation environment created using mobility model plays a major role to evaluate the performance of ad hoc routing protocols. In this research, new chain mobility model is proposed by integrating existing Random Waypoint mobility model and Gauss-Markov mobility model to get the better performance in FANET routing protocols.

The performance of protocols varies significantly by using different mobility models. The objectives of this thesis is to simulate the AODV and DSR routing protocols in FANETs using different mobility models and to get the best mobility model which will optimize the end to end delay, packet delivery ratio and throughput performance parameters.

The AODV and DSR routing protocols are simulated using NS2 simulator and the performance parameters are analyzed for Random Waypoint model, Gauss-Markov model and RGIM the proposed chain mobility model. The results show improvements in terms of Packet Delivery Ratio, Throughput and End to End Delay with RGIM.

Keywords: FANETs, AODV, DSR, Random Waypoint Mobility Model, Gauss-Markov Mobility Model, Chain Mobility Model.

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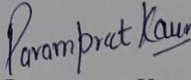

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Table of Contents

Table of Contents	Page No.
Certificate.....	i
Abstract.....	ii
Acknowledgement.....	iii
Table of Contents.....	iv
List of Figures.....	vii
List of Tables.....	viii
List of Abbreviations.....	ix
Chapter 1: Introduction.....	1-12
1.1 Wireless Network.....	1
1.1.1 Characteristics of Wireless Network.....	1
1.2 Wireless Ad-hoc Network.....	2
1.2.1 MANET.....	2
1.2.2 VANET.....	3
1.2.3 FANET.....	5
1.2.3.1 Applications of FANET.....	6
1.3 Routing Protocols.....	7
1.3.1 Ad hoc On-demand Distance Vector.....	7
1.3.1.1 Characteristics of AODV.....	7
1.3.1.2 Working of AODV.....	7
1.3.1.3 Routing in AODV.....	8
1.3.2 Dynamic Source Routing.....	9
1.3.2.1 Characteristics of DSR.....	10
1.3.2.2 Working of DSR.....	10
1.4 Chapterization.....	12
1.5 Summary.....	12
Chapter 2: Literature Survey	13-20
2.1 Routing in FANETs.....	13
2.1.1 Proactive Protocols.....	13
2.1.2 Reactive Protocols.....	13
2.1.3 Hybrid Protocols.....	13

2.1.4 Position/Geographic based protocols.....	13
2.1.5 Hierarchical protocols.....	14
2.2 Mobility Models.....	15
2.2.1 Random Waypoint Mobility Model.....	16
2.2.2 Gauss-Markov Mobility Model.....	17
2.2.3 Semi Random Circular Movement Model.....	18
2.2.4 Mission Plan Based Model.....	19
2.2.5 Chain Mobility Model.....	19
2.3 Summary.....	20
Chapter 3: Problem Statement and Methodology.....	21-29
3.1 Research Gaps.....	21
3.2 Problem Statement.....	21
3.3 Objectives.....	22
3.4 Methodology.....	22
3.5 Summary.....	24
Chapter 4: Proposed Model.....	25-29
4.1 Components of Proposed Chain mobility model: RGIM.....	25
4.1.1 Random Waypoint Model.....	25
4.1.2 Gauss-Markov Model.....	26
4.2 RGIM: The Proposed Chain Mobility Model.....	27
4.3 Summary.....	29
Chapter 5: Simulation and Implementation	30-38
5.1 Simulation.....	30
5.1.1 Network Simulator.....	30
5.1.2 NS-2 Architecture.....	31
5.1.3 Network Animator (NAM).....	31
5.1.4 Trace File.....	32
5.1.5 AWK script.....	34
5.2 Installation of NS2.....	34
5.3 BonnMotion.....	35
5.3.1 Installation Steps.....	35
5.3.2 Mobility Scenario Generation.....	35
5.4 Summary.....	38
Chapter 6: Results and Analysis	39-48
6.1 Simulation Parameters.....	39

6.2 Performance Parameters.....	39
6.3 Simulation Results of AODV routing protocol with different mobility models.	40
6.3.1 Number of nodes vs. PDR.....	40
6.3.2 Number of nodes vs. End to End delay.....	41
6.3.3 Number of nodes vs. Throughput.....	42
6.4 Simulation Results of DSR routing protocol with different mobility models....	43
6.4.1 Number of nodes vs. PDR.....	43
6.4.2 Number of nodes vs. End to End delay.....	44
6.4.3 Number of nodes vs. Throughput.....	45
6.5 Simulation Analysis.....	46
6.5.1 Simulation analysis of AODV.....	46
6.5.1.1 Packet Delivery Ratio.....	46
6.5.1.2 End to End delay.....	47
6.5.1.3 Throughput.....	47
6.5.2 Simulation analysis of DSR.....	47
6.5.2.1 Packet Delivery Ratio.....	47
6.5.2.2 End to End delay.....	48
6.5.2.3 Throughput.....	48
6.6 Summary.....	48
Chapter 7: Conclusion and Future Scope	49-50
7.1 Conclusion.....	49
7.2 Unique Contribution.....	49
7.3 Limitation.....	49
7.4 Future Scope.....	50
References.....	51-55
Publication.....	56

List of Figures

Figure 1.1 Wireless Network.....	1
Figure 1.2 Mobile Ad hoc Network.....	3
Figure 1.3 Vehicular Ad hoc Network.....	4
Figure 1.4 Flying Ad hoc Network.....	5
Figure 1.5 Message routing in AODV.....	9
Figure 1.6 Route Discovery mechanism.....	11
Figure 1.7 Route Maintenance mechanism.....	11
Figure 2.1 Mobility Models in FANETs.....	15
Figure 2.2 Node movement in random waypoint model.....	16
Figure 2.3 Node movement in Gauss-Markov model	18
Figure 2.4 Semi Random Circular Movement model.....	19
Figure 2.5 Mission Plan Based model	19
Figure 3.1 Activity Diagram- Methodology	23
Figure 4.1 Activity diagram showing proposed chain mobility model	29
Figure 5.1 Basic Architecture of NS-2.....	31
Figure 5.2 NAM window	32
Figure 5.3 Network of 50 nodes generated in NAM.....	32
Figure 5.4 Trace file format	32
Figure 5.5 DSR trace file	33
Figure 5.6 Mobility scenario for Random waypoint.....	36
Figure 5.7 Mobility scenario for Gauss-Markov	37
Figure 5.8 Mobility scenario for Chain model	37
Figure 6.1 Number of nodes vs. PDR for AODV	41
Figure 6.2 Number of nodes vs. End to End delay for AODV.....	42
Figure 6.3 Number of nodes vs. Throughput for AODV	43
Figure 6.4 Number of nodes vs. PDR for DSR	44
Figure 6.5 Number of nodes vs. End to End delay for DSR	45
Figure 6.6 Number of nodes vs. Throughput for DSR.....	46

List of Tables

Table 6.1 Parameters used in Simulation.....	39
Table 6.2 Number of nodes vs. PDR in AODV.....	40
Table 6.3 Number of nodes vs. End to End delay for AODV.....	41
Table 6.4 Number of nodes vs. Throughput for AODV.....	42
Table 6.5 Number of nodes vs. PDR for DSR.....	43
Table 6.6 Number of nodes vs. End to End delay for DSR.....	44
Table 6.7 Number of nodes vs. Throughput for DSR.....	45

List of Abbreviations

MANET	Mobile Ad-hoc Network
VANET	Vehicular Ad-hoc Network
FANET	Flying Ad-hoc Network
AODV	Ad-hoc On-demand Distance Vector
DSR	Dynamic Source Routing
LAN	Local Area Network
UAV	Unmanned Aerial Vehicle
PDR	Packet Delivery Ratio
DSDV	Destination Sequenced Distance Vector
AOMDV	Ad-hoc On-demand Multipath Distance Vector
ZRP	Zone Routing Protocol
TORA	Temporarily Ordered Routing Algorithm
HWMP	Hybrid Wireless Mesh Protocol
RPGM	Reference Point Group Mobility Model
OBU	On Board Unit
AU	Application Unit
RSU	Road Side Unit
GPS	Global Positioning System
GPMOR	Geographic Position Mobility Oriented Routing
LANMAR	Landmark Routing Protocol
DREAM	Distance Routing Effect Algorithm for Mobility
GPSR	Greedy Perimeter Stateless Routing
WRP	Wireless Routing Protocol
RGR	Reactive Greedy Reactive
EGM	Enhanced Gauss-Markov
RGIM	Random Gauss Integrated Model
NAM	Network Animator
NS	Network Simulator
OLSR	Optimized Link State Routing
FSR	Fisheye State Routing
MANET	Mobile Ad-hoc Network
VANET	Vehicular Ad-hoc Network
FANET	Flying Ad-hoc Network
ZRP	Zone Routing Protocol
TORA	Temporarily Ordered Routing Algorithm
HWMP	Hybrid Wireless Mesh Protocol
RWPM	Random Waypoint Model
GMM	Gauss-Markov Model
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
FTP	File Transfer Protocol
HTP	Hypertext Transfer Protocol

Chapter 1

Introduction

This chapter discusses about Wireless Network, Wireless Ad-hoc network i.e. MANET, VANET, and FANET along with the characteristics. Also, the routing protocols i.e. AODV and DSR are discussed along with its working.

1.1 Wireless Network

Wireless Network refers to the network which uses radio signals for communication between two or more computers or networking devices [1]. Wireless network is also known as WiFi network or Wireless LAN. In this network the computers are connected without the need of cables. Wireless network is gaining popularity today as the setup cost and complexity is very low.

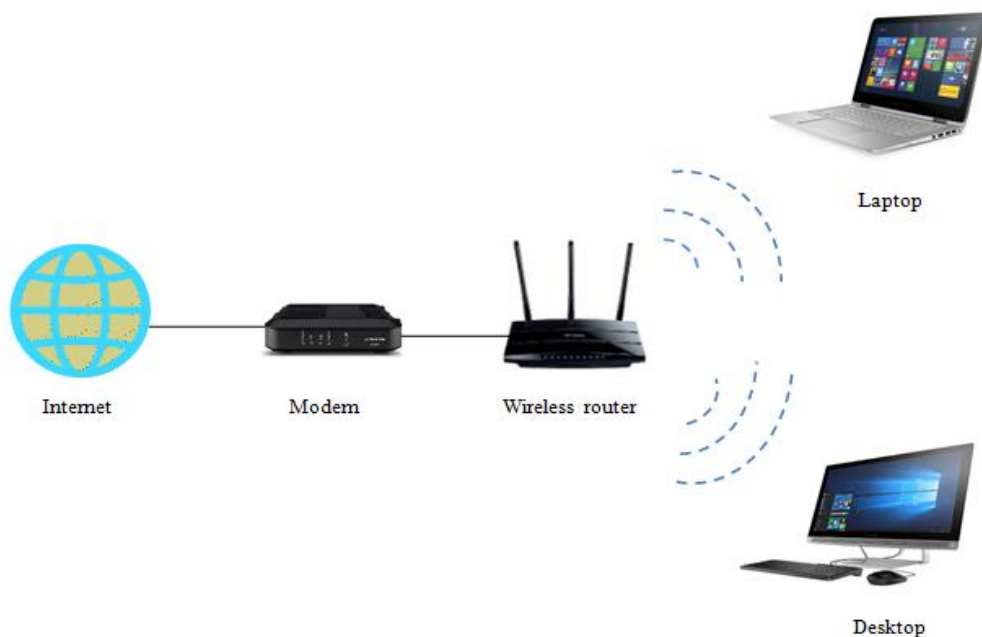


Figure 1.1 Wireless Network

1.1.1 Characteristics of Wireless Network

The various characteristics of wireless network due to which it gained popularity are listed below [2]:

- **Mobility:** In wireless communication network the user can get the information from anywhere in the world without the need of a wired connection.
- **Simplicity:** The wireless network is very easy to setup as compared to wired network. In wireless network, the various advantages overcome the starting high deployment cost.
- **Reachability:** In wireless communication network the users are connected and are reachable without any worry of their operating site.
- **Maintainability:** In wireless network very less cost is required to maintain the connection setup.
- **Roaming services:** In wireless communication network the people can get services at all places at any time such as trains, buses and airplanes.
- **Easy setup:** The installation of setup is easy and cost effective in wireless network as there are no wired connections required.
- **Expandable:** The wireless network can be easily expanded with existing equipments, whereas a wired network requires extra wiring.

1.2 Wireless Ad-hoc Network

It is a network which comes in the decentralized category. In this wireless network, the temporary connection is formed by connecting one computer to another computer without connecting to router or any WiFi access point. Ad-hoc network means there is no pre-defined infrastructure required to form network between nodes. In this network, the decentralized feature increases its applicability in various applications. Wireless ad-hoc network is having further classifications on the basis of applications [3] as given below.

1.2.1 MANET

A Mobile Ad-hoc Network is the system in which nodes are connected wirelessly with no utilization of infrastructure. In this network, the nodes are self configured and self organized continuously [3]. In MANET, the network is created and joined “on the fly” basis. The various characteristics of MANET are described below [4]:

- **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.

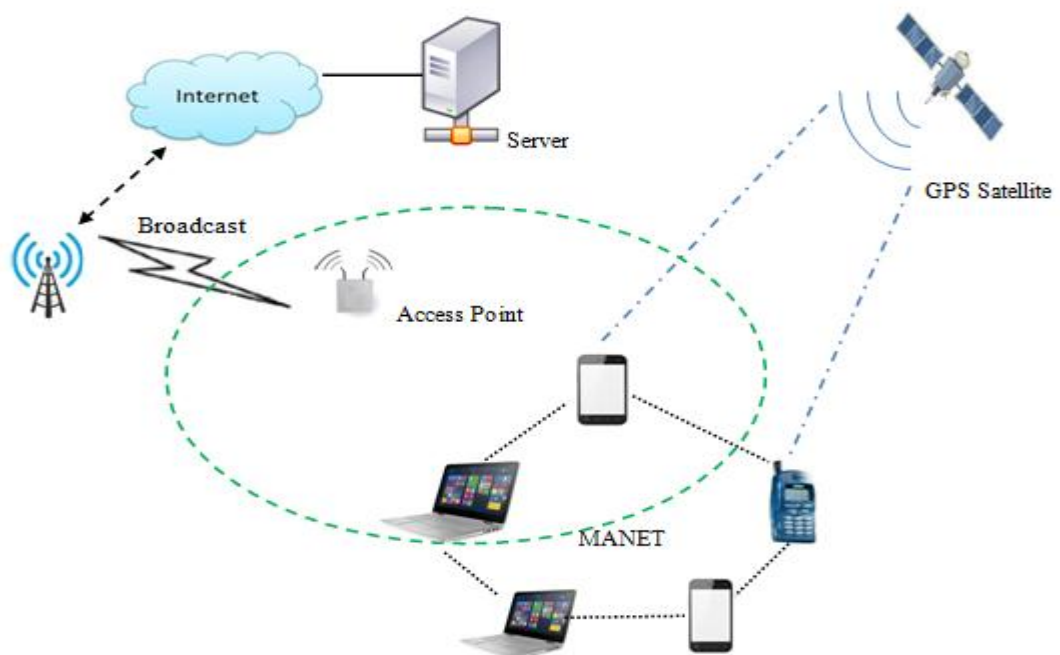


Figure 1.2 Mobile Ad hoc Network

1.2.2 VANET

Vehicular Ad-hoc Network is a category of MANET in which vehicle is used as mobile node. In VANETs the vehicles communicate either with the other vehicles named as Vehicle to Vehicle (V2V) communication or with the Road Side Units named as Vehicle to Infrastructure (V2I) communication [5]. As similarity to MANET, VANET does not need any infrastructure for network setup. The various characteristics which make VANET different from MANET are described below:

- High mobility: In VANET, the nodes move at high speed during communication 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.

The architecture of VANET contains three components [5]:

- OBU (On Board Unit),
- AU (Application Unit) and
- RSU (Road Side Unit).

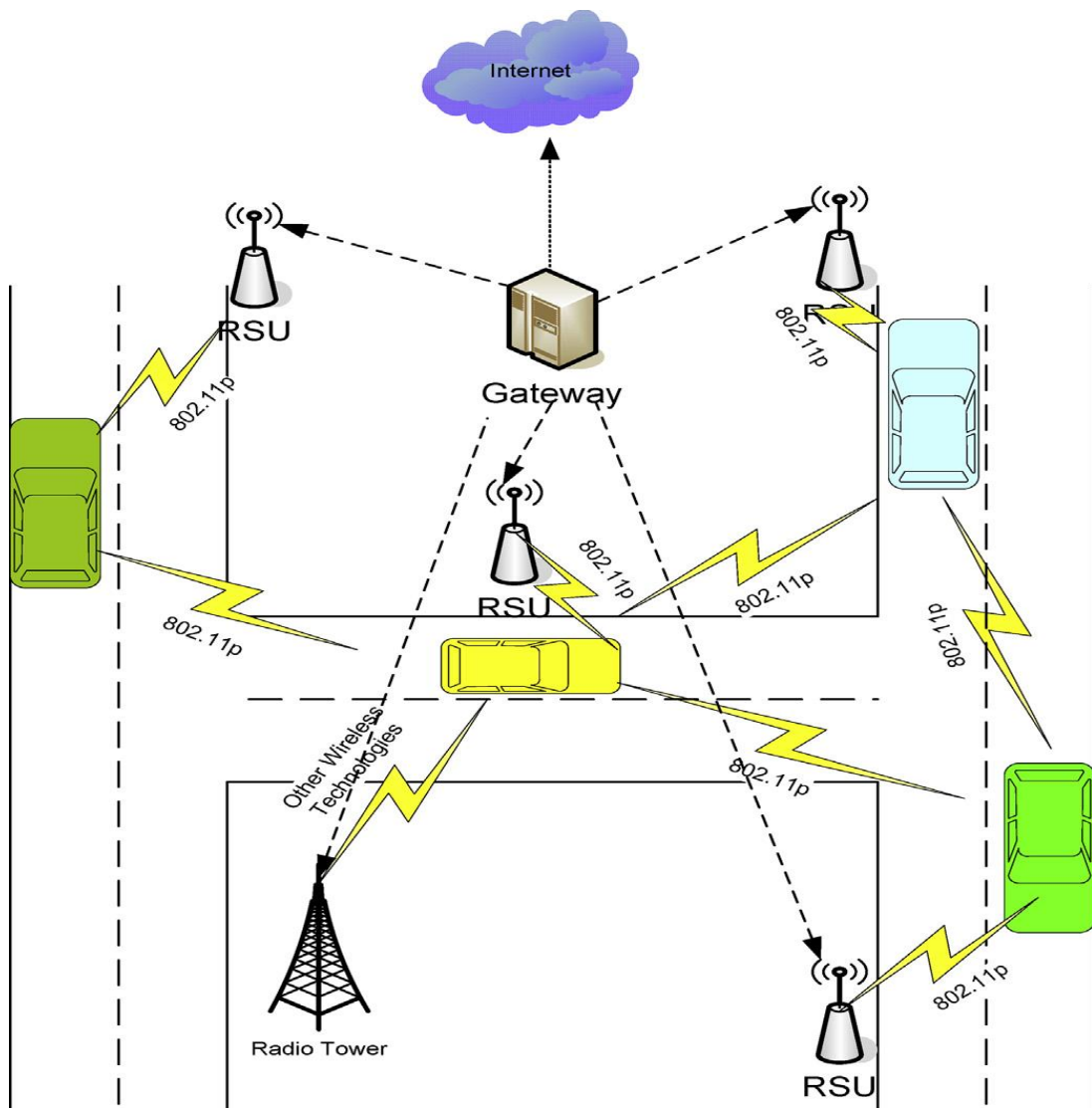


Figure 1.3 Vehicular Ad hoc Network [5]

RSU provide services to the clients by acting similar to a router whereas OBU and AU are the consumers for these services. OBU is a device mounted on a vehicle and is utilized to exchange data with RSU or with another OBU. OBU is also used for providing communication with AU. AU is the device capable of providing safety applications and also provides communication with RSU with the help of OBU. AU can act as an independent unit or can be combined with OBU to form a single unit. RSU is a device commonly fixed along the side of road or in committed areas, for example, at the junction or near parking spots. RSUs are fixed along the roadside in a way so that the connectivity and coverage of the vehicles is preserved. The OBUs and AUs communicate with RSUs is possible with the use of wireless standards, for example, IEEE 802.11p, IEEE 802.11 a/ b/g. The architecture of VANET having different components is shown as above in Figure 1.3.

1.2.3 FANET

Flying Ad-hoc Network is a specialized category of Mobile Ad-hoc Network. In FANET, the network is between Unmanned Aerial Vehicles (UAVs). In FANET, UAVs fly independently without carrying any human personnel [6]. FANET is less costly and fast to deploy compared to MANET and VANET. These features make FANET an exceptionally appealing innovation for some nonmilitant and militant applications. FANET allows sending data rapidly and precisely in a circumstance, where non-specific ad-hoc networks are unable to do so. During natural disaster like floods, earthquakes FANET perform superior to other network types.

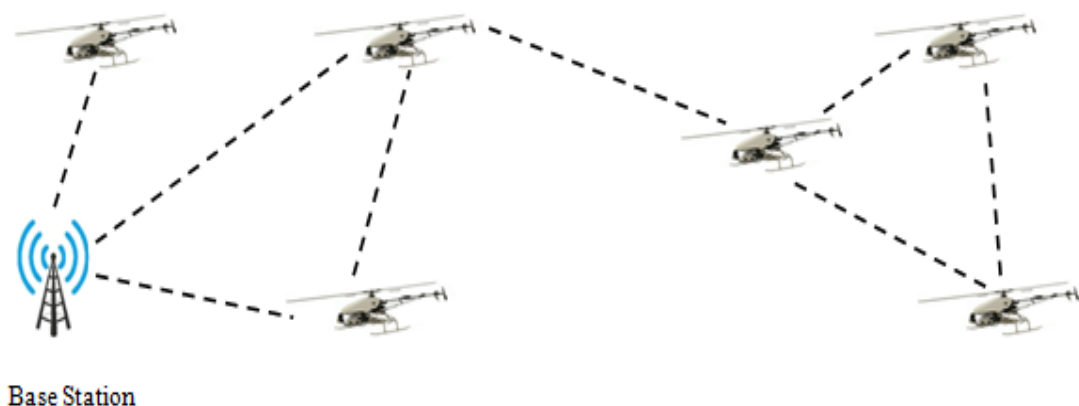


Figure 1.4 Flying Ad hoc Network

In FANET, multiple Unmanned Aerial Vehicles form a network as the capability of having only one UAV is limited. There are various advantages of having multi-UAV system are described as follow:

- Cost: The cost of buying and maintaining many small UAVs is very less than of a large UAV.
- 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: If mission is carried with single UAV the mission will not proceed if the UAV fails but in multiple UAVs system the mission will proceed with other UAVs.

1.2.3.1 Applications of FANET

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

- Remote sensing: Unmanned Aerial Vehicles are used as a very reliable and flexible way to do remote sensing of agricultural field. Remote sensing also finds it role in weather forecasting.
- Disaster monitoring: FANET is used in transferring the data collected from the disaster affected area to the base station for monitoring.
- Search and Rescue operations: Unmanned Aerial Vehicles has the ability to carry resources for search and rescue operation.
- Wind estimation: Unmanned Aerial Vehicles are used for estimating the direction and speed of wind.
- Border surveillance: Unmanned Aerial Vehicles are equipped with cameras at border areas for detecting, tracking and recognizing unauthorized intruders.
- Relay for ad hoc networks: Unmanned Aerial Vehicles at lower altitude provides relay services to MANET. UAVs also used as a relay to send data from user on ground to remote base station.
- Managing wildfire: Unmanned Aerial Vehicles captures the images of the burned area and to the base station this information is forwarded.

1.3 Routing Protocols

Routing protocols are used to specify the router how it will communicate with other routers. It facilitates to find most appropriate route that starts from source node and ends at destination node for packet forwarding.

1.3.1 Ad hoc On-demand Distance Vector

AODV routing protocol is created for wireless ad-hoc network having mobile nodes. It is designed for unicast as well as multicast routing. In AODV, route is found only if it is requested by starting node and because of this feature it is known as on-demand routing. In AODV, the route is active for the time the packets containing data travel from origin node to target node. The route will close when source stop sending packets. This routing protocol is considered as a reactive one.

1.3.1.1 Characteristics of AODV

- The routes are developed on demand in AODV. To find the current route to the target, the destination sequence number is used. The delay of setting a connection is very low.
- It supports the route which is congested least rather than the route which is shortest. It supports the packet transmission of both unicast and multicast for nodes which move constantly.
- It reacts rapidly to the topological changes that influence the route which are active.
- It doesn't use the source routing because of which there is not any extra overhead on the data packets
- Loop free routes are provided in AODV.

1.3.1.2 Working of AODV

In AODV, for operation the control message types used are defined as follow [7]:

- RREQ: When any node wishes to determine a path for any target node, route request message is broadcasted. The intermediate node in a network uses this message to update its routing tables. The RREQ message contains the following fields:

- RREQ id
 - Destination sequence number
 - Destination IP address
 - Originator sequence number
 - Originator IP address
- RREP: Upon reaching of RREQ message at target, that node unicast route reply message backward to the origin node. A RREP message is generated by node only whenever its route to destination is active or it is the target node. As the RREP message propagates back, the routing tables are updated by the intermediate nodes. The RREP message contains the following fields:
 - Destination IP address
 - Originator IP address
 - Lifetime
 - Destination sequence number
 - RERR: Route error message is broadcasted only when the link fails. RERR message is used only if the active route is no more valid or the node is not able to communicate with the neighbor node. The RERR message contains the following fields:
 - Unreachable destination sequence number
 - Unreachable destination IP address

1.3.1.3 Routing in AODV

The routing in AODV is shown in Figure 1.5. There are two phases used in AODV routing approach described as follow:

- Route Discovery: This phase is needed whenever an origin node wants to forward any packet to the target node. In this phase, RREQ messages are broadcasted to the neighbor nodes. As the RREQ message propagates, the routing tables are updated by the intermediate nodes. This RREQ message is forwarded by the node if it is not destination node. On reaching of RREQ message at target, the target node revert back the RREP message to the origin node. This way path for communication between nodes is discovered.

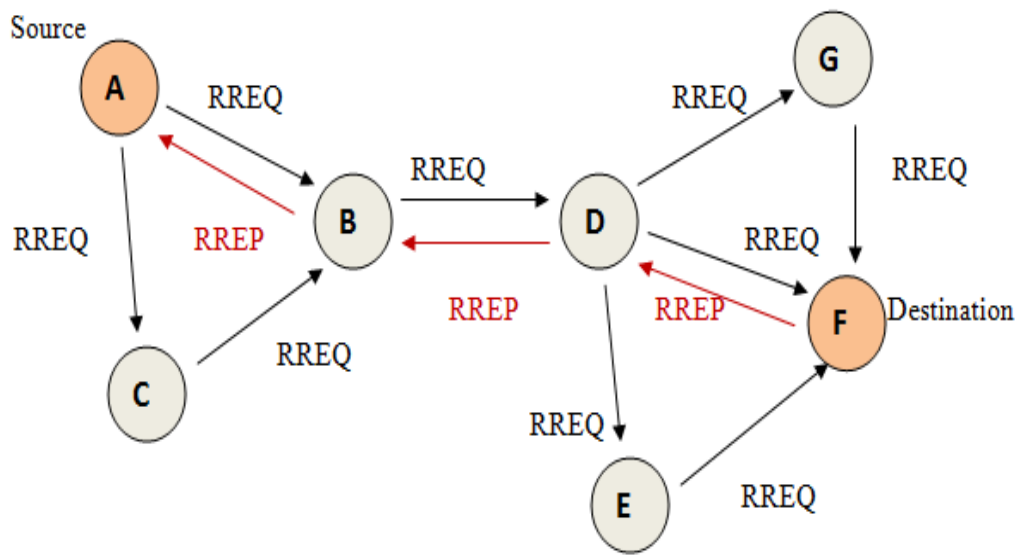


Figure 1.5 Message routing in AODV [7]

- **Route Maintenance:** When the node finds that any route is invalid for communication, the RERR message is sent to the neighbor nodes by that particular node. This RERR message is propagated towards the origin node. Whenever the origin node gets RERR message, it either starts the mechanism of rebroadcasting RREQ message in the network or it will stop sending data through the invalid route.

1.3.2 Dynamic Source Routing

It is an on-demand routing protocol efficient to perform routing in MANETs. Using DSR, the nodes form a self-configured and self-organized network without the requirement of predefined infrastructure. Because the nodes in the network move dynamically, the routing is automatically decided and its maintenance is done by the DSR protocol. The DSR protocol enables nodes to find a source path dynamically in multiple network hops for a target node. It is used specially to find a route in a multi-hop wireless ad-hoc network. As compared to other protocols, DSR does not need periodic packets within the network.

1.3.2.1 Characteristics of DSR

- In DSR the network bandwidth is reduced and the generation of large routing updates is avoided in the network as DSR does not use periodic messages for routing.
- It can adjust rapidly to changes, for example, host movement.
- In DSR, the whole route is enclosed in the header packet, so to route a given packet containing data, there is not any need to manage the routing table.
- In DSR, only between those nodes which communicate, the routes are maintained.
- In DSR the route caching reduces the overhead on route discovery process. This is because a one route discovery results in multiple routes from the origin node to the target node.
- In DSR, the loop-free routing is ensured and if there are changes in the routes in network the recovery is very fast.
- In DSR, the perfect routes are found out when the links are asymmetric in the network.

1.3.2.2 Working of DSR

In this protocol, the mobile nodes are responsible for storing all the routing data and it purely works on the basis of source routing. DSR protocol includes the following two mechanisms which are used to discover and maintain source route in network [8]:

- **Route Discovery:** This mechanism is useful when an origin node wishes to forward data to a target node. Also the node which needs to forward packet attains a source route to target node. In the mechanism, the source node places a source route providing the order of hops followed by the packet on its way to destination node in the header of packet.

Figure 1.6 illustrates route discovery mechanism, where origin node “A” attempts to determine a path to target node “E”. At starting of this phase, a Route Request message is transmitted, which is collected by nodes inside transmission scope of “A”. The route request message finds the starting and ending node of the path. In each message a separate request id is contained which is decided by the request initiator. In every route request the record having the address of every intermediary node is

contained through which the specific copy of the route request message is sent. The initiating node of the route discovery process initializes the route record with the null list.

At the point whenever any node gets a route request message, in the case it is the destination of the route discovery process, a route reply message to the initiator is restored and the copy of the collected route record is provided.

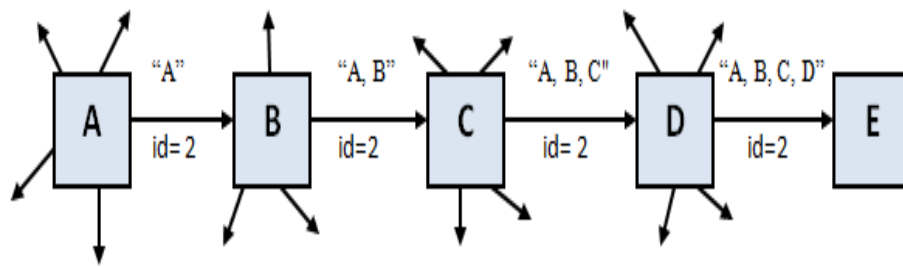


Figure 1.6 Route Discovery mechanism [8]

- **Route Maintenance:** It is utilized by originator node to recognize link breakage when the topology of network changes. At the point when link breakage is identified by route maintenance mechanism, the other route for destination known by origin node is used or Route Discovery mechanism is invoked to find different route. This mechanism is utilized exclusively if origin node is really sending packets to target node.

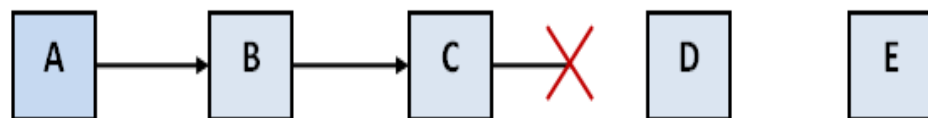


Figure 1.7 Route Maintenance mechanism [8]

If any packet is transmitted for many numbers of times by some hop and affirmation of receipt is not obtained, the link over which the data couldn't be sent is recognized

and a ROUTE ERROR message is returned by the node to the origin of data. Figure 1.7 illustrates the example of route maintenance where node “C” is not able to convey the data to the next node “D”. In this case, the node “C” restores the Route Error message to node “A”, expressing the breakage of connection from node “C” to node “D”.

1.4 Chapterization

The organization of rest of the thesis is as given below:

Chapter 2 describes the literature review of the related work done on various FANET reactive routing protocols along with other routing protocols. This chapter also reviews the related work done on existing mobility models i.e. RWPM, GMM and chain model.

Chapter 3 describes the research gaps encountered from literature review and problem statement of this work. Also the methodology to be followed in this research is discussed in details.

Chapter 4 discussed the proposed chain mobility model in details. Also the algorithms of RWPM, GMM, and Chain mobility model are explained.

Chapter 5 discussed about the network simulation along with its installation and about the implementation of mobility scenarios generated by mobility models used in research.

Chapter 6 explains the simulation results obtained by using different mobility scenarios on routing protocols in FANETs and also analysis of the simulation done is discussed in detailed manner.

Chapter 7 presents the conclusion along with the unique contribution and limitation. At the end, the future scope of this research is described.

1.5 Summary

This chapter provides detailed information about the wireless ad-hoc networks such as MANET, VANET and FANET and about routing protocols such as AODV and DSR along with its characteristics and working.

Chapter 2

Literature Survey

In the following chapter, literature review is done on various routing protocols and mobility models in FANETs.

2.1 Routing in FANETs

Routing is a mechanism that decides how nodes will route the packets between source and target in a network. Routing protocols in FANET are categorized into five categories: Proactive protocols, Reactive protocols, Hybrid protocols, Position/Geographic based protocols, Hierarchical protocols [9].

2.1.1 Proactive Protocols

In Proactive routing, tables are used to store latest route data of each node in the network. In this routing, shortest direction is mostly likely to get because each node is having connectivity graph. Some Proactive protocols are FSR, Optimized Link State Routing Protocol (OLSR) [9].

2.1.2 Reactive Protocols

Reactive protocol establish route between nodes only when required. It uses RouteRequest and RouteReply messages for communication between nodes. Examples of Reactive protocols are AODV, DSR. It is also referred as on-demand routing protocol.

2.1.3 Hybrid Protocols

Hybrid protocol is formed by combination of proactive and reactive protocol. It overcomes the limitation of extra time needed to discover route in reactive protocol and huge overhead of control messages in proactive protocol. ZRP, TORA and HWMP [9] are some examples of Hybrid protocols.

2.1.4 Position/Geographic based protocols

It uses physical position information of the nodes in network for routing. Each node calculates the location through GPS or by other positioning facility. Some examples

of Geographic based protocols are GPSR, Geographic Position Mobility Oriented Routing (GPMOR).

2.1.5 Hierarchical protocols

In hierarchical routing protocol, the reactive and proactive routing is chosen on the basis of hierarchic level. In this routing, firstly some proactive routes are used and then reactive protocols are used at lower level. This protocol use hierarchy model to find route. Some examples of hierarchical routing are Landmark Routing Protocol (LANMAR) and DREAM.

The reactive routing protocols are analyzed and compared with other routing protocols by various research fellows as following:

S. K. G and Mr. P. V. Parande [10] compared AODV, AOMDV and DSDV routing protocol in FANET environment. NS-2 simulator is used for analyzing the performance of routing protocols and performance parameters PDR, End to End Delay and Throughput are considered. The parameters are analyzed by taking different speed of mobile nodes. The simulation results show that performance of FANET is optimized using AODV routing protocol as AODV perform better than AOMDV and DSDV.

Danil S. Vasiliev et al. [11] compared AODV, OLSR and HWMP (Hybrid Wireless Mesh Protocol) routing protocols in FANETS. The author experiments on Quality of Service metrics i.e. hop count, Packet Delivery Ratio, overheads using NS-3 simulation tool. The simulation results show that HWMP routing protocol gives high PDR when comparison is done with other protocols.

P. Rohal et al. [12] studied the performance of DSDV (proactive), AODV and DSR (reactive) protocols in mobile ad hoc network environment. The DSDV, AODV and DSR performance is calculated by using delay, throughput and PDR metrics in NS2. The number of nodes varies from 50 to 250 for calculating metrics. From the results it is concluded that reactive protocols give improved results than proactive routing protocol.

L Raja and Dr. S. S. Baboo [13] compared the performance of reactive routing protocols AODV, DSR and TORA in mobile ad hoc network. The authors evaluated the end to end delay and packet delivery ratio for routing protocols by varying the

number of nodes and time using NS2 simulator. The AODV protocol gives the best all round performance. DSR protocol is best suited for moderate mobility rate network. TORA protocol is suitable for network having high population of nodes.

M. Safdar et al. [14] studied AODV, DSDV, DSR and OLSR protocols using NS2 simulator. The performance analysis these protocols for throughput, delay and routing overhead is done using NS2 simulation tool. From the results it is concluded that AODV is the best for Mobile Ad hoc Network.

S. K. Patel et al. [15] calculated TCP performance over MANET routing protocols. The DSR, AODV and WRP protocols are simulated using GloMoSim simulator. The routing protocols are analyzed for delay, throughput, packet delivery ratio and routing overhead performance parameters.

2.2 Mobility Models

Mobility models are designed to represent the movement pattern of nodes and it also represents how the node changes its location, acceleration and velocity over time. A realistic simulation environment created using mobility model play a major role in evaluating ad hoc routing protocols performance. The performance of protocols varies significantly by using different mobility models. Figure 2.1 given below shows the mobility models used in FANET [16].

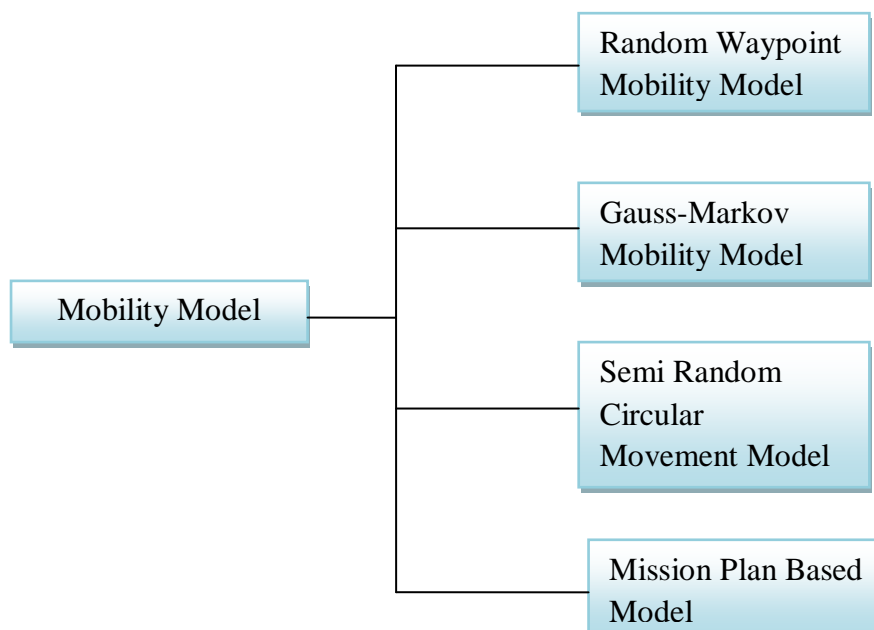


Figure 2.1 Mobility Models in FANETs [16]

2.2.1 Random Waypoint Mobility Model

The Random Waypoint Mobility Model uses pause time before changing the node direction or speed. In the simulation area, the nodes move freely in random directions with any speed using random based mobility model. In FANET, the UAVs which move randomly in this model, decide their action on the basis of fixed probabilities. This mobility model depends on three activities: “go straight”, “turn left” and “turn right” [17]. Figure 2.2 shows the node movement in random waypoint model. Random Waypoint mobility model is used for Ad hoc wireless network by various research fellows as discussed below:

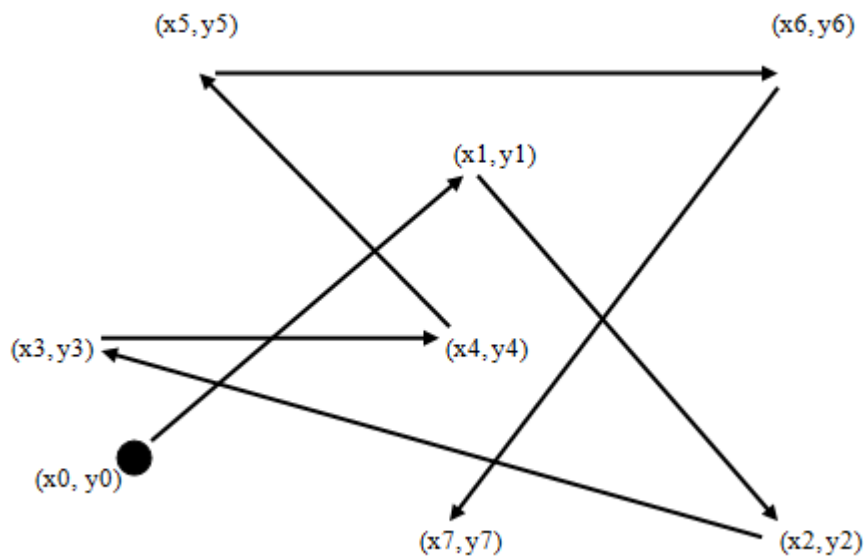


Figure 2.2 Node movement in random waypoint model [16]

P. Sharma and I. Yadav [18] performed simulation on improved RGR protocol under Random Waypoint mobility model over a FANET network. The results show that performance of RGR protocol is improved in terms of performance metrics Delay and Throughput when compared to original AODV and RGR protocol.

Alexey V. Leonov [19] performed experimental analysis on protocols AntHocNet and BeeAdHoc to solve the routing problems in FANET. The simulation is done under RWPM using NS-2 simulator. The performance of protocols is analyzed using Throughput, Routing Overhead and Delay parameters. The results show that bio-inspired algorithms AntHocNet and BeeAdHoc are more efficient when compared with AODV, DSDV and DSR protocols.

G. Gankhuyag et al. [20] proposed a novel directional hybrid routing scheme with enhancement of AODV routing protocol for FANETs. The proposed hybrid routing uses both unicast and geocast routing. The proposed routing is compared with the traditional AODV routing by using Random Waypoint mobility model for success of route setup and lifetime of active path. The results show that enhanced AODV routing performs better than traditional AODV.

J. M. M. Biomo et al. [21] optimized the RGR routing protocol for recovery strategy in Unmanned Aerial Ad-hoc Network. The performance evaluation is done using OPNET under RWPM for PDR, delay and control overhead. The results show that optimized RGR performs better for packet delivery ratio when compared to modified RGR.

P. Gupta and S. Gupta [22] evaluated the mobility effect on AODV, DSDV, OLSR and DSR using RWPM. The protocols are simulated on NS2 simulator using parameters PDR, Delay and routing load. The performance parameter values are obtained by varying node density (20, 30, 40, 50 and 75) and node speed (10, 20, 30 and 40). The results show that AODV give better performance compared to other protocols.

2.2.2 Gauss-Markov Mobility Model

In the Gauss-Markov Mobility Model each mobile node is initialized with a particular speed and direction. After fixed interval of time the speed and direction of each node is updated. To be precise, the value of nodes direction and speed at n^{th} instance of time is calculated on the basis of direction and speed value at the $n-1^{\text{st}}$ instance of time. This model is used for the simulation of UAVs behavior in a swarm. Figure 2.3 given below shows the node movement in Gauss-Markov model as per earlier node position. Gauss-Markov mobility model is used for Ad hoc wireless network by various research fellows as discussed below:

J. M. M. Biomo et al. [23] proposed Enhanced Gauss-Markov (EGM) mobility model for Unmanned Aerial Vehicles. The EGM model eliminates rapid pause and quick turning of mobile vehicles. The simulation is done with OPNET to analyze the performance of routing protocols in terms of packet delivery ratio. The results show that EGM produces large number of network partitions when compared to Random Waypoint mobility model.

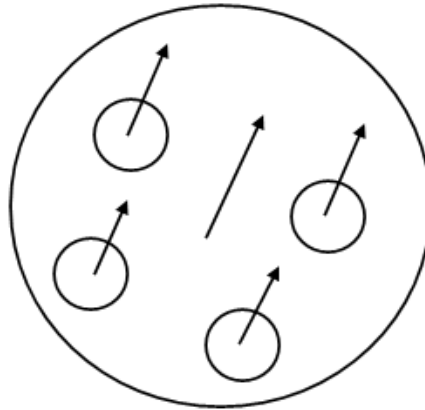


Figure 2.3 Node movement in Gauss-Markov model [16]

Lin Lin et al. [24] proposed a geographic mobility prediction routing protocol, MPGR for AdHoc UAVs network. The simulation is based on Gauss mobility model. From the results it is concluded that MPGR outperforms AODV and GPSR in terms of end to end delay and packet delivery ratio.

D. Chenghao [25] improved DSR routing protocol using Gauss Markov mobility model for reducing impact of mobile node movements in simulation area. The simulation results calculated using Qualnet shows improvement in performance of improved DSR routing protocol in terms of PDR, throughput, delay and jitter when compared with original DSR routing protocol.

M. Alenazi and C. Sahin [26] modified the NS-3 implementation of 3D Gauss Markov mobility model. From the results, it is observed that in improved model the mobile nodes follow smooth movements by avoiding reaching at boundaries of simulation area.

2.2.3 Semi Random Circular Movement Model

The Semi Random Circular Movement Model is created for the UAVs moving in curved scenarios. This mobility model simulates the UAVs turning around a definite position to gather information. The semi random circular movement model is used for UAVs, the flight plan of which is not determined before. At each moment, each airplane looks at distinct position and the desired object in a square range is picked up as shown in figure 2.4.

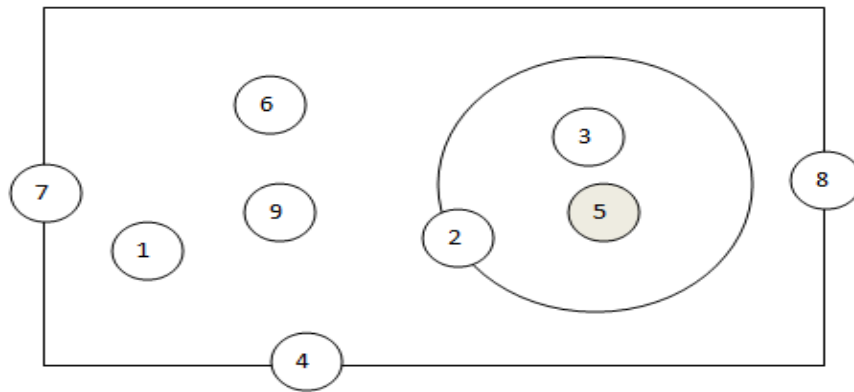


Figure 2.4 Semi Random Circular Movement model [16]

2.2.4 Mission Plan Based Model

In Mission Plan Based Model, the aircraft is having complete and planned awareness about whole trajectory information. It infers that the aircraft moves on the predetermined path to reach at mission area. In this mobility model, the mobility of aircraft after some particular period of time is updated frequently. In this model, if aircraft is assumed to move towards or far from goal. For every aircraft, the velocity and flight time of aircraft is decided before while starting and ending point are selected randomly. Figure 2.5 shows the aircraft which has to reach at mission area using mission plan based model.

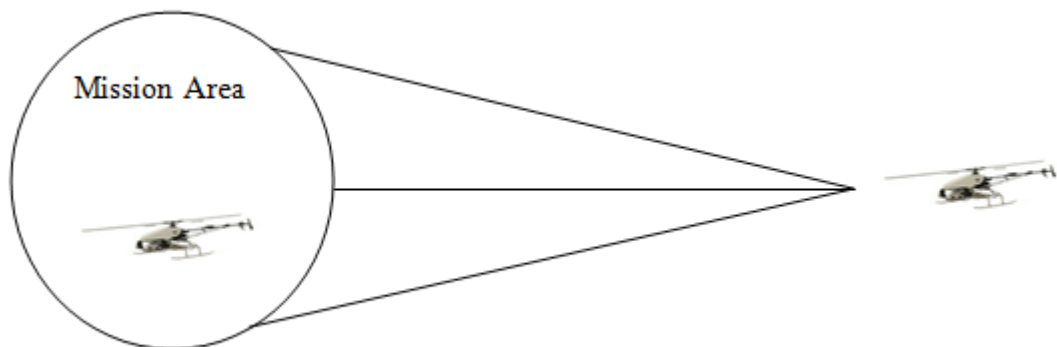


Figure 2.5 Mission Plan Based model [16]

2.2.5 Chain Mobility Model

The chain model is concatenation of various mobility models (Random Waypoint, RPGM, Manhattan Grid, Gauss-Markov). In chain model, the final position of node in $n-1^{\text{th}}$ scenario is connected with first position of n^{th} scenario. The 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 [27] 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 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 [28] compared chain mobility model (Random Waypoint model and Manhattan Grid model) with Random Waypoint model. The different performance parameters like throughput, delay and PDR 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. [29] compared the performance of Random Waypoint, RPGM, Manhattan and Freeway mobility models in 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 sparse network.

2.3 Summary

This chapter discussed about the related work done on reactive routing protocols and about existing mobility models such as Random Waypoint model, Gauss-Markov model and chain model by various authors.

Chapter 3

Problem Statement and Methodology

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. The third section presents the objectives of this research and the last section briefs methodology used in the present work.

3.1 Research Gaps

This section explains the gaps which are encountered while reviewing the existing work done in the area of mobility models in wireless ad-hoc networks.

- i. In wireless ad-hoc networks, the chain mobility model is mainly formed by integrating Manhattan Grid mobility model and Random waypoint model [27, 28]. 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.
- iii. The existing work is done in bits and pieces and not well conclusive regarding mobility models applicable in FANETs.

3.2 Problem Statement

In flying ad-hoc network, routing is a major issue of concern. It is a tedious task to improve various Quality of Service (QoS) performance parameters like delay, packet delivery ratio and throughput. Mobility model plays a major role to evaluate the performance of the routing protocols. In FANETs, the implementation of different routing protocols is done with the help of various mobility scenarios. Mobility models are used to generate these mobility scenarios in wireless ad-hoc network. It requires in depth study and analysis to choose the mobility models for routing in FANETs. The purpose of the work is to find effective scenarios in mobility model to improve various QoS parameters.

3.3 Objectives

The objectives of this research are outlined below:

1. To study various existing mobility models in FANETs.
2. To carry out simulation on selected routing protocols for FANET using different mobility models.
3. To propose an effective mobility model for selected routing protocols.
4. To compare and validate proposed mobility model for End to End Delay, Packet Delivery Ratio and Throughput performance parameters with existing mobility models.

3.4 Methodology

Purpose of this research is to improve the performance of FANETs routing protocols for various performance parameters. This is achieved by using the proposed chain mobility model defined further in this chapter and by following the methodology as shown in Figure 3.1 which is explained below in details:

Step 1: Initially, the simulation environment for AODV and DSR routing protocol is created using simulator. Also the mobility scenarios of various mobility models such as Random Waypoint model and Gauss-Markov model are generated.

Step 2: The generated mobility scenarios are used by AODV and DSR for simulation. Then for AODV and DSR routing protocol trace files are generated by varying the mobility scenarios used.

Step 3: The user can view the topology of the AODV and DSR routing protocols using the NAM tool, which is used to animate the simulation trace file.

Step 4: The user can also compare the performance of reactive routing protocols using the mobility scenarios. For this purpose, firstly AWK scripts are created and then used to get the values of performance parameters like Packet Delivery Ratio, Throughput and End to End Delay from trace files.

Step 5: Results of routing protocols are compared and analyzed by generating graphs for various performance parameters. The simulation analysis is done to obtain best mobility model for reactive protocols in FANET.

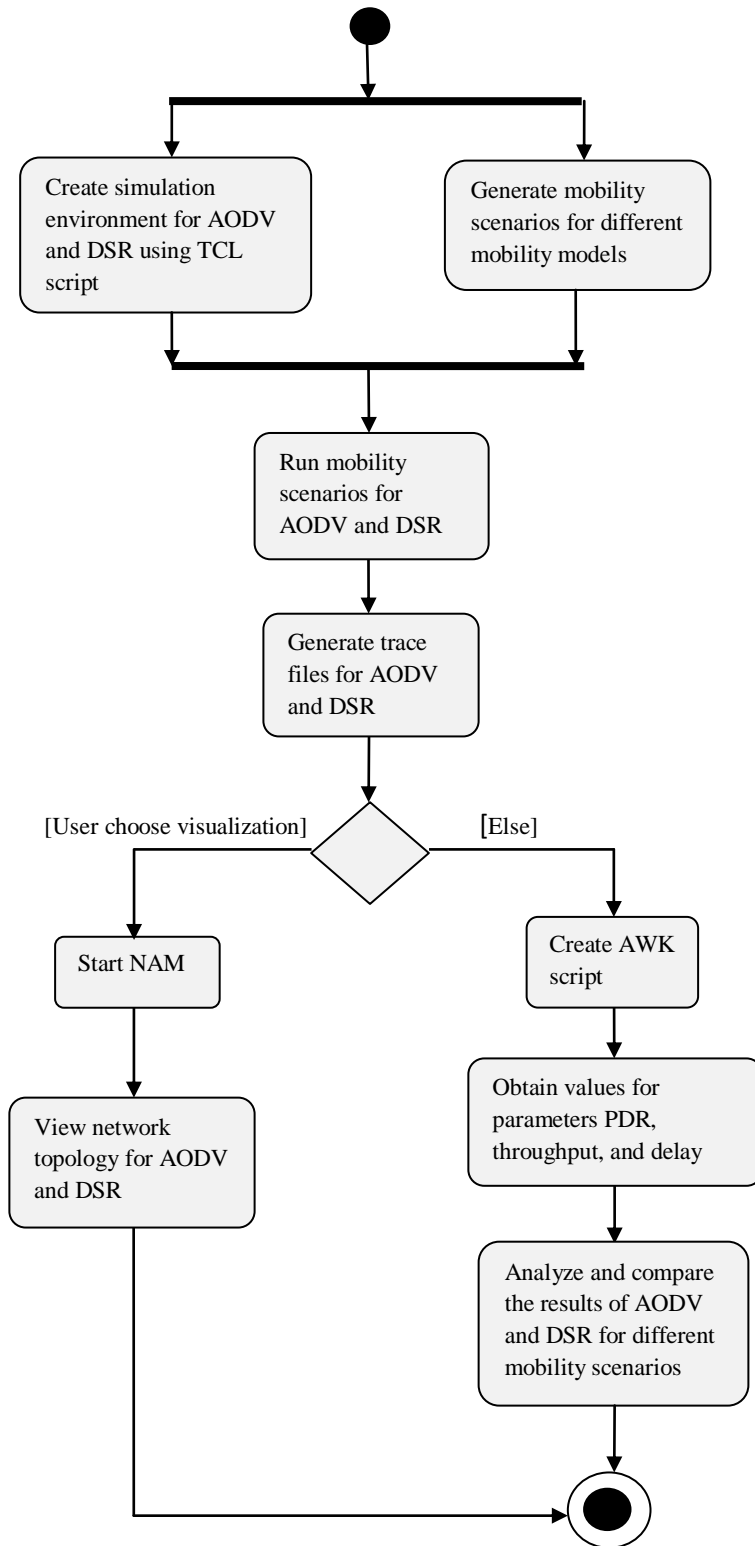


Figure 3.1 Activity Diagram showing Methodology

In the methodology, the scenarios are generated using mobility models and are applied on AODV and DSR routing protocols to compute and analyze the results obtained from the simulation.

3.5 Summary

In this chapter, the research gaps in the study are discussed first. Then problem statement and objectives of the work are defined. The chapter explains the methodology which is to be followed to perform the research work.

Chapter 4

Proposed Model

This chapter explains the chain mobility model which is proposed in this research. The algorithms used for chaining i.e. RWPM and Gauss-Markov model are explained in details. Also, the algorithm of the proposed model is defined.

4.1 Components of Proposed Chain Mobility Model: RGIM

To analyze the performance of routing protocols in FANET, a new chain model is proposed. The proposed model is formed by integrating two mobility models i.e. Random waypoint model and Gauss-Markov model. In proposed chain mobility model, for integration, Random Waypoint model and Gauss-Markov model are selected because from the existing research it is found that these two mobility models are mainly used for simulation of FANET routing protocols [18, 19, 20, 21, 23, and 24]. Various tools are used for simulation of routing protocols. In this research, NS-2 is used because it is one of the widely used network simulator by research fellows for simulation of FANET routing protocols [10, 19].

The existing Random waypoint model and Gauss-Markov model are explained in the form of algorithms as given below. The algorithm gives the steps that must be followed for the completion of a process.

4.1.1 Random Waypoint Model

Random waypoint model allows nodes to move randomly in any direction with random speed within the simulation area. Using this model, the nodes decide their movement based on fixed probabilities. This model uses pause time before changing the node speed or direction.

Random Waypoint Model is one of the simplest and easiest to use model. This model can be used to build other mobility models [30]. This model is included in network simulator (NS-2) and also in Global Mobile Simulator (GLOMOSIM) [31]. It lacks regular movement modeling because of pause time. It possess problem of speed decay, which means if the duration of simulation is increased, the average speed of

node decrease in dramatic manner [30]. The algorithm of Random Waypoint model [32] is explained below.

Algorithm for Random Waypoint Model (RWPM)

1. Define the parameters i denoting the movement duration of node and j which identifies the particular node.
2. The random waypoint for each node is represented as vector $P_i^{(j)}$
3. The movement trace of a node in Random waypoint model is as given below:

$$\{P_i^{(j)}\}_{i \in N_0} = P_0^{(j)}, P_1^{(j)}, P_2^{(j)}, P_3^{(j)}, \dots [32] \quad (4.1)$$

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:

$$\{(P_i, V_i, T_{p,i})\}_{i \in N} = (P_1, V_1, T_{p,1}), (P_2, V_2, T_{p,2}), (P_3, V_3, T_{p,3}), \dots [32] \quad (4.2)$$

4.1.2 Gauss-Markov Model (GMM)

In Gauss-Markov model, each node is given a particular speed and direction at starting. The speed and direction is updated at fixed interval of time. It states that the speed and direction at n^{th} instance of time is based on $n-1^{\text{th}}$ instance of time.

Gauss Markov Model has feature of temporal dependency, which is important characteristic to emulate the behavior in real scenario [33]. It provides more realistic behavior by addressing the problem of sudden and sharp turns in random mobility models. This model is mostly used in real life scenarios, having different levels of randomness. It is difficult to handle the communication in this model. The algorithm of Gauss-Markov model [34] is explained below.

Algorithm for Gauss-Markov Model

1. Assign initial speed, initial direction, average speed and average direction parameters for each node.
2. At set interval of time, the new speed and direction parameters are calculated as given below:

$$s_n = \alpha s_{n-1} + (1 - \alpha)\bar{s} + \sqrt{(1 - \alpha^2)s_{x_{n-1}}} \quad [34] \quad (4.3)$$

$$d_n = \alpha d_{n-1} + (1 - \alpha)\bar{d} + \sqrt{(1 - \alpha^2)d_{x_{n-1}}} \quad [34] \quad (4.4)$$

where s_n = speed of node for n duration

d_n = direction of node for n duration.

\bar{s} = mean speed

\bar{d} = mean direction

$s_{x_{n-1}}$ = random variables in Gaussian distribution to give randomness to the new speed parameter.

$d_{x_{n-1}}$ = random variables in Gaussian distribution to give randomness to the new direction parameter.

α is a constant. Its value can be 0 or 1.

If $\alpha = 0$, the speed and direction is maximized and if $\alpha = 1$ the speed and direction is minimized.

4.2 RGIM: The Proposed Chain Mobility Model

The chain model is formed by connecting final position of n-1th scenario with first position of nth scenario. The proposed model RGIM is formed by integration of Random waypoint model and Gauss-Markov model in a chain. The algorithm of RGIM is explained below:

Algorithm for Random Gauss Integrated Model (RGIM) generation

Step 1: Start

Step 2: Create the scenario for Random Waypoint model by initializing the number of nodes as n_1 , providing values to the x, y, and z coordinates and by initializing the duration parameter as d_1 .

Step 3: Create the scenario for Gauss-Markov mobility model by initializing the number of nodes as n_2 , providing values to the x, y, and z coordinates and by initializing the duration parameter as d_2 .

Step 4: If $n_1 = n_2$ and $n-1^{\text{th}}$ scenario simulation area is in scope of n^{th} scenario

Generate chain scenario with the integration of Random Waypoint model and Gauss-Markov model, having duration value equal to $d_1 + d_2$, i.e. the sum of both models duration and number of nodes will be equal to n_1 or n_2 , i.e. nodes in any of the model

Else

The chain scenario generation fails

Step 5: End

The proposed algorithm of chain mobility model is represented with the help of activity diagram as given below in Figure 4.1.

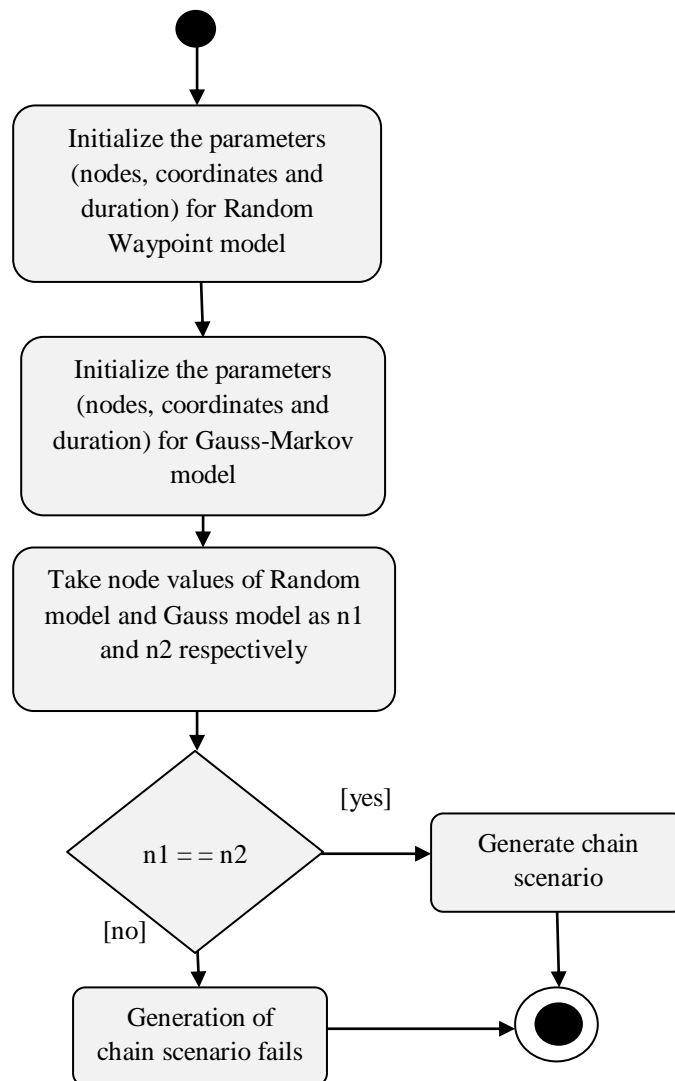


Figure 4.1 Activity diagram showing proposed chain mobility model

The proposed model is formed by integrating two mobility models: Random waypoint model and Gauss-Markov model. According to proposed model, 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.

The proposed chain model i.e. RGIM is formed only if the nodes of both scenarios i.e. Random Waypoint Model and Gauss-Markov Model are equal and the simulation area of first scenario is within scope of second scenario. If these conditions are satisfied, the chain model is generated otherwise the generation fails.

4.3 Summary

In this chapter, the proposed chain mobility model is explained in detailed manner with the help of algorithms. Integration of two mobility models i.e. Random Waypoint Model and Gauss-Markov Model has been done and a new model is proposed.

Chapter 5

Simulation and Implementation

This chapter elaborates the implementation done during the research work. Implementation details include installation of network simulator, installation of BonnMotion, implementation of mobility models to generate scenarios for creating Test bed for proposed model.

5.1 Simulation

Shannon defines the simulation as the procedure to design the model for any real system and to conduct experiments using this model to understand how the system will behave and also to evaluate different strategy to operate the system [35]. Simulation makes it possible to study, analyze and to evaluate the situations that are otherwise impossible to do. To develop a FANET for real applications is very expensive. Because of this cost, simulators are used for testing and evaluating the routing protocols. The first step of implementing any FANET protocol is performed with the simulation of routing protocol. There are various communication simulators like OPNET, NS-2 and Qualnet which present already for providing the testing platform and for the evaluation of different routing protocols. For the simulation of any ad-hoc network, node mobility is considered as one of the most significant parameter. The real world mobility models are needed so that the results from the simulation correctly reflect the real-world performance of a FANET. In this thesis, for the generation of real world mobility model for FANET, a tool BonnMotion, developed in java has been used.

5.1.1 Network Simulator

Network simulator is software used to study the dynamic behavior of communication network without actual existence of network. Network simulator is a name given to set of discrete event simulators, such as NS-1, NS-2 and NS-3. NS-2 simulates both wired and wireless networks and it supports simulation of various protocols like TCP, UDP, FTP and HTP. NS-2 is an open source, discrete event driven simulator used for research in networking. NS-2 is based on C++ code for modeling the nature of OTCL script and simulation nodes to handle the simulation.

5.1.2 NS-2 Architecture

The basic architecture of NS-2 is shown in Figure 5.1. Tcl simulation script is provided by users as input to the NS-2 Shell Executable Command (ns) which generate simulation results as simulation trace file. The simulation trace file is used by NAM tool for creating animation and by Xgraph for plotting graph.

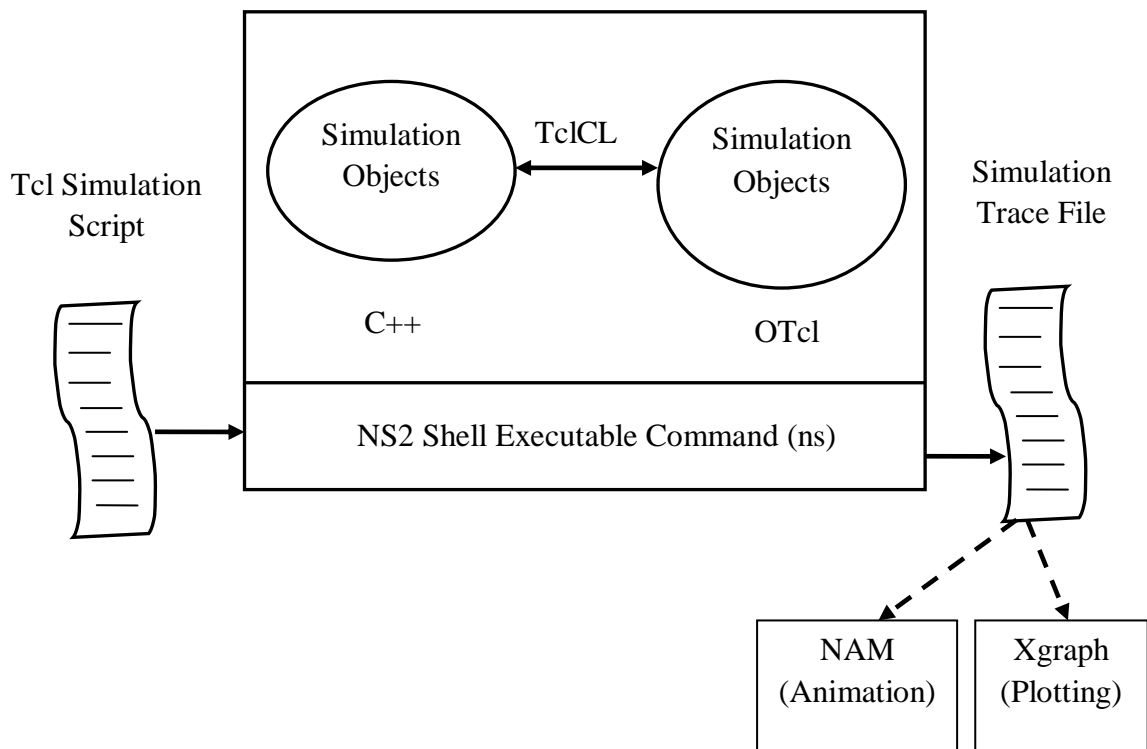


Figure 5.1 Basic Architecture of NS-2[36]

5.1.3 Network Animator (NAM)

NAM is tool based on Tool Command Language to animate simulation trace file to view network topology. For starting NAM, the command used is given as below:

```
nam <nam_filename.nam>
```

here <nam_filename> is the NAM trace file developed by Network Simulator.

Figure 5.2 shows the Network Animator window used for viewing the network topology.

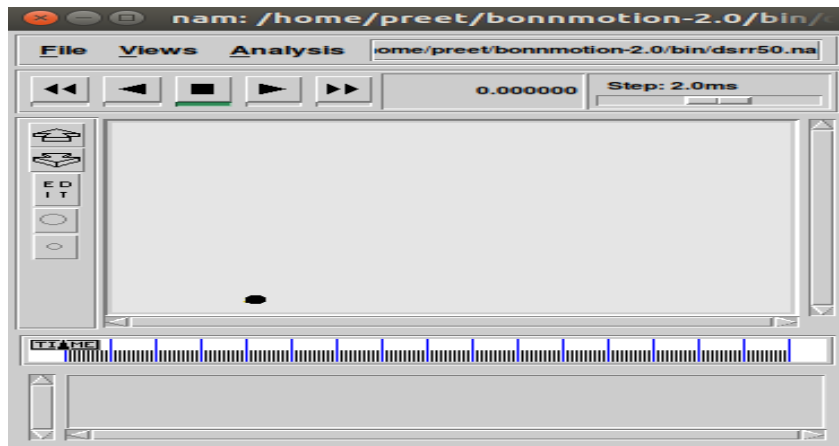


Figure 5.2 NAM window

Figure 5.3 shows the network topology of 50 nodes in NAM. The NAM will show complete view of how the origin node is sending the data packets to target node with the help of intermediate nodes.

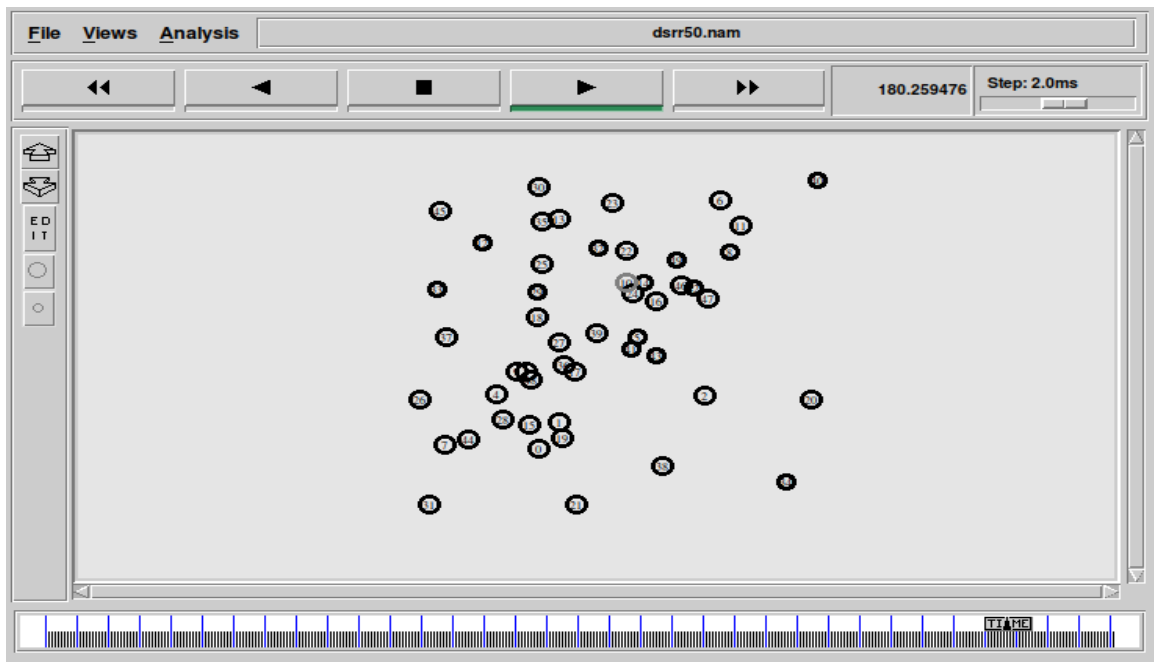


Figure 5.3 Network of 50 nodes generated in NAM

5.1.4 Trace File

The trace file is a file generated in NS-2 to store complete network information. Figure 5.4 shows the format of trace file for wireless network.

```
s 0.032821055 _1_ RTR - - - 0 message 32 [0 0 0 0] - - - - - [1:255 -1:255 32 0]
```

Figure 5.4 Trace file format [37]

The explanation of trace file fields is given below:

1. Action takes place at node as s, r and d which is sent, received and dropped respectively.
2. The time when the action takes place.
3. The node where the action takes place.
4. Layer is defined as AGT, RTR, LL, IFQ, MAC, PHY which corresponds to application, routing, link layer, outgoing packet queue, mac and physical respectively.
5. Flags
6. The sequence number of packet
7. The type of the packet is defined as CBR, DSR, RTS and ARP.
8. The size of the packet
9. MAC details
10. Flags
11. IP details

Figure 5.5 shows trace file generated for DSR wireless network.

```

dsrr50.tr (~/.bonnmotion-2.0/bin) - gedit
Open [ ] Save
s 1.000000000 _0_ AGT --- 0 tcp 40 [0 0 0 0] ----- [0:0 27:0 32 0] [0 0] 0 0
r 1.000000000 _0_ RTR --- 0 tcp 40 [0 0 0 0] ----- [0:0 27:0 32 0] [0 0] 0 0
s 1.006101991 _0_ RTR --- 1 DSR 32 [0 0 0 0] ----- [0:255 27:255 32 0] 1 [1
1] [0 1 0 0->0] [0 0 0 0->0]
s 1.006516991 _0_ MAC --- 1 DSR 90 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237119 _26_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237132 _7_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237174 _31_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237221 _28_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237332 _44_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237363 _37_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237401 _18_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237412 _21_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237431 _45_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237472 _5_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237521 _15_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 1.007237537 _48_ MAC --- 1 DSR 32 [0 ffffffff 0 800] ----- [0:255 27:255 32
0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
Plain Text Tab Width: 8 Ln 60, Col 1 INS

```

Figure 5.5 DSR trace file

5.1.5 AWK script

AWK is a programming language used to process the data from the trace files generated as output of NS-2. AWK script process the data column wise and the values are stored in variables as following:

\$1 represents Action, \$2 Time, \$3 Node Id, \$4 Layer, \$5 Flags, \$6 Sequence number, \$7 Packet type and \$8 Packet size

To run AWK script, firstly install gawk in Linux using command in terminal as follows:

```
sudo apt-get install gawk
```

and the AWK script is used by running command as follows:

```
gawk -f <awk_file_name.awk> <trace_file_name.tr>
```

5.2 Installation of NS2

The NS 2.35 is installed on Ubuntu 16.10 using following steps:

Step I: Set the Prerequisites

1. Firstly download NS-2.35 from link <https://sourceforge.net/projects/nsnam/>
2. Update the Ubuntu using command “sudo apt-get update” in terminal.
3. Install essential packages required by NS2 using commands “sudo apt-get install build-essential autoconf automake”, “sudo apt-get install tcl8.5-dev tk8.5-dev” and “sudo apt-get install perl xgraph libxt-dev libx11-dev libxmu-dev”

Step II: Installation of NS-2

1. Paste NS-2 folder “ns-allinone-2.35.tar.gz” from Downloads to Documents and extract the NS-2 zip folder.
2. Move to the directory where NS-2 package is extracted using command “cd /home/user_name/Documents/ns-allinone-2.35” and install NS-2 using command “./install”

Step III: Set environmental variables

1. Environmental variables are added by editing `.bashrc` file using command “`sudo gedit .bashrc`”
2. Save the changes to file and reload the `.bashrc` file using command “`source ~/.bashrc`”

Step IV: Validation of installation

1. Move to directory “`/Documents/ns-allinone-2.35/ns-2.35`” using terminal.
2. Run the command “`./validate`”
3. Execute NS-2 by typing “`ns`” in terminal. If “`%`” sign is shown, it means NS-2 is installed successfully and validated.

5.3 BonnMotion

BonnMotion is software developed in Java known for creating and analyzing mobility scenarios. It is a tool used to investigate characteristics of Mobile Ad-hoc Networks [38]. Mobility scenarios generated by BonnMotion are used by various simulators like NS-2, NS-3 and QualNet. The Communication Systems group developed the BonnMotion at the University of Bonn, Germany [38]. The various mobility models which the BonnMotion supports are: RWPM, GMM, Random Walk model, RPGM, Manhattan Grid model, and Disaster Area model.

5.3.1 Installation Steps

To install BonnMotion following steps are followed:

Step 1: Install JRE and JDK using command “`sudo apt-get install openjdk-8-jre openjdk-8-jdk`” in terminal.

Step 2: Download BonnMotion and extract it using command “`unzip bonnmotion-2.0.zip`”

Step 3: Change the directory using command “`cd bonnmotion-2.0`”

Step 4: Run “`./install`” and query is shown as: Please enter your java binary path
[`/usr/bin`]: Press Enter

5.3.2 Mobility Scenario Generation

To create certain mobility model scenario, the input parameters are given on the command line using scenario generator. BonnMotion uses `bm` wrapper script to run

various mobility models using syntax as follow:

```
./bm <parameters> <mobility_model> <mobility_model parameters>
```

The parameters used by mobility models are as follows:

- -n : number of nodes
- -d : the duration of scenario (in seconds)
- -i : number of seconds to be skipped at the start of scenario.
- -x: the width of simulation area (in meters)
- -y: the height of simulation area (in meters)
- -z: the depth of simulation area

To create scenario, firstly run the bonnmotion by using command “cd bonnmotion-2.0/bin/”. The mobility scenario for different models is generated as follows:

1. Mobility scenario for Random Waypoint model

Figure 5.6 shows the scenario generated for Random waypoint model having 50 number of nodes, 500 value for x, y, z and d as 200. The command used in terminal is:

```
“./bm -f randomscenario RandomWaypoint -n 50 -x 500 -y 500 -z 500 -d 200”
```



```
preet@ubuntu: ~/bonnmotion-2.0/bin
preet@ubuntu:~$ cd bonnmotion-2.0/bin/
preet@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f randomscenario RandomWaypoint -n 50 -
x 500 -y 500 -z 500 -d 200
BonnMotion 2.0


Starting RandomWaypoint ...
Next RNG-Seed =463777339966516881 | #Randoms = 2523
RandomWaypoint done.
Runtime: 1 sec
preet@ubuntu:~/bonnmotion-2.0/bin$
```

Figure 5.6 Mobility scenario for Random waypoint

2. Mobility scenario for Gauss-Markov model

Figure 5.7 shows the scenario generated for Gauss-Markov model having 50 number of nodes, 500 value for x, y, z and d as 200. The command used in terminal is:

```
“./bm -f gaussscenario GaussMarkov -n 50 -x 500 -y 500 -z 500 -d 200”
```



```
preet@ubuntu: ~/bonnmotion-2.0/bin
preet@ubuntu:~/bonnmotion-2.0/bin$ cd bonnmotion-2.0/bin/
preet@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f gaussscenario GaussMarkov -n 50 -x 500 -y 500 -z 500 -d 200
BonnMotion 2.0

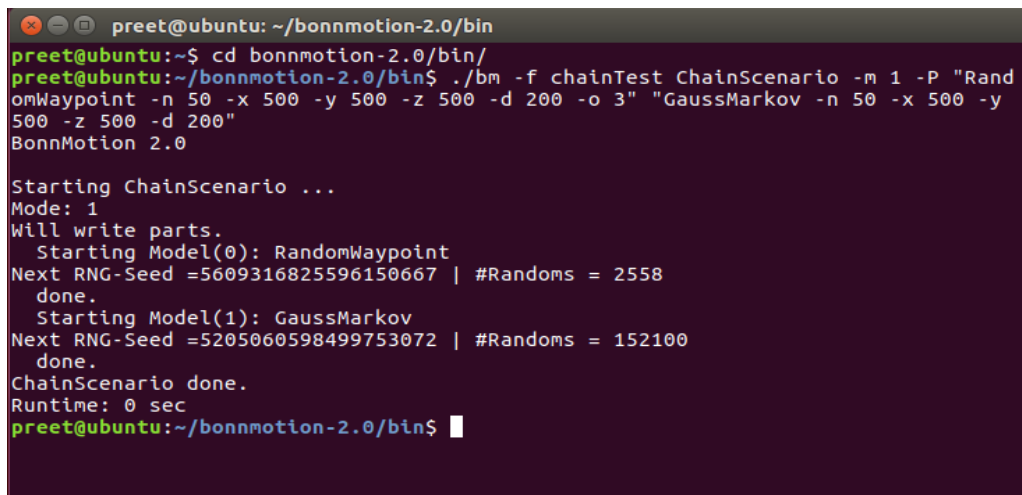
Starting GaussMarkov ...
Next RNG-Seed =2114741102932716512 | #Randoms = 152200
GaussMarkov done.
Runtime: 1 sec
preet@ubuntu:~/bonnmotion-2.0/bin$
```

Figure 5.7 Mobility scenario for Gauss-Markov

3. Mobility scenario for Chain model

Figure 5.8 shows the scenario generated for Chain model (Random Waypoint, Gauss-Markov) having 50 number of nodes, 500 value for x, y, z and d as 200. The command used in terminal is:

```
“./bm -f chainTest ChainScenario -m 1 -P “RandomWaypoint -n 50 -x 500 -y 500 -z 500 -d 200 -o 3” “GaussMarkov -n 50 -x 500 -y 500 -z 500 -d 200”
```



```
preet@ubuntu: ~/bonnmotion-2.0/bin
preet@ubuntu:~/bonnmotion-2.0/bin$ cd bonnmotion-2.0/bin/
preet@ubuntu:~/bonnmotion-2.0/bin$ ./bm -f chainTest ChainScenario -m 1 -P "RandomWaypoint -n 50 -x 500 -y 500 -z 500 -d 200 -o 3" "GaussMarkov -n 50 -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 =5609316825596150667 | #Randoms = 2558
done.
Starting Model(1): GaussMarkov
Next RNG-Seed =5205060598499753072 | #Randoms = 152100
done.
ChainScenario done.
Runtime: 0 sec
preet@ubuntu:~/bonnmotion-2.0/bin$
```

Figure 5.8 Mobility scenario for Chain model

5.4 Summary

This chapter provides the detailed installation of network simulator and BonnMotion tool used for simulation in this research. Also, the implementation of mobility models is provided to generate various mobility scenarios to be used in simulation.

Chapter 6

Results and Analysis

This chapter presents the results obtained by simulation of routing protocols and also simulation results are analyzed.

6.1 Simulation Parameters

The various parameters for simulation are described in Table 6.1.

Table 6.1 Parameters used in Simulation

Parameter	Value
Simulator	NS-2(Version-2.35)
Channel Type	Channel/Wireless Channel
Protocol	AODV,DSR
Mobility Models	Random Waypoint, Gauss-Markov, and Chain Mobility Model
Traffic Type	TCP
MAC Layer Protocol	802.11
Number of Nodes per Simulation	10,30,50

6.2 Performance Parameters

Three performance parameters i.e. PDR, End to End Delay, and Throughput are used to analyze the performance of AODV and DSR routing protocol with different Mobility Models.

- Packet Delivery Ratio (PDR): PDR is the ratio of the packets which the target receives and the packets which the origin node sends as found in the trace file.
$$PDR = (\text{Total packets received by target} / \text{Total packets send by origin})$$

- End to End Delay: It is calculated as the average of time which the sent data packets take for reaching at the target and is represented in ms.
End to End delay = (Packet arrival time – Packet sent time) / Total count of connections
- Throughput: It is the rate of successfully received packets and is represented in kbps.

6.3 Simulation Results of AODV routing protocol with different mobility models

The results of simulation are obtained from the generated trace files using AWK scripts as shown.

6.3.1 Number of nodes vs. PDR

Table 6.2 display the variation of packet delivery ratio of AODV routing protocol with different mobility models (Random Waypoint, Gauss-Markov, and Chain model) with the change in number of nodes.

Table 6.2 Number of nodes vs. PDR in AODV

Mobility Model	Number of nodes		
	10	30	50
AODV with Random Waypoint	99.4689	99.9366	99.7916
AODV with Gauss-Markov	99.7392	99.5773	99.9368
AODV with Chain Model	99.9693	99.1519	99.9139

The graph obtained by variation of packet delivery ratio because of change in number of nodes as displayed in Figure 6.1. The graph shows that the AODV with chain model give rise in packet delivery ratio values as compared to RWPM and GMM.

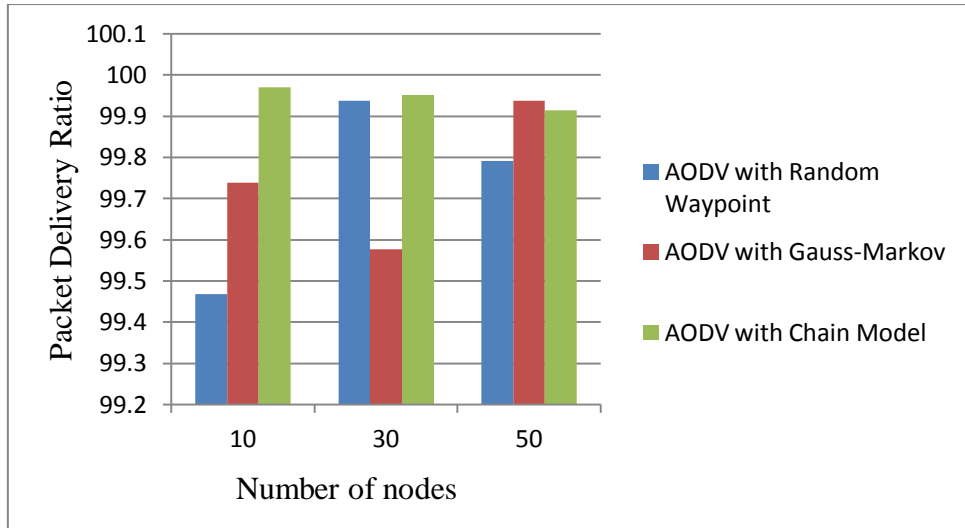


Figure 6.1 Number of nodes vs. PDR for AODV

6.3.2 Number of nodes vs. End to End delay

Table 6.3 display the variation in end to end delay for AODV routing protocol with different mobility models (Random Waypoint, Gauss-Markov, and Chain model) with the change in number of nodes.

Table 6.3 Number of nodes vs. End to End delay for AODV

Mobility Model	Number of nodes		
	10	30	50
AODV with Random Waypoint	115.022	86.6471	144.113
AODV with Gauss-Markov	129.104	86.1668	102.179
AODV with Chain Model	51.8012	86.6831	100.862

The graph obtained by variation of end to end delay by changing nodes number as displayed in Figure 6.2. From the graph, it is shown that AODV with chain model give decline in end to end delay values as compared to Random Waypoint and Gauss-Markov model.

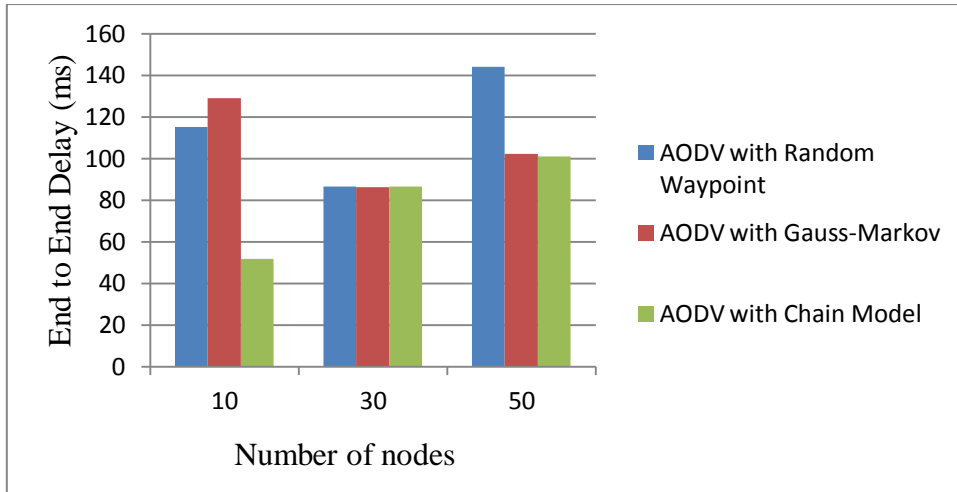


Figure 6.2 Number of nodes vs. End to End delay for AODV

6.3.3 Number of nodes vs. Throughput

Table 6.4 display the variation of throughput of AODV routing protocol with different mobility models (Random Waypoint, Gauss-Markov, and Chain model) with the change in number of nodes.

Table 6.4 Number of nodes vs. Throughput for AODV

Mobility Model	Number of nodes		
	10	30	50
AODV with Random Waypoint	390.39	782.22	392.06
AODV with Gauss-Markov	389.11	776.64	774.56
AODV with Chain Model	787.51	782.14	773.68

The graph obtained by variation of throughput with the change in number of nodes is shown in Figure 6.3. The graph shows that the AODV with chain model give rise in throughput values as compared to RWPM and GMM.

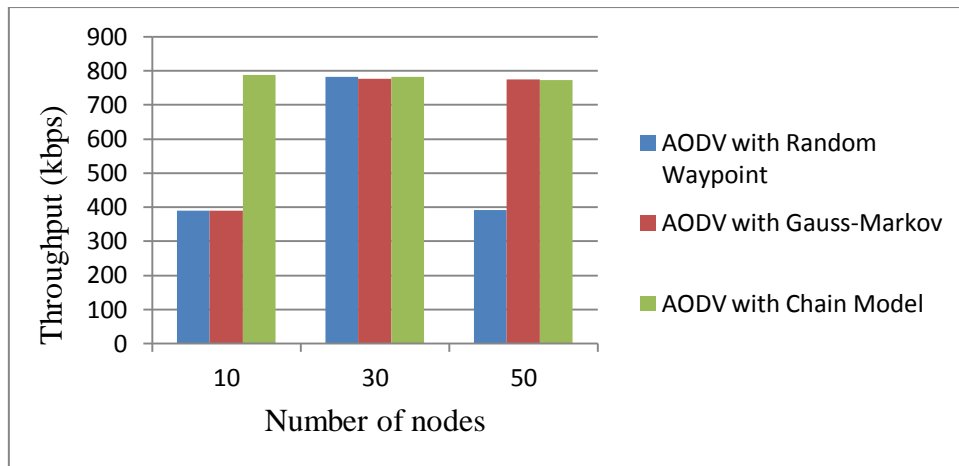


Figure 6.3 Number of nodes vs. Throughput for AODV

6.4 Simulation Results of DSR routing protocol with different mobility models

The simulation results are obtained from the generated trace files using AWK scripts as shown.

6.4.1 Number of nodes vs. PDR

Table 5.5 display the variation of PDR of DSR routing protocol with different mobility models (Random Waypoint, Gauss-Markov, and Chain model) with the change in number of nodes.

Table 6.5 Number of nodes vs. PDR for DSR

Mobility Model	Number of nodes		
	10	30	50
DSR with Random Waypoint	94.5055	98.1132	98.7654
DSR with Gauss-Markov	95.5556	98.0645	98.7654
DSR with Chain Model	98.136	98.0645	98.75

The graph obtained by variation of packet delivery ratio with the change in number of nodes is shown in Figure 6.4. The graph shows that the DSR with chain model give rise in packet delivery ratio values as compared to RWPM and GMM.

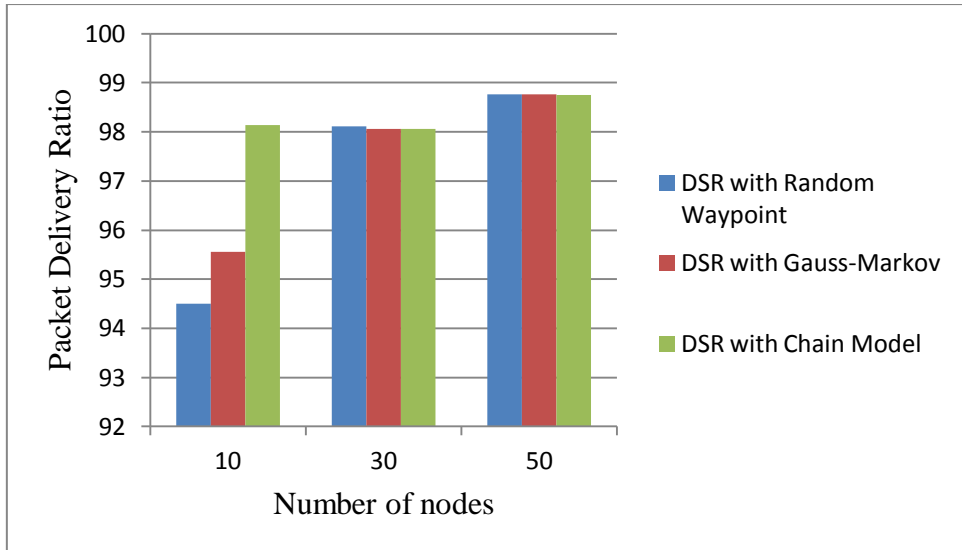


Figure 6.4 Number of nodes vs. PDR for DSR

6.4.2 Number of nodes vs. End to End delay

Table 6.6 display the variation in end to end delay for DSR routing protocol with different mobility models (Random Waypoint, Gauss-Markov, and Chain model) with the change in number of nodes.

Table 6.6 Number of nodes vs. End to End delay for DSR

Mobility Model	Number of nodes		
	10	30	50
DSR with Random Waypoint	76.5982	85.5966	90.7914
DSR with Gauss-Markov	93.9502	74.412	110.027
DSR with Chain Model	79.7321	84.2627	89.0561

The graph obtained by variation of end to end delay by changing nodes count is shown in Figure 6.5. The graph shows that the DSR with chain model give decline in end to end delay values as compared to Random Waypoint and Gauss-Markov model.

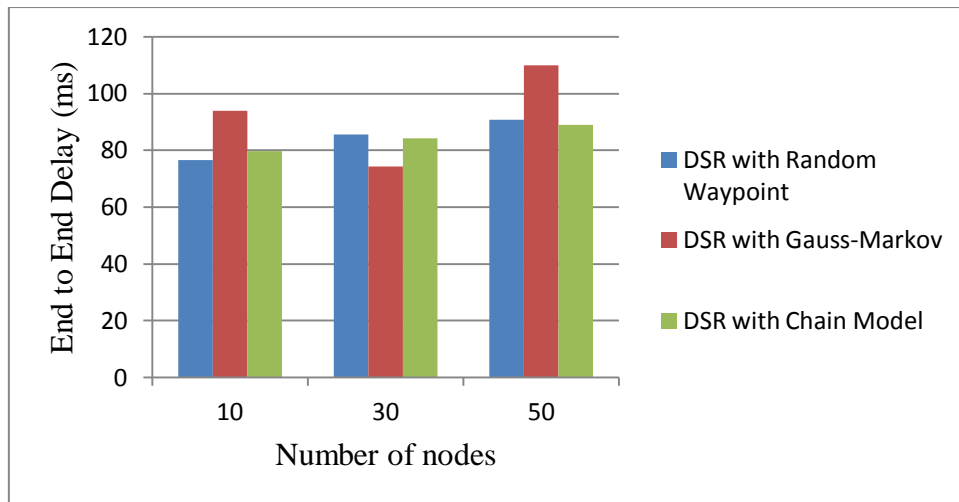


Figure 6.5 Number of nodes vs. End to End delay for DSR

6.4.3 Number of nodes vs. Throughput

Table 6.7 display the variation of throughput of DSR routing protocol with different mobility models (Random Waypoint, Gauss-Markov, Chain model) with the change in number of nodes.

Table 6.7 Number of nodes vs. Throughput for DSR

Mobility Model	Number of nodes		
	10	30	50
DSR with Random Waypoint	379.91	764.32	755.97
DSR with Gauss-Markov	384.22	766.17	753.20
DSR with Chain Model	757.59	751.52	755.41

The graph obtained by variation of throughput with the change in number of nodes is shown in Figure 6.6. From the graph it is found that DSR with chain model give rise in throughput values as compared to RWPM and GMM.

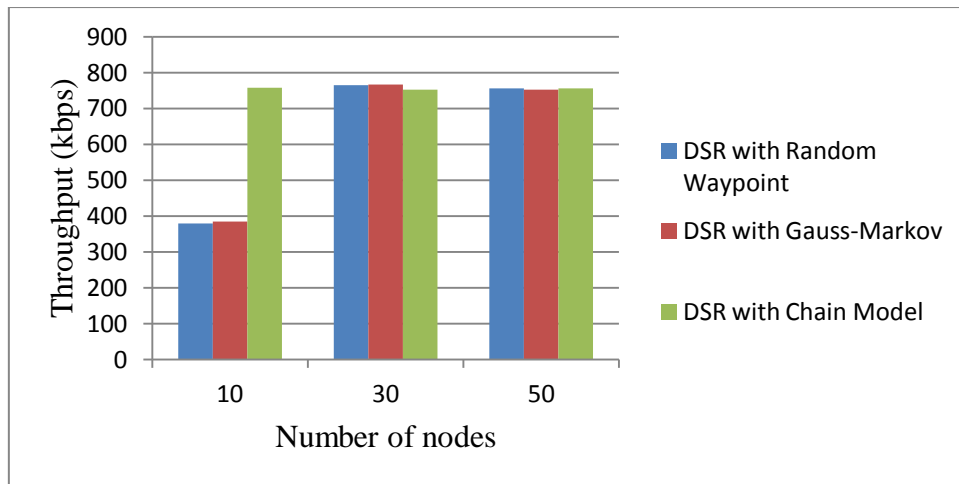


Figure 6.6 Number of nodes vs. Throughput for DSR

6.5 Simulation Analysis

In the simulation, AODV and DSR routing protocol has been analyzed with different mobility models (RWPM, GMM, Chain Model) for different number of nodes (10, 30 and 50). The results obtained from the simulation are shown in table (6.2, 6.3, 6.4, 6.5, 6.6 and 6.7) and on the basis of tables graphs are drawn. The analysis done is discussed below in details.

6.5.1 Simulation analysis of AODV

6.5.1.1 Packet Delivery Ratio

Table 6.2, shows the calculated values of parameter Packet Delivery Ratio for AODV routing protocol by using different mobility models. These packet delivery ratio values are displayed in the form of graph as shown in Figure 6.1.

From the graph, it is observed that for 10 numbers of nodes, AODV with chain model gives 0.2% rise in value of packet delivery ratio when compared to Gauss-Markov model and gives 0.5% rise in value when compared to Random waypoint model. For 30 nodes, AODV with chain model gives 0.37% rise in value of packet delivery ratio when compared to Gauss-Markov model and gives 0.01% rise in value when compared to Random waypoint model. For 50 nodes, AODV with chain model gives 0.12% rise in value of packet delivery ratio when compared to Random waypoint model.

6.5.1.2 End to End delay

Table 6.3, shows the calculated values of parameter End to End delay for AODV routing protocol by using different mobility models. These delay values are displayed in the form of graph as shown in Figure 6.2.

From the graph, it is clearly observed that for 10 nodes, AODV with chain model gives 59% decline in value of delay as compared to Gauss-Markov model and gives 54% decline in delay value when compared to Random waypoint model. For 30 nodes, the all mobility models give almost similar value for delay. For 50 nodes, AODV with chain model observes 1.2% decline in value of delay compared to Gauss-Markov model and 30% decline in delay value compared to Random waypoint model.

6.5.1.3 Throughput

Table 6.4, shows the calculated values of parameter Throughput for AODV routing protocol by using different mobility models. These throughput values are displayed in the form of graph as shown in Figure 6.3.

From the graph, it is observed that for 10 nodes, AODV with chain model gives 50% rise in value of throughput as compared to AODV with Gauss-Markov model and with Random Waypoint model. For 30 nodes, the AODV gives almost similar throughput with all mobility models. For 50 nodes, AODV with chain model gives 49% rise in value of throughput as compared to AODV with Random waypoint model.

6.5.2 Simulation analysis of DSR

6.5.2.1 Packet Delivery Ratio

Table 6.5, shows the calculated values of parameter Packet Delivery Ratio for DSR routing protocol by using different mobility models. These packet delivery ratio values are displayed in the form of graph as shown in Figure 6.4.

From the graph, it is observed that for nodes equal to 10, DSR with chain model gives 2.7% rise in packet delivery ratio as compared to DSR with Gauss-Markov model. Also for 10 nodes, DSR with chain model gives 3.8% rise in packet delivery ratio as

compared to DSR with Random waypoint model. For number of nodes equal to 30 and 50, the DSR gives almost same packet delivery ratio for all mobility models.

6.5.2.2 End to End delay

Table 6.6, displays the calculated values of parameter End to End delay for DSR routing protocol by using different mobility models. These delay values are displayed in the form of graph as shown in Figure 6.5.

From the graph, it is observed that for number of nodes equal to 10, DSR with chain model gives 15% decline in delay value as compared to DSR with Gauss-Markov model and for 50 nodes, DSR with chain model gives 19% decline in value of delay as compared to DSR with Gauss-Markov model. When results of DSR with chain model is compared with DSR with Random waypoint model, for 30 nodes, chain model shows decline of delay value by 1.5% and for 50 nodes, the decline of 1.9% in delay value is observed.

6.5.2.3 Throughput

Table 6.7, shows the calculated values of parameter Throughput for DSR routing protocol by using different mobility models. These throughput values are displayed in the form of graph as shown in Figure 6.6.

From the graph, it is observed that for number of nodes equal to 10, DSR with chain model gives 97% more efficient throughput than DSR with Gauss-Markov model. Also for nodes equal to 10, DSR with chain model gives 99% more efficient throughput than DSR with Random Waypoint model. For nodes 30 and 50, DSR give almost same Throughput with all mobility models.

6.6 Summary

This chapter discussed about the simulation parameters and performance parameters used for simulation. Also, the simulation results of AODV and DSR using different mobility models are discussed along with simulation analysis. The simulation analysis shows the effectiveness of chain model as compared to other models used individually

Chapter 7

Conclusion and Future Scope

This chapter concludes the present thesis. It also presents the unique contribution, limitation and future scope of the research done in this thesis.

7.1 Conclusion

In this thesis, Chain mobility model using existing Random Waypoint mobility model and Gauss-Markov mobility model is proposed for flying ad-hoc network. It integrates Random Waypoint model and Gauss-Markov model and gives effective improvement in various QoS parameters. Using the proposed chain model i.e. RGIM, different mobility scenarios by varying number of nodes are developed. The reactive protocols AODV and DSR are experimentally analyzed for various performance parameters i.e. packet delivery ratio, end to end delay and throughput by using these generated mobility scenarios. From the simulation results, it is observed that AODV and DSR protocol under chain model gives less end to end delay, more packet delivery ratio and better throughput than under Random Waypoint mobility model and Gauss-Markov mobility model. So, it is concluded that chain model gives better performance for reactive routing protocols as compared to Random Waypoint and Gauss-Markov model applied individually.

7.2 Unique Contribution

In this work, the new chain mobility model is developed to provide more efficient performance of routing protocols. It is implemented by integrating Random waypoint model and Gauss-Markov model in chain using BonnMotion tool. These two mobility models are not integrated by any research fellow for simulation. Analysis of the results shows that Packet delivery ratio has been increased, Throughput has been increased and End to end delay has been decreased.

7.3 Limitation

For simulation of FANET routing protocols, there are limited network simulators. So, it is an issue of concern to choose a simulator for evaluating the performance parameters of various routing protocols.

7.4 Future Scope

In the present research, chain mobility model is applied only to evaluate the performance of AODV and DSR reactive routing protocols. In future, other reactive protocols or proactive routing protocols performance can be evaluated using the proposed chain model. Also, the chain model can be varied by using combination of some different existing mobility models to get better results of routing protocols.

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