Chapter-1

Introduction

1.1 Mobile Ad-hoc Network (MANET)

Mobile Ad-hoc Network (MANET) is an infrastructure less network in which collection of autonomous mobile nodes forming a temporary (Ad-hoc) network without using any centralized assistance and infrastructure where all nodes in the network behave as routers and take part in the discovery and maintenance of routes to other nodes in the network, Gulati and Kumar (2014)\(^1\). The availability of routes at an instant can increase or decrease due to mobility hence availability of paths can vary in an Ad-hoc network. This type of network is commonly set up on a temporary basis to facilitate communication in rough conditions and under specific situations.

In MANET all nodes are wireless, mobile and powered through a battery. The participating nodes systematize themselves automatically, and can be a standalone network or attached to a large network, including the Internet, IETF (2002)\(^2\). Minimal configuration, quick deployment, absence of a central governing authority make Ad-hoc networks suitable for emergency situations Corson and Macker (1999)\(^3\), and Kopp (1999)\(^4\).

In other words, a mobile Ad-hoc network (MANET) is generally defined as a network that has many free or autonomous nodes, often composed of mobile devices or other such devices that can arrange themselves in a structured manner and operate without any central administration. There are many different types of setups that could form MANETs and with immense potential and scope for rendering effective service in communication. An ideal means of communication for managing the relief and rescue operations during natural calamities and medical emergencies; as also in military conflicts etc.
Fig.1.1: Mobile Ad-hoc Network

The IEEE 802.11 "WI-FI" protocol is capable of providing the Ad-hoc network facilities. MANETs are well suited for a situation where either the infrastructure is lost or where deployment of an infrastructure is not viable. Because of its versatility and diversified utility MANET has gained prior importance. In the present day tech-savy society MANETs find many users in the armed forces, government organizations, private organizations etc. Even standalone users like drivers of motor vehicles also use MANETs for seeking information about traffic situation and weather. The large scale use of wireless and nano technology in communication will definitely transform MANETs as the most preferred means of communication in future; by replacing the existing traditional telephony.

1.1.1 Characteristics of MANETs

MANETs have several salient characteristics (https://tools.ietf.org):  

i) Dynamic topologies: In MANET, nodes are free to move in an arbitrary manner; thus, the network topology may change rapidly at any instant.

ii) Bandwidth-constrained and variable capacity links: Wireless links will continue to have significantly lower capacity than their wired counterparts. In addition, the realized throughput of wireless communications is less than a radio's maximum transmission rate. In general mobile Ad-hoc users
demand services in a similar manner as in infrastructure supported networks. These demands will continue to increase with the rising multimedia computing and collaborative networking applications.


iv) Limited physical security: Mobile wireless networks are generally more prone to physical security threats than the fixed-cable networks. The increased possibility of eavesdropping, spoofing, and denial-of-service eventualities should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. The decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches.

1.1.2 MANET Applications

The MANET is in a way, tantamount with Mobile Packet Radio Networking. There are current and future needs for dynamic Ad-hoc networking technology. MANETs can be used in any situation that involves an emergency, such as search-and-rescue operations, military deployment in a hostile environment, civil administration in disaster management etc. In addition, the lack of a wired infrastructure reduces the cost of establishing such a network and makes MANETs a very attractive technology. Most of the areas can be easily identified where MANET technology can be applied. Some applications of MANET technology could include industrial and commercial applications involving cooperative mobile data exchange, Adamson (1994).
The most common MANET applications are as follows:

i) Personal Area Network (PAN): In general a PAN covers very limited area. MANETs serve appropriately in such type of coverage areas. A PAN network can be formed by using Laptops, PDA’s (Personal Digital Assistants), communication equipments, etc.

ii) Vehicle Network: The drivers of vehicles in a traffic stream can pass information regarding traffic conditions, jams, obstructions etc to other drivers-thus forming a vehicle networks.

![Fig. 1.2: Vehicular Network](image)

iii) Other applications: MANETs find large scale usage in transport service networks viz. airways, waterways, highways and railways for exchange of information. Also in meeting centres, business establishments, market places, city centres etc where speedy services are the criteria. MANETs are the ideal means of communication for civil administration in disaster management and during relief and rescue operations. During military conflicts also MANETs find wide spread usage for locating targets, forecasting threats and passing information about enemy positions, formations etc.
Fig. 1.3: MANET Applications in Military Operations, Allwright et al. (2007)\(^8\).

Main issue in a MANET is the identification of optimal path between the source node and destination node. MANETs are highly prone to link failure due to node mobility and dynamic environment. Routing in MANETs is a challenging task as topology is not fixed and it changes very frequently. Hence routing in MANET has been the focus for researchers and scholars.

In MANETs, movement of a node from one place to another is characterized by mobility; thus resulting in mobility is directly responsible for link failure. Mobility is an important factor for MANETs and it plays a vital role in routing protocols evaluation. The aspect of mobility as proposed by Larsson and Hedman (1998)\(^9\), is based on relative nodes movement, and same has been represented by considering a parameter known as mobility factor (mob); which depends on speed and movement pattern (directions). Under mobility modeling, the pattern of user’s movement can be described using both analytical and simulation models. Simulation models consider more detailed and more realistic mobility scenarios. Such models are useful for resolving problem situations. Various mobility models
are designed to describe the movement pattern of mobile users, which characterize their dynamic movement over a period of time. Some of the mobility models are Random Waypoint mobility model, Group mobility model, File based mobility model, Pedestrian mobility model, Manhattan mobility model, Free way mobility model, Random Gauss-Markov mobility model etc. The Random Waypoint model has been widely used in performance comparison studies of routing protocols. As mobility models stipulate mobility the same can also be used to emulate the movement pattern in the entire premeditated scenario. Hence, the mobility models are helpful in recording the observations and drawing conclusions from the simulation studies. Hence, there is a real need for investigating the effect of mobility and its impact on MANET routing protocol performance. The QualNet5.0.2 simulator is allowed to a user to deploy the four mobility models namely Random Waypoint mobility model, Group Mobility model, Pedestrian mobility model and File based mobility model. Out of these mobility models; in the present study; the researcher has used three mobility models namely Random Waypoint mobility model, Group mobility model and File based mobility model have been used. However, the Pedestrian mobility model has not been considered in this work due to technical flaws encountered during simulation. The detailed description of the mobility models considered in this thesis to engender the mobility effect in performance evaluation of routing protocols has been represented in Chapter-3.

In MANET, there are many issues which need attention of a researcher like routing, mobility, security, Ad-hoc network deployment, energy consumption etc. Out of these, routing is a critical issue that needs to be taken care of more accurately due to frequent changes in the network topology over time. Moreover, each node in the network operates as a mobile node and also functions as a router that stores and forwards data packet from other nodes. The lack of a backbone infrastructure in MANET allows entire network to change its topology frequently and without prior information (www.etd.unipi.it)\textsuperscript{10}. The major goals of routing are to discover and maintain routes between source and destination in a
dynamic topology with identified links using minimum resources. In MANET, a mechanism is required for routing the data packets from the source to the destinations. In Ad-hoc networks, each node is participating in communication, and so the determination of which nodes forward the data is made dynamically based on the network connectivity. Hence for effective communication and passage of information; it is of paramount importance to identify and maintain all the routing protocols.

Routing is the exchange of information (packets) between two nodes. The routing protocol presents the mechanism which reduces route loops and confirms trustworthy message exchange, Loganathan and Ramamoorthy (2012). There are many ways to classify the MANETs routing protocols depending on packet delivery mechanism from source to destination such as unicast routing, multicast routing and broadcast routing. However, the most widely used routing protocols are broadly classified into three categories namely Proactive, Reactive and Hybrid protocols, Abolhasan et al. (2004).

1.2 Routing Protocols

Since the inception of MANET, the research community has focused on routing protocols and has treated the same as a major challenge due to its dynamic nature. In the process numerous routing protocols have been developed for the MANET. In this section; various routing protocols that can be deployed in a MANET are presented together with their functional aspects.

1.2.1 Desirable Properties of MANET Routing Protocols

The routing protocols must be capable enough to support the dynamic network. Following are the desirable properties of MANET routing protocols.

i) Distributed operation: A routing protocol for MANET should be distributed in nature because a routing protocol cannot function efficiently in a
dynamic network under any centralized entity. In an Ad-hoc environment each node should be intelligent enough to execute routing related decisions.

ii) Loop-freedom: The routing protocols should have the loop free property i.e. the routes supplied must be loop free in order to improve overall performance. The loop free mechanism also ensures proper utilization of available bandwidth or CPU power.

iii) Quality of Service (QoS): A routing protocol must have an idea about the delay and throughput for a particular route followed in communication. It is also desirable that a routing protocol must have information about the longevity of route so that uninterrupted support mechanism is available during communication.

iv) Security: A MANET routing protocol is susceptible to many forms of security threats. It may be relatively simple to snoop network traffic, manipulate packet headers, and redirect routing messages, within a wireless network without appropriate security provisions. At the physical interface, denial of service attacks can be avoided by using frequency hopping spread spectrum. Sufficient security protection to prevent disruptions or modifications in protocol operations is desired.

v) Power Efficient: The routing protocol should be energy efficient. As the source of power for a node in an Ad-hoc network is based on battery; a routing protocol should operate in a power saving mode; in order to conserve energy. The best way to optimize the power is to distribute the routing load among the participating nodes.

vi) Alternative Routes: Towards a solution for topological changes and congestion an alternative route could be used. If existing route became faulty, it is possible to choose another stored path from multiple routes.
This process refrain routing protocol from initiating another route discovery process from initiation.

None of the proposed routing protocol of MANET supports all the above properties, but as routing protocols for MANET is still in developing stage one may further extend these properties for the better functionality. However, the primary function is still to find and discover a route rather than to find the optimal route. The next part of this chapter will describe the different MANET routing protocols.

1.2.2 Types of Routing Protocols in MANET

Routing is the exchange of information (packets) between two nodes. The major goals of routing are not only to discover but also to maintain routes between source to destination in a dynamic topology with discovered link by using minimum resources. The one of the most interesting issue in MANET regarding the routing protocols is that whether or not the nodes in the network should keep track of routes to all probable paths of destinations, or instead of keeping track for only those destinations of immediate interest. Generally, a node in MANET does not require to form a route with any another node until the node is necessarily participate in the communication. As this is still a controversial issue, no mechanism has been fixed for all types of scenarios. However, based on the situation and application at hand, any of the methods could be chosen. Though there are no common thoughts about the method of keeping the information about routes in the network, many routing protocols have been proposed by this time on the basis of all the available methods.

The routing protocol presents the mechanism which reduces route loops and confirms trustworthy message exchange, Nigam et al. (2014). In the past years, there has been a significant amount of research conducted in this area, Dubois-
Ferrie et al., (2003)\textsuperscript{14}, Lap et al. (2005)\textsuperscript{15}, and Gomez et al. (2011)\textsuperscript{16}. In general, the functions of a routing protocol can be summarized as follows:

The main functions of a routing protocol are as follows:

i) Path Generation: In this path is generated from scattered environment of network. There are multiple paths generated from sender to destination.

ii) Path Selection: In the previous phase, there were multiple path and from the pool of multiple paths, suitable paths have been chosen so that time, memory and overhead will be less and performance is better.

iii) Data transmission: In this, data is transmitted from sender to destination on the selected path.

iv) Path Maintenance: The suitable path must have to maintain the link using control messages like "Hello". If the link is broken and not active then using hello messages, maintenance of the route is done.

There are many ways to classify the MANETs routing protocols depending on packet delivery mechanism from source to destination such as, unicast routing, multicast routing and broadcast routing. In general routing protocols are broadly classified into three types of protocols namely proactive, reactive and hybrid protocols, Abolhasan et al. (2004)\textsuperscript{17}, Amit Singhal, and V. K. Saraswat (2011)\textsuperscript{18}.

There are many routing protocols available for Ad-hoc networks such as AODV, DSDV, DSR, DYMO, FSR, OLSR, STAR, TORA, RIP and ZRP etc., Nigam et al. (2014)\textsuperscript{13}. In this study the performance evaluation of different type of routing protocols with respect of mobility has been conducted by using three metrics namely Average Jitter(s), Average-End-To-End Delay(s), and Throughput (bits/s).
1.2.2.1 Proactive Protocols

These types of protocols are Table driven protocols in which, the routes are consistent and up-to-date the routing information to all nodes. Packets are transferred over the available route specified in the routing Table. Proactive protocols have lower latency because all available routes are maintained at all times for all available nodes. Some of the proactive routing protocols are DSDV, OLSR, WRP, FSR, and STAR.

i) Optimized Link State Routing (OLSR)

Optimized Link State Routing (OLSR) protocol is an IP routing protocol, Jacquet et al (2000)\textsuperscript{19}, Clausen and Jacquet (2003)\textsuperscript{20}. It is a proactive routing protocol in nature. OLSR uses hello and topology control (TC) messages in order to discover and then share route information in entire network. OLSR routing protocol uses the link-state policy in an optimized manner to spread routing information. Technique Multi Point Relaying (MPR) is used in OLSR for performance optimization. OLSR defines three basic types of control messages and these are:-

i) HELLO: HELLO messages are transmitted to all neighbors. These messages are used for neighbor sensing and MPR calculation.

ii) TC: Topology Control messages are the link state signaling done by OLSR. This messaging is optimized in several ways using MPRs.

iii) MID: Multiple Interface Declaration messages are transmitted by nodes running OLSR on more than one interface. These messages list all IP addresses used by a node.
The OLSR routing mechanism is shown in Fig. 1.4.

![OLSR Routing Mechanism](image)

**Fig. 1.4: OLSR Routing Mechanism**

ii) **Source Tree Adaptive Routing (STAR)**

In STAR routing protocol router sends latest information to all neighbors about the links. Every mobile node collects and maintains routing information of the network and establishes a shortest path tree to store preferred paths to destinations Garcia-Luna-Aceves and Spohn (1999)\(^21\). Two mechanisms are followed in order to discover neighbors of the node. When a node receives a hello message from another node that it does not know previously, it discovers a new neighbor and maintains its information. If for a certain period a node does not receive any message from its neighbor it means neighbor is out of its range. STAR protocol perfectly suits for large network as it has significantly reduced the bandwidth consumption for the routing updates. It can be used with distributed hierarchical routing schemes proposed in the past for distance-vector and link state routing Murthy and Garcia-Luna-Aceves (1997)\(^22\), and Behrens and Garcia-Luna-Aceves (1998)\(^23\).
iii) **FSR State Routing (FSR)**

FSR is an implicit hierarchical routing protocol, Sheikh et al. (2010)\(^{24}\) and it is the next generation technology of Global State Routing strategy (GSR), Pei et al. (2000)\(^{25}\). It uses the FSR technique proposed by Klein rock and Stevens. It maintains entries of nearby nodes in the routing table and update with neighbors more frequently, as the eye of a fish captures more accurate and detailed pixels for all locations which are near to its focal point. The detail transferred as per the distance variation from its focal point. In routing scheme, this approach translates to maintain accurate distance and path quality in sequence about the neighborhood of a node Pei et al. (1999)\(^{26}\).

![Fig. 1.5: Accuracy of information in FSR](image)

iv) **Bellman Ford Routing Protocol**

The Bellman-Ford, a distance-vector routing algorithm, is used for exchanging the information during the communication for the current status of the network and packets transmission. Bellman-ford merges routing information provided by different routers into routing tables. In some cases, looping occurs in which a packet goes through the same node more than once.
v) **Destination-Sequenced Distance-Vector Routing (DSDV)**

DSDV is based on the Bellman–Ford algorithm and it was developed by Charles et al. (1994)\(^1\). In DSDV each node maintains a routing table which stores all possible routes towards each destination. A sequence number is created by the destination itself to ensure the loop free process. Each node periodically forwards routing information to neighbors and nodes are also get appended its sequence number when sending its routing information. The every route is tagged with a sequence number; routes with greater sequence numbers are preferred. In order to update the neighbors every node advertises a monotonically increasing sequence number for itself. When a node decides that a route is broken, it increments the sequence number of the route and advertises it in entire network and destination advertises new sequence number.

vi) **Routing Information Protocol (RIP)**

RIP is implemented on top layer of the User Datagram Protocol (UDP) as its transport protocol. RIP allowed limited number of hops count up to 15 in a specific path for preventing the routing loops. RIP selects paths with the smallest hop counts. In RIP, routing information is passed on in every 30 seconds to neighbors and the neighbors in turn will pass the information on to their nearest neighbors, and so on, until all RIP hosts within the network have the same knowledge of routing paths.

### 1.2.2.2 Reactive Protocols

These types of protocols are also known as ‘on demand routing protocols’, where routes are not maintained before transferring the packets for routing. When a source wants to send information to a destination, it invokes the route discovery mechanisms to find the path to the destination. This route discovery is done by flooding mechanism in which a source node just broadcasts the packet to all of its neighbors nodes and forward that packet to their neighbors until it reaches to
the destination. Reactive techniques have smaller routing overheads because of no prior routing information requirement, but higher latency. The Reactive Protocols are much suited and perform better for Ad-hoc networks. Some of the reactive routing protocols are: DSR, AODV, and DYMO.

i) **Dynamic Source Routing (DSR) Protocol**

DSR is a routing protocol for wireless mesh networks, Johnson and Maltz (1996)\textsuperscript{28}. DSR routing protocol is quite similar in characteristic with AODV. DSR protocol works on the basis of source routing. The protocol can work with cellular telephone systems and mobile networks with up to about 200 nodes. In DSR, each source determines the route to transmitting its packets to selected destinations. DSR perform two functions, called route discovery and route maintenance. In route discovery an optimum path for a transmission is selected. While route maintenance ensures that the transmission path remains optimum and loop-free, even if network conditions changes during a transmission.

ii) **Ad-hoc On demand Distance Vector (AODV) Routing Protocol**

AODV is a stateless on-demand routing protocol. It was jointly developed at Nokia Research Center, University of California, Santa Barbara and University of Cincinnati by Perkins et al. (2003)\textsuperscript{29}. In AODV, the network is silent until a connection is needed. When a node needs to transmit information it request for connection. After the request broadcast, other nodes in the network forward this message and record information about the node from which they heard it, creating temporary routes back to the source node. When a node receives such a message and already has a route to the desired node, it sends a message backwards through a temporary route to the requesting node. The source node starts communication by picking a shortest path.

iii) **Dynamic MANET On-demand (DYMO) Routing Protocol**

It is a successor protocol for AODV. It has the combine features of AODV and DSR routing protocols. DYMO has two main operations, route discovery and
route preservation just like in AODV. During route discovery, the source node broadcast a RREQ message through the network to find the suitable route. Throughout this procedure each node among nodes records a route to the source node and rebroadcast the RREQ after appending its own address. When the destination node receives the RREQ, it responds with RREP to the all participating nodes. Each intermediate node that receives the RREP records a route to the principle node, Hu et al. (2006)\textsuperscript{30}. When the source node receives RREP message, the route is established between the source node and the destination node. When a link breaks, the source of the packet is notified and sends the RERR message to the sender node as an acknowledgement.

1.2.2.3 Hybrid Protocols: Hybrid protocols comprises the features of both reactive and proactive routing protocols and take the advantages of both protocols which results in quick routes discovery in the routing zone. Some of the Hybrid Routing Protocols are: ZRP, and TORA.

i) Zone Routing Protocol (ZRP)

The ZRP routing protocol proposed by Haas (1997)\textsuperscript{31}. It uses both proactive and reactive routing protocols during communication over the network. It was designed to speed up delivery and reduce processing overhead by selecting the most efficient type of protocol to use throughout the route.

Initially ZRP creates the different zones of its entire network, where every node proactively maintains routes to any destination inside the zone and reactively obtains routing information for any node outside of the zone. The routing in ZRP is divided into two parts: Intrazone routing, and Interzone routing.

In Intrazone routing, each node collects information about all the nodes in its routing zone proactively. This strategy is similar to any proactive protocol and node maintains a routing table for its routing zone, so that it can find a route to any node in the routing zone from this table. In order to maintain the information,
each node work similar to a hello message concept. In ZRP the message is known as a zone notification message. However, in the interzone routing discovers routes to the destination reactively. It reduces the control overhead in comparison with the proactive approach. In this, routes are discovered much faster than the proactive strategy. The reason is because to find a route to a node placed outside the routing zone, the route request is sent only to the border router within the zone. This border router can answer to the request since it has a routing Table to do the proactive routing and knows how to reach the destination.

1.3 Thesis Organization

This thesis presents the impact of mobility on the performance of routing protocols in MANETs. The thesis report has been organized in six chapters, and the brief description of each chapter is given as under:

**Chapter 1** is introductory and provides an overview of the state of the art about the area of study including MANET characteristics, advantages, and applications. This chapter also covers the routing protocols with their desirable properties and types. The different routing protocols have been discussed in thesis which was considered for the performance evaluation and simulation.

In **Chapter 2**, a review of the literature related to the thesis has been presented. Numbers of studies have been reported in the literature showing simulated and evaluated performance comparisons of several routing protocols. The past studies related to the various routing protocols namely AODV, DSR, RIP, STAR, LANMAR, DYMO, FSR, and ZRP, etc. have been presented here.

**Chapter 3** contains the information about the research methodology employed in the study. It contains information about statement of the problem, objectives of the research work, scope of the study, limitations, tools and techniques used in the study.
In **Chapter 4**, the particulars related to the simulation design and implementation has been presented. The selected routing protocols chosen for the study has been detailed including the introductory part related to the simulator. The chapter gives the detail about the network simulation and scenario design with the related parameters used in performance evaluation of the routing protocols including mobility and traffic models.

**Chapter 5** contains the detailed analysis and interpretation of data. This chapter presents the simulation results obtained from the various simulations using QualNet simulator. The analysis part is summarized in four sections in the present chapter.

In the first section, the impact of mobility on MANET routing protocols using both OLSR and STAR routing protocols with the help of Random Waypoint mobility model has been investigated. It has been observed that the OLSR routing protocol has given the better performance than that of STAR routing protocol. In absence of mobility, the STAR routing protocol has given better performance than that of OLSR. In a subsection of first section, the effect of varying mobility speed on DSR and DYMO routing protocols has been presented. It is observed that the DSR routing protocol outperformed DYMO routing protocol in case of throughput while the DYMO has least delay and jitter than that of DSR.

In the second section, the Impact of mobility on MANET routing protocols under different traffic pattern has been investigated. The performance of AODV and DSR routing protocols using CBR and FTP traffic patterns under random waypoint mobility model has been presented. The interpretation of results indicates that the AODV routing protocol has given the better performance in comparison of DSR routing protocol for both type of traffic patterns. It has also been observed that the mobility has an adverse affect on the performance of AODV and DSR.

Summarized results of the performance comparison of DSR, DYMO and FSR routing protocols with CBR and FTP traffic patterns are presented in a
subsection. It is observed that the performance of FSR, DSR, and DYMO routing protocols decreases under the CBR traffic pattern. However, the DYMO routing protocol gives quite satisfactory results for average-end-to-end delay and average jitter in comparison of DSR and FSR. Therefore, it can be concluded that traffic pattern have the significant effect on the performance of routing protocols.

The subsection of second section contains the performance comparison of AODV, DSR and DYMO routing protocols for varying node density and speed with different traffic patterns. It is observed that the AODV routing protocol has given the overall better performance in both CBR and FTP traffic than that of DYMO and DSR routing protocols. However, DYMO has higher throughput in case of FTP traffic than that of DSR, while the DSR outperform DYMO in case of CBR traffic.

The third section embodies the outcomes related to the impact of mobility on MANET routing protocols using Group mobility, Random Waypoint and File mobility models with CBR traffic. The performance of nine routing protocols namely: Bellman Ford, FSR, LANMAR, RIP, STAR, AODV, DSR, DYMO, and ZRP using varying node density under Group mobility model has been investigated. It is observed that the group mobility has significant impact on the performance of all type of routing protocols. Simulation results show that varying density in groups and their mobility have a significant impact on the network performance which has not been revealed before.

However, choosing an efficient routing protocol is a critical task to study the operations and performance of MANETs. It is clearly indicated that reactive routing protocols AODV, DSR and DYMO are best suited in large dense scenarios under group mobility. While proactive routing protocols Bellman Ford, FSR, LANMAR, RIP, and STAR are not showing good performance with the increasing node density due to increase in routing overheads increase. In highly dense and large groups reactive routing protocols gives quite satisfactory results
than that of proactive routing protocols. It has been observed that the hybrid routing protocol ZRP is not suitable for MANET with large group type of scenarios as its performance is nastiest for all the metrics.

A subsection of this section summarizes the performance of five proactive (FSR, LANMAR, Bellman ford, RIP and STAR), three reactive (AODV, DSR, and DYMO) and one hybrid routing protocol (ZRP) under the Random Waypoint mobility model. Simulation results are presented for performance metrics. It is observed that the performance of these routing protocols degraded with the increasing mobility speed and node density. It happened due to frequent route failure with high mobility which resulted downfall in packet delivery during communication.

The next section covers performance comparison under File mobility model. It is observed that the performance of AODV reactive protocol is consistently showing better result with varying node density in case of all performance metrics.

The last section represents the discussion related to the impact of mobility models on MANET routing protocols. It is has been observed that overall the performance of various routing protocol highly affected in term of average end-to-end delay under file mobility model. On other side, Random Waypoint mobility and Group mobility models shows the quite improved results for average end-to-end delay. The Random Waypoint mobility model is the winner in terms of end-to-end delay.

In general the reactive AODV, and RIP routing protocols performed better in comparison to all other routing protocols under all three mobility models in terms of average jitter.

In case of average throughput, the performance of DSR routing protocol is satisfactory under File model in case of low node density. Similarly, the DSR outperforms all other routing protocols in case of high node density under group mobility model. In case of Random Waypoint model, the performance of DSR
Routing protocol is highly degraded and it shows almost worst performance for both high and low node density situations.

In general, the throughput of AODV routing protocol improves with the increasing node density and it outperforms all other routing protocols in high node density under File and Random Waypoint mobility models. While the DSR shows better results in case of Group mobility model.

The DYMO routing protocol shows the better result for high node density in File and Random Waypoint mobility models in comparison to low node density. However, it is reversed in case of group mobility model.

From File mobility model outcomes, it is concluded that the AODV, DSR, DYMO, RIP, ZRP and Bellman Ford perform satisfactorily in term of throughput. While the performance of STAR and ZRP downgraded very poorly.

From Random Waypoint mobility model outcomes, it has been found that the performance of Bellman-Ford, RIP, STAR and ZRP downgraded in comparison to other protocols in low node density. In Group mobility model it is observed that the AODV, DSR, Bellman-Ford, RIP, STAR, and FSR routing protocols indicated better throughput with increasing node density. On the other hand, the DYMO, LANMAR and ZRP routing protocols indicate the moderated downfall in term of throughput performance with increasing node density.

The results and conclusions of the thesis are presented in Chapter 6. It covers the summary of all outcomes including the general observations regarding the routing protocols, impact of mobility and mobility models on performance of routing protocols in tune of finding the answers of research objectives. The chapter ends with the scope of future work.

Finally, the thesis ends with a list of the references and resources that have been used in the research.