CHAPTER-2

General Review and the Tools used

This chapter proposes study of various key parameters associated with networking and wireless technologies that affect performances of the routing protocols of Mobile Ad-hoc Networks (MANETs). This chapter primarily focuses on reviews of some important investigations reported by various researchers over the past decades in the area of performance analysis and improvements in routing protocols. Various pre-requisites such as; mobility models, traffic generators, quality of service, issues and challenges, performance improving techniques, performance evaluating parameters etc. were also discussed in detail in this chapter. Parameters which affect performances of the routing protocols were discussed in detail. Revisions of various parameter attributes associated with the routing protocols have been discussed. Simulation tools used for the analysis are also discussed in detail in this chapter.

2.1 MANET Routing Protocols

Mobile ad hoc networks are basically infrastructure less networks and the dynamic nature of MANETs exploits a key challenge towards error free, accurate and efficient routing. This has promoted lot of research in routing protocols adjustable to the dynamic network topology scenarios. Routing is said to be intelligent when it utilizes limited resources and at the same time routing must be adaptable to the variable network situations such as: size of the network, density of the traffic and network partitioning. MANET routing protocols possesses many characteristics which are different as compare to those in wired networks. The probability of errors is high in MANET routing protocols because of deficiencies in the wireless transmission channels. The transmission power is usually low in order to conserve energy. Major challenge in MANET routing protocols is link breakage, it is because mobile nature of the network nodes from one place to another. There are many number of routing protocols in the MANETs that are proposed by the research community, and are normally categorised as topology-based [Royer *et al.* (1999)] and position-based routing protocols [Mauve *et al.* (2001)].

2.1.1 Topology Based Routing Protocols

Topology based routing protocols are generally operated by recognising the neighbour nodes or by available link-state information. Many topology-based routing protocols are proposed based on route discovery mechanism which can be classified as proactive and reactive routing protocols. Proactive routing protocols maintain routing related information among all the nodes of the network. Addition of new routes or updating the existing ones is done by exchanging of link-state information that is, distributing their routing tables periodically with each and every other node of the network. This makes immediate availability of routes to the required destinations as and when required, due to this, packet delay gets minimized. However, in proactive routing protocols, a large overhead involved is trade-off with the flooding routing tables throughout the network. DSDV (Destination Sequenced Distance Vector) and OLSR (Optimized Link State Routing) are the two well-known proactive routing protocols.

Reactive routing protocols discover the route only when they are needed and these routing protocols do not maintain routes to all the nodes of the network. To discover new routes and when there is a need of an existing route, reactive routing protocols initiate route request messages. Nodes with the required route information send back a route reply message to the route initiated source nodes. Reactive routing protocols ensure the route discovery by flooding route request packets throughout the network. The main disadvantage of the reactive routing protocol is delay in discovering the routes to the new destinations. Networks with highly dynamic nodes experience problems of route discovery as these nodes keep moving out with one another. AODV (Ad hoc On Demand Distance Vector) and DSR (Dynamic Source Routing) are well-known reactive routing protocols [Yufei Cheng *et al.* (2014)].

2.1.2 Location Based Routing Protocols

In highly dynamic networks, topology of the network changes frequently and quickly. The control overheads associated with the route calculations in the highly dynamic networks are very high, which results in low-performance of the network. In order to overcome from such low performances, a different and new forwarding model for these networks is needed. Location-based routing protocols are different from the topology based routing protocols, they make routing decisions totally based on the geographical coordinates of nodes. The Algorithms of location based routing protocols recognize network nodes by their geo-location instead of IP (Internet Protocol) addresses [Yufei Cheng *et al.* (2014)].These routing algorithms utilize the geographical coordinates to discover route to the destinations. Some examples of location-based routing protocols are GPSR (Greedy Perimeter Stateless Routing), LAR (Location-Aided Routing), SIFT (Simple Forwarding over Trajectory) and DREAM (Distance Routing Effect Algorithm for Mobility).

Position-based routing protocols are proved more efficient for highly dynamic network scenario. A service pertaining to the location is used by the source node in order to determine the position of the destination node and the position of the destination address. Some limitations of topology-based routing protocols are eliminated by the position-based routing algorithms. In position based routing protocols, routing decisions at every node is based on the position of the destination and the position of the neighbours of the packet forwarding node. Position-based routing does not require maintenance of the entire routes. The nodes do not store routing tables to keep them up to date. Position-based routing prompts delivery of data packets to all the nodes in a particular geographic region and it is therefore called geo-casting. According to forwarding strategies, position-based routing protocols are classified as three main categories: greedy forwarding, restricted directional flooding and hierarchical.

2.2 Classification of MANET Routing Protocols

Based on dissimilar criteria, mobile ad-hoc network routing protocols can be classified into numerous types. Few of them with their properties, and the foundation of classifications are discussed here. These classifications of routing protocols are not reciprocally exclusive, and few of them may fall in multiple classes. These routing protocols can be generally classified into four categories based on the following mechanisms [Siva Ram Murthy *et al.* (2007), Charles E. Perkins (2008)]:

- Topology of routing
- Consumption of specific resources
- Mechanism of routing information
- Usage of time-based information for routing

2.2.1 Based on Topology of Routing

Due to lesser number of nodes, ad hoc wireless networks use either hierarchical or flat topology for routing. In internet technologies, hierarchical routing topology is used in order to decrease the state information. There are two types of routing topology which are hierarchical and flat routing topology [Siva Ram Murthy *et al.* (2007)].

- **Hierarchical topology:** In hierarchical routing topology, routing protocols uses an associated addressing scheme and the logical hierarchy. Examples: CGSR, FSR and HSR.
- **Flat topology:** In flat topology, routing protocols uses flat addressing schemes, by which routing protocols undertakes globally unique addressing mechanism for the member nodes of the mobile ad-hoc network. Examples: DSR, AODV, ABR, SSA, FORP and PLBR.

2.2.2 Based on Consumption of Specific Resources

Based on consumption of specific resources, mobile ad-hoc network routing protocols are classified as geographical information assisted routing and the power-aware routing protocols [Siva Ram Murthy *et al.* (2007)].

- **Geographical information assisted routing:** Those routing protocols falls in this category enhance the routing performance and minimize control overheads by the usage of available geographical information. Example: LAR.
- **Power-aware routing:** Routing protocols of this category reduces consumption of the node battery power. These routing protocols take routing decisions based on reduced battery power consumption in the network either globally or locally. Example: PAR.

2.2.3 Based on Routing Information Update Mechanism

Based on routing information update mechanism, MANET routing protocols are classified into three major categories, which are: proactive or table driven, reactive or on-demand and hybrid routing protocols [Siva Ram Murthy *et al.* (2007), Charles E. Perkins (2008)]

- **Proactive or table-driven:** In proactive or table-driven routing protocols, each and every node of the network maintains the topological information in the form of tables called routing tables by exchanging routing information periodically. This routing information gets transmitted throughout the network by flooding. Nodes of the network ensure the required path for a desired destination by the help of path-finding algorithm. Example: DSDV, WRP, CGSR, STAR, OLSR, FSR, HSR and GSR.

- **Reactive or on-demand:** Routing protocols belongs to this category does not maintain topological information of the network. These routing protocols provide the requested paths by connection creation process on demand basis. These routing protocols do not exchange information pertaining to the routing. Example: DSR, AODV, ABR, SSA, FORP and PLBR.

- **Hybrid routing protocols:** Routing protocols of this category were emerged by combining the features of proactive or table driven and reactive or on-demand routing protocols. To route within a specific geographical region or zone, a proactive or table-driven approach is used and to route beyond the region or zone a reactive or on-demand approach is used. Example: CEDAR, ZRP, and ZHLS.

2.2.4 Based on usage of Time-based information for Routing

Routing protocols which falls in this category uses time-based information. Mobile ad-hoc networks generally have dynamic topological scenarios and they encounter often path breaks, the usage of time-based information is pertaining to link life time and the path life times. Routing protocols of this category are two types, they are: future time-based and past time-based routing protocols [Siva Ram Murthy *et al.* (2007)].

- **Future time-based:** Routing protocols of this category makes routing decisions by using information pertaining to the status of expected future of the links. Besides the life time of the links, the future status information holds the information about node life time, location prediction and prediction of the link availability. Example: FORP, RABR and LBR.

- **Past time-based:** Routing protocols which falls in this category utilizes information related to the past status of the wireless links. Prior to the routing decisions for establishing a new link, these protocols consider the past status of the link. Example: DSDV, WRP, STAR, DSR, AODV, FSR, HSR and GSR.

2.3 QoS in Mobile Ad-hoc Networks

Quality of service refers to performance levels of the services make available to the network users. The main intension behind quality of service provisioning is to make network services better in terms of information delivery and utilization of network resources. Networks offer different kind of services to its users. Network services are categorized by some specific assessable service requirements like jitter, rate of maximum packet loss, bandwidth and maximum delay. Delay comprises queuing delay, propagation delay and transmission delay. Networks should offer some kind of service guarantees while providing its services to the users. When a network receives service requests from its users, it has to provide suitable loop-free paths and these paths must be equipped with the required resources in order to cater quality of service requirements [Siva Ram Murthy *et al.* (2007)]. This can be achieved by the help of QoS routing.

Quality of service guarantees can only be given by means of resource reservation techniques. Quality of service provisioning needs; co-operation between network and host, resource reservation, call admission control and packets scheduling priorities. Quality of service can be incorporated in mobile ad-hoc networks by certain ways that is per node or per link and per flow. In mobile ad-hoc networks, issues of quality of services becomes challenging due their characteristics such as; mobility of nodes, limited resource availability and lack of essential coordination [Charles E. Perkins (2008)].

2.3.1 QoS Parameters

Unlike in conventional wired networks, in mobile ad-hoc networks the requirements of quality of service are more inclined by the nodes resource constraints. Few of such resource constraints are buffer space, processing power and the battery charge level. Different applications may have their own particular requirements, the services needed by such applications must be fulfilled by the QoS provisioning. For different applications different quality of service measures are required. For instance, a multimedia application requires key QoS parameters such as delay, jitter and the bandwidth. Likewise, a military application needs strict security measures. Emergency search-rescue operations require high network availability, which is a major QoS parameter. Similarly, communication takes place in group conferences require low energy consumption of communicating nodes. Here, Battery life is considered as the key quality of service parameter [Siva Ram Murthy *et al.* (2007)].

2.3.2 QoS Issues and Challenges

Some characteristics of mobile ad-hoc networks pose many complications towards QoS provisioning. These characteristics are; dynamic nature of the network topology due to node mobility, lack of accurate state information, insecure medium, hidden terminal problems, and availability of limited resources, error-prone shared radio channel and lack of central organizer. Provisioning of QoS in mobile ad-hoc networks is a lively area of research. Research community is presently concentrating on QoS provision techniques for such applications which require guarantees in terms of soft real-time [Siva Ram Murthy *et al.* (2007)].

2.3.3 QoS Solutions

There are some design choices to make available quality of service provision namely, hard state resource reservation, soft state resource reservation, stateful approach, stateless approach, hard QoS approach and soft QoS approach. QoS solutions are classified in two methods; one is based on the QoS approach engaged and the other one is based on the network protocol stack layer at which they function. Based on interface between the QoS facility mechanism and the routing protocol, QoS approaches can be classified in two ways; one is coupled QoS approach and another one is decoupled QoS approach. Likewise, based on interface between MAC protocol and the routing protocol, these can further classified in two ways; dependent QoS approach and independent QoS approach. Similarly, layer-wise classifications are classified into; mac layer solutions and network layer solutions.

2.4 Applications of Mobile Ad-hoc Networks

As discussed in earlier chapter, mobile-ad hoc networks are self-forming and self-healing new generation wireless networks, they do not depend upon any centralized control setup such as base stations and access points to operate. These networks can be deployed quickly and their deployments involve less cost, this makes these networks easy and economical. Applications of mobile ad-hoc networks can find in several areas, some of them include military applications, emergency rescue operations, collaborative and distributed computing, wireless mesh networks, wireless sensor networks and hybrid wireless networks [Siva Ram Murthy *et al.* (2007), Charles E. Perkins (2008)].

2.4.1 Military Applications

Mobile ad-hoc networks are very helpful for creating communication between different military troops for strategic operations. Deployment of infrastructure based communication network setup at enemy territories may not possible. In such situations, mobile ad-hoc networks are useful as they provide quick communication requirements. Military objects that move in high speed like war planes, jet fighters etc., require coordination among them by means of certain communication system, mobile ad-hoc networks are the reliable solution to establish instant communication setup without the need of any sort of centralized control mechanism. Situations like war fields, emergency operations require secure network services for instant communication and safety of peoples involved in such operations. At any cost military applications require very secure communication systems.

In military applications, sophisticated and powerful network nodes are generally mounted on the vehicles. These powerful nodes can have multiple high power transceivers, for security reasons, such nodes possesses the capability to hop among different frequencies. Network nodes in military applications are designed such that they must operate for long by having log-lasting batteries which might not be economically feasible [Siva Ram Murthy *et al.* (2007)]. Military networks are designed for multi-purpose operations such as; voice-video communications, global positioning system (GPS), tracking systems and satellite-based services. In some types of applications (like military applications), mobile ad-hoc networks may not encounter resource constraints like battery life and node transmit power. The primary nature of communications required in military applications is efficient, reliable and secure with multicast support.

2.4.2 Emergency and Rescue Operations

Emergency operations like crowd control, search and rescue operations (during earth quakes, flood, tsunami, natural calamities etc.), commando operations and mob control requires wireless mobile ad-hoc network services because of their easy, quick and economical deployments. Self-forming and self-healing nature of mobile ad-hoc networks favours emergency operations. Major aspects that support mobile ad-hoc networks for emergency operations are; self-system configuration with minimum overhead, independent of fixed infrastructure, freedom and flexibility of mobile nodes. In some emergency situations discussed above, conventional communication infrastructure gets destroyed; instant deployment of mobile ad-hoc networks would be helpful for supporting rescue undertakings. Mobile ad-hoc networks require minimal initial configurations for their operation hence, very slight delay or sometimes no delay is involved during full operation of the network. Emergency situations are generally occurring unexpectedly, such situations are unavoidable, which affects large number of humans and the assets. Ad-hoc networks that deploy in emergency and rescue operations must be scalable to maximum numbers of nodes and it should be distributed. Ad-hoc networks that deployed in emergency and rescue operations must be capable of delivering fault-tolerant communication paths and real-time communication capabilities.

2.4.3 Collaborative and Distributed Computing

Collaborative and distributed computing is another area where services of wireless mobile ad-hoc networks are useful. The need of temporary communication system for instant communication between groups of people in a gathering requires creation of wireless mobile ad-hoc network. For instance, an assembly of researchers who intends to share their research results during a symposium, during such situations, the establishment of a wireless ad-hoc network with the required provision of reliable multicast routing can be helpful. In such instances, distributed file sharing applications are utilized and these applications do not require the level of security as needed in military applications; however consistency in data transfer is very important here. Applications such as multimedia video streaming between the wireless ad-hoc network nodes may require real-time communication support. Such multimedia application users generally prefer handy and inexpensive battery powered devices. Such mobile devices or nodes may drain their battery resulting in varied transmit power and unidirectional links with their neighbouring nodes. Such applications can be processed by using devices like; laptops, personal digital assistants (PDAs) and other mobile devices as nodes of the network.

2.4.4 Wireless Mesh Networks

Wireless mesh networks are actually wireless ad-hoc networks which are used as alternatives to the conventional fixed or mobile wireless networks. Wireless mesh networks operates without the spectrum reuse constraints and cellular network planning. These networks use mesh network topologies, which delivers various alternate paths in between a source node and the destination node during a data transfer session. These alternate paths get quickly reconfigured when the main link between a source and destination node fails. Wireless mesh networks offers most economical data transfer capabilities together with the autonomy of mobility. Wireless mesh networks nodes can either be mobile or fixed; these nodes are small radio relaying devices generally mounted on the rooftops at the residences or fixed at lamp posts on the streets. As compare to cellular networks, wireless mesh networks are more economical and are shaped by wireless relaying equipment range through the geographical area to be covered by the network [Siva Ram Murthy *et al.* (2007)]. Some deployment circumstances of the wireless mesh networks are; residential sectors, highways, business sectors, main civilian areas and university or college campuses. These wireless mesh networks possesses the capabilities of self-organization and maintenance. The key advantages of wireless mesh networks are; provision for high data rate, low cost per bit, high availability, easy extendibility, high scalability, enhanced services and quick, low cost deployment. Wireless mesh networks operate at 2.4 GHz and 5 GHz frequencies.

2.5 Mobility Models

MANET nodes has the nature of mobility, due to mobility characteristics of nodes, network performance evaluation needs mobility models. In mobility model of nodes, node movements are closely relates to the movements like in a real network [Fan Bai *et al.* (2003)]. Various mobility models have been proposed for MANETs [Tracy Camp *et al.* (2002)]. Scenarios of realistic motion of the nodes are complex in nature and they vary from one mobility model to another, this poses major challenge in the analysis of MANET routing protocols. Various mobility models are required to evaluate the routing protocols in order to decide which one would be the best for different network scenarios. There are different mobility models are available for analysing the mobile ad-hoc network routing protocols, some of them are: Random Walk, Random Waypoint, Random Direction and Gauss-Markov.

2.5.1 Random Walk

In order to emulate the randomness of movements of mobile nodes the random walk mobility model is used. In random walk, after travelling for a specified amount of time, nodes can change their directions, and then they choose random direction and speed. If a node reaches the boundary of the simulation, it bounces off at some angle which is determined by the incoming direction. Random walk mobility model is said to be memory less mobility because in which, the current velocity and direction are not depends on the previous ones. Fig.2.1 shows the node mobility in a random walk mobility model [Tracy Camp *et al.* (2002), Fan Bai *et al.* (2003)].

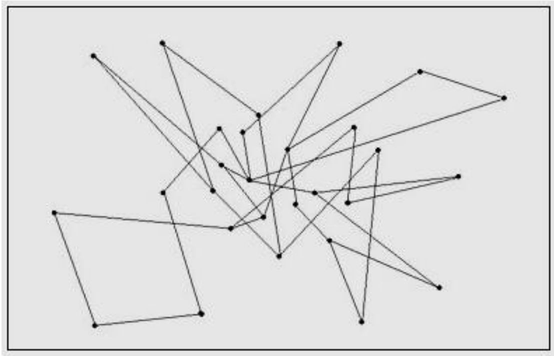

Fig.2.1. Random Walk Mobility Model

2.5.2 Random Waypoint

The random waypoint mobility model is one of the well-known and commonly used mobility models in the simulation scenarios of the MANETs. In random waypoint mobility model, a node chooses a random speed, a random destination and a pause time from a specified range. Then the node moves towards the selected destination with the specified speed and pause times for a specified amount of time. In this mobility model, the speed and pause times can be defined as any specific value or a range of values. It is widely accepted [Josh Broch *et al.* (1998)] that the Random waypoint mobility model has a drawback as its average speed is much lesser than the expected and the nodes tend to form in between the simulation [Jungkeun Yoon *et al.* (2003)].This drawback of the random waypoint mobility model is fixed with its improved version the steady-state random waypoint mobility model [Navidi *et al.* (2004)]. Fig.2.2 illustrates the mobility of nodes in a network by the random waypoint mobility model.

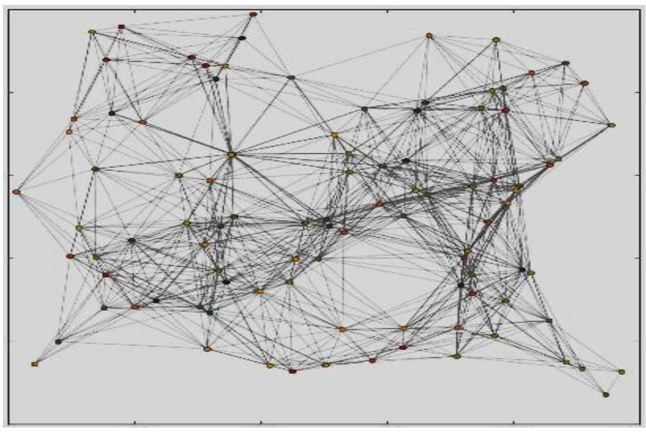

Fig.2.2. Random Waypoint Mobility Model

2.5.3 Random Direction

Random direction mobility model is a memoryless mobility model. Density wave is the cluster of all the nodes in the centre of the simulation area. The random direction mobility model was designed to improve the conventional random waypoint mobility model. This mobility model has improved the density wave problems of the random waypoint mobility model. In random direction mobility model, nodes select mobility in a random direction with a specified speed along this random direction. This mobility goes on until the nodes reach the boundary of the simulation area. In the simulation area, where it pauses for the set pause time before it selects random angular direction that is in between 0 and 180 degrees and repeats the process. This process ensures the high probability traversing area for the nodes in the entire simulation area. The random direction mobility has the disadvantage as it is unrealistic because in this mobility model, nodes are required to travel to the simulation boundary and take a bounce [Yufei Cheng *et al.* (2014)]. Fig.2.3 demonstrates the node mobility to the simulation boundary and bouncing back.

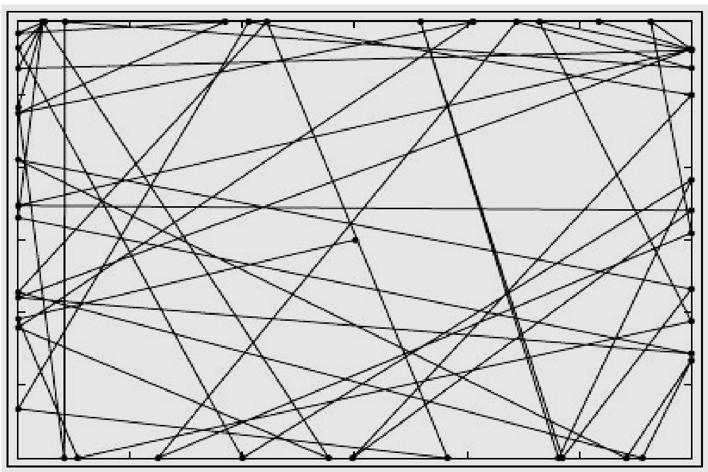

Fig.2.3. Random Direction Mobility Model

2.5.4 Gauss-Markov

The gauss-markov is a memory based synthetic mobility model. Unlike other mobility models the gauss-markov combines random movements of the nodes with memory. Other mobility models tend to produce node movements in a straight line because of lack of memory [Dan Broyles *et al.* (2010)]. In gauss-markov mobility model, node mobility begins randomly from the initial point and travel for a specified time interval called a time step. This happens prior to the speed and the direction changes to newly calculated values, all the new values are based on the previous values. In NS-3 (Network Simulator-3), a 3-D (Three Dimension) version of gauss-markov mobility model has been developed by Dan Broyles of University of Kansas [Dan Broyles *et al.* (2010)]. Fig.2.4 shows the movements of the network nodes in the gauss-markov mobility model.

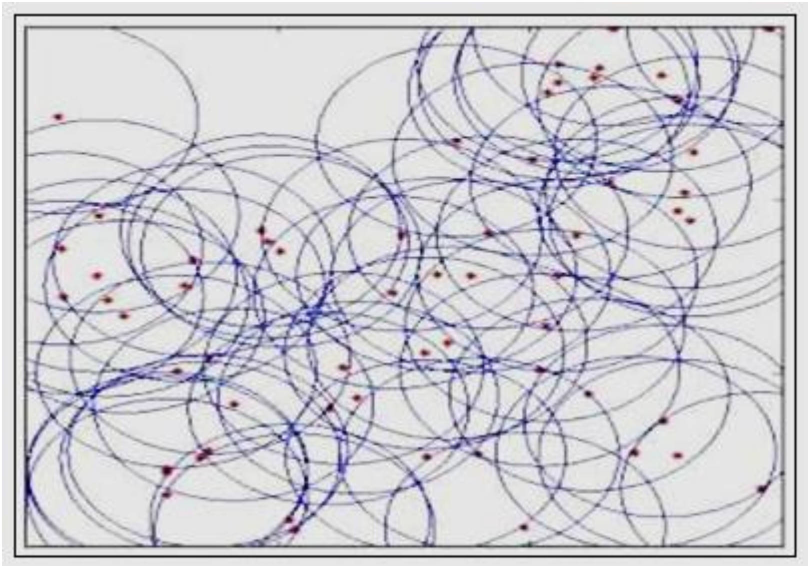

Fig.2.4.Gauss-Markov Mobility Model

2.6 Traffic Generators

There are different traffic generators available for the analysis of mobile ad-hoc network routing protocols. Traffic generators models the traffic in a predefine structure and schedule manner. Traffic generators provide the transmission demands of traffic payloads regardless position of agent which is attached at a specific interval and time [Megha Rastogi *et al.* (2012)].

2.6.1 FTP (File Transfer Protocol) Traffic

A FTP traffic generator produces the payload as per the bandwidth of the connection. FTP traffic generator utilizes the total available bandwidth during the transmission process.

2.6.2 CBR (Constant Bit Rate) Traffic

Creation of payload in CBR traffic generator is fixed in size and the interval of packet generation is also fixed.

2.6.3 Exponential Traffic

Exponential traffic generator is also called as variable bit rate traffic generator, it creates the payloads similar to CBR traffic generator excluding the feature of ON/OFF interval states. This unique feature differences itself with the CBR traffic generator. In exponential traffic generator, the ON state represents the start of the traffic generation and OFF state represents the off state of the traffic generation in a specific time interval. These ON and OFF states of this traffic generator are exponentially distributed.

Probability Distribution Traffic (PDT) is defined as;

$$f(x\,;\,\lambda) = \begin{cases} \lambda e^{-\lambda x}, & x \geq 0 \\ 0, & x < 0 \end{cases} \tag{2.1}$$

Where λ is the rate of average exponential occurrence, an ON/OFF traffic can be generated by varying λ parameter [Bindeshwar *et al.* (2016)].

2.6.4 Pareto Traffic

Pareto traffic generator is also called as Poisson traffic generator; it has got similar features that of exponential traffic generator. In Pareto traffic generator, ON/OFF states are referred as ON/OFF periods and these periods are depends upon Pareto distribution. A random variable X is said to follow Pareto distribution, when it follows the following probability distribution function.

$$F(x) = P(X > x) = \begin{cases} \left(\frac{x_m}{x}\right)^{\propto} & x \geq x_m, \\ 1 & x < x_m. \end{cases} \tag{2.2}$$

Where, x_m is the parameter of scale, α is a parameter of shape. By varying x_m and $\propto$, an ON/OFF traffic can be generated. Parameters such as packet size, burst time, idle time, rate and shape are needs to configured [Bindeshwar *et al.* (2016)].

2.6.5 Pack Mime Traffic

Pack mime traffic generator creates the traffic similar to the HTTP 1.1 (Hyper Text Transfer Protocol) traffic. Pack mime traffic generator controls two types of applications, one is server grade applications and another is client grade applications. These client-server traffic generators support only the FULL-TCP (Transmission Control Protocol) agents.

2.7 Associated Work

Numerous research works have been conducted in the area of new generation wireless networks like; wireless sensor networks and wireless mobile ad-hoc networks. This thesis is presenting research works related to the performance analysis of some routing protocols in wireless ad-hoc networks. Many researchers were worked on performance analysis of the routing protocols in mobile ad-hoc networks; some were considered certain general network parameters and traffic load related parameters as variable factor for their analysis. Few researchers were introduced their own version by adding new features to the existing routing protocols. Still such researches are going on for achieving better functioning of MANET routing protocols. In most of the earlier works, performance comparisons of different standard routing protocols were carried out by considering diverse network parameters as variable factor using NS-2 (Network Simulator-2). Some of these factors include; variation in number of network nodes, node pause times, different traffic generators, different geographic regions, and different mobility models etc. Most of these works can only justify the best performing routing protocol in some general network scenarios.

Researchers who have devoted towards performance analysis of MANET routing protocols were used different set of standard MANET routing protocols for their analysis. Many researchers have studied comparative analysis of MANET routing protocols and presented their results to the research community for further scope of research. Some of them are discussed here; researchers Teressa Longjam *et al.* [Teressa Longjam *et al.* (2013)] have studied comparative study of standard DSDV and AODV routing protocols by considering different network node sets (10, 20, 30, 40 and 50 nodes)using NS-2 and concluded better performance of DSDV as per their simulation setup. Rakesh Kumar Jha *et al.*[Rakesh Kumar Jha *et al.* (2015)] have studied comparative analysis of standard OLSR, AODV and DSR routing protocols for 5, 10 and 15 nodes using NS-3 (Network Simulator-3) and realized superior performance of AODV. Kumar *et al.* [Kumar *et al.* (2015)] have studied transmission range, density & speed based performance analysis of OLSR, DSR and ZRP (Zone Routing Protocol) routing protocols. Based on their simulation arrangement, they determined better performance of the DSR protocol. Rajneesh Kumar *et al.* [Rajneesh Kumar *et al.* (2013)] have studied analysis of network survivability with variable transmission range and mobility on AODV over MANET and resolved that the performance of AODV routing protocol is better with highest mobility speed and higher transmission ranges in terms of network survival and QoS parameters.

Some researchers Ali Khosrozadeh *et al.* [Ali Khosrozadeh *et al.* (2011)] were reviewed the conventional AODV routing protocol model and added a new route maintenance algorithm to it for avoiding route breaks. Other researchers were worked on resolution to the energy limitations in mobile ad-hoc network routing protocols. Loganathan *et al.* [Loganathan *et al.* (2013)] investigated DSDV routing protocol to present the multicast parameters based DSDV (MPB-DSDV) routing protocol, which improves the energy efficiency in ad hoc networks. Researchers Charles E. Perkins *et al* [Charles E. Perkins *et al.*(1994)] were basically proposed the ad-hoc network which has supportive selection of set of mobile nodes or hosts without the necessary participation of centrally controllable base stations or access points. Researcher Charles E. Perkins has proposed an advanced design of ad-hoc networks operation. The idea behind the advanced design is to declare every mobile node as a dedicated router. These nodes periodically broadcast their interconnection related topological information to their immediate neighboring nodes and other mobile nodes in the network. This advanced research works scopes to a new kind of routing protocol in mobile ad-hoc networks.

Charles E. Perkins has inspected alterations to the basic Bellman-Ford routing mechanism as measured by conventional Routing Information Protocol (RIP) to spot it suitable for the dynamic and self-starting network utilization as per choice of the network users. These new alterations were addressed the looping problems associated with the conventional Bellman-Ford techniques. This new version of the Bellman-Ford technique is supportive for the broken links between source and the destination nodes in mobile ad-hoc networks. Nimmy *et al.* [Nimmy *et al.* (2014)] have studied various schemes of intrusion detection systems along with their advantages and disadvantages and proposed the proof-based intrusion detection systems in mobile ad-hoc networks. Researchers Lalitha *et al.* [Lalitha *et al.* (2013)] have studied the impact of transmission power on the performance of MANET routing protocols, they conducted evaluation of these routing protocols under different levels of transmission range/power and concluded that; change in transmission range/power results significant impact on the performance of the routing protocols. Boomija *et al.* [Boomija *et al.* (2014)] studied the optimization of transmission power in ad-hoc networks and proposed some methods of finding an optimized power allocation to solve the power control problem. Conclusion of this study explores that the small number of nearest interfering transmitters have a significant effect on the feasibility of a channel.

Researchers Megha Rastogi *et al.* [Megha Rastogi *et al.* (2012)] have studied traffic generator based performance evaluation of proactive and reactive protocols in mobile ad-hoc networks, they evaluated the effects of different traffic generators over the mobile ad-hoc network routing protocols. Researchers Nurul I. Sarkar *et al.* [Nurul I. Sarkar *et al.* (2010)] were studied mobile ad-hoc network routing protocols such as; AODV, DSR, OLSR and TORA (Temporally Ordered Routing Algorithm), considering the factors like; joint node density, packet length and mobility. Their investigations include development of OPNET (Open Network Simulation Tool) based simulation models to study combined effect of node density, packet length and mobility on the performance of a typical MANET. Dmitri *et al.* [Dmitri D. Perkins *et al.* (2002)] have studied factors affecting the performance of ad-hoc networks and proposed some contributions to the modelling and development of adaptive ad hoc protocols such as; routing, medium access control, scheduling and buffer management.

Researchers Ying Ge *et al.* [Ying Ge *et al.* (2002)] were studied quality of service routing in ad-hoc networks using OLSR routing protocol. They developed heuristics that allow OLSR routing protocol to find the maximum bandwidth path through the simulation based analysis, they proved that the developed heuristics were improved the OLSR in the static network case and guaranteed the highest-bandwidth path between any two nodes. Researcher Yufei Cheng [Yufei Cheng (2014)] had studied performance analysis of transactional traffic in mobile ad-hoc networks, his analysis includes fine tuning of some core parameters of the default routing models of the AODV, DSDV, OLSR and DSR routing protocols to test different traffic transactions in the performance of the mobile ad-hoc networks. Researchers Asutosh Sharma *et al.* [Asutosh Sharma *et al.* (2016)] have studied “performance comparison and detailed study of AODV, DSDV, DSR, TORA and OLSR routing protocols in ad hoc networks” considering standard routing models. Their results conclude better performance of the AODV routing protocol in terms of average throughput and packet delivery ratio.

Researchers Md. Niaz Imtiaz*et al.* [Md. Niaz Imtiaz*et al.* (2015)] were studied “performance evaluation of routing protocols (AODV, DSR, OLSR and DYMO) in MANET considering mobility factor”, their conclusion reveals better performance of OLSR routing protocol.

Researchers Dinesh Singh *et al.* [Dinesh Singh *et al.* (2011)]have studied “comparative performance analysis of LANMAR, LAR1, DYMO and ZRP routing protocols in MANET using random way point mobility model” considering varied node pause time. Their analysis concludes better performances of the LANMAR routing protocol. Researchers Sweta Kriplani *et al.* [Sweta Kriplani *et al.* (2016)] have studied malicious nodes identification and classification of nodes and detection of UDP flood attack with ICMP using OLSR Routing Protocol. Researchers Madhu Bala *et al.* [Madhu Bala *et al.* (2017)] have reviewed various routing protocols in MANETs under different network scenarios. Researchers Qutaiba Razouqi *et al.* [Qutaiba Razouqi *et al.* (2013)] have studied “extensive performance analysis of standard DSDV, DSR, and AODV routing protocols for different network scenarios”, their study states better behavior of DSR and AODV routing protocols for combined traffic scenarios. Kanu Bala *et al.* [Kanu Bala *et al.* (2016)]have studied “enhancement of OLSR routing protocol in MANET” proposing a new version of the OLSR routing protocol using node grouping techniques, their conclusion reveals better performance of the newly proposed protocol.

Researchers Ashutosh Dixit *et al.* [Ashutosh Dixit *et al.* (2015)] have studied "Performance Evaluation of DSDV, AODV and DSR Routing Protocol in MANET", they conclude better performance of the DSDV routing protocol. Researchers Chen*et al.* [Chen *et al.* (2002)] were introduced QoS based OLMQR (On-Demand Link-State Multipath QoS Routing) routing protocol in a Wireless Mobile Ad Hoc Network. Unlike other QoS routing protocols which find a single route between nodes fulfilling the QoS requirements, the OLMQR (On-demand Link state Multipath QoS Routing) routing protocol seeks for multiple routes which jointly gratify the QoS requirements. In OLMQR, total bandwidth required is divided into sub-bandwidths; the routes established by the multipath routing protocol are permitted to share the same sub-routes. Researchers Taing *et al.* [Taing *et al.* (2006)] were projected an enhanced DSR called MDSR (Modified DSR), which delivers improved number of hop paths and minimum delays between source nodes to the destination nodes, as compare to the conventional DSR routing protocol.

Researchers Safa *et al.* [Safa *et al.* (2007)] were projected a routing protocol known as HAODV (Heterogeneous AODV), which optimizes the existing AODV routing protocol to upkeep routing in heterogeneous networks such as Wi-Fi and Bluetooth. HAODV regulates an optimum path with the lesser traffic density and high stability. Researchers Sjaugi *et al.* [Sjaugi *et al.* (2008)] were projected a new kind of route maintenance mechanism for DSR known as DISTANCE. The prime indication is to present a different node referred as 'bridge-node' into the source tables for avoiding link failures. Every node updates its position by piggybacking in packet header. By this technique, they achieved improvement in delays and packet sending ratios. Researchers Yi *et al.* [Yi *et al.* (2003)] were projected a mobile ad-hoc network routing protocol called CADV (Congestion Aware Distance Vector) to enhance performance of the network with respect to routing load and packet delivery. CADV routing protocol incorporates congestion avoidance approach in a table-driven routing protocol such as DSDV.

Researchers Bai *et al.* [Bai *et al.* (2006)] have developed DOA (DSR over AODV) routing protocol for MANET, aiming on route maintenance process. DOA provides two level route repairs; intra-segment level and intersegment level. When a route fails, an intra-segment repairs it by using available alternative routes within that segment. Researchers Yifei *et al.* [Yifei *et al.* (2008)] have projected a routing protocol known as PC-AODV (Power Control AODV) to enhance network throughput and power consumption. The indication of this work is to institute a path with a suitable data-rate link within the broadcast range and to regulate the transmit power level. Researchers Khamforoosh *et al.* [Khamforoosh *et al.* (2008)] have projected another AODV class routing protocol referred as AODV (CDM-AODV) (Centre base Distance Multi-path-AODV). The suggestion is to select two routes from the midpoint of the network. The aim behind it is that there is an opposite association between the distances of the node to the midpoint of network. When demand data packets are sent, response data packets have the info about the midpoint of network and distance between network nodes.

Researchers Abdelkabir Sahnoun *et al.* [Abdelkabir Sahnoun *et al.* (2017)] have introduced an energy efficient and path reliability protocol for proactive mobile ad-hoc network routing. The proposed schemes motivated previous works on mobile ad-hoc networks on comparison of routing performances by extensive simulations. Researchers Biao *et al.* [Biao *et al.* (2004)] inspected the performance of AODV, DSDV, DSR and TORA routing protocols through extensive simulations with growing number of network nodes in mobile ad-hoc networks.

2.8 Inherent Characteristics of MANETs

In mobile ad-hoc networks, each node acts as the host and the router thus, MANETs are possessing autonomous behaviour. MANETs supports multi-hop radio relaying. Absence of centralized firewall leads to lack of security operations in mobile ad-hoc networks. In mobile ad-hoc networks, free movements of nodes leads to join or leave the network region at any time causes them to have a dynamic network topology. MANET nodes possess less memory, less power and features light weight. As compare to wired links, wireless links have substandard reliability, stability, efficiency and capacity; this causes fluctuations in link bandwidth. Mobile and spontaneous behaviour of MANETs reduces human intervention to configure the network. All the nodes of the ad-hoc networks have similar features, accountabilities and capabilities; this makes them to form the symmetric scenarios. These networks have higher density of users, high user mobility, and they have irregular nodal connectivity [IR 5].

2.9 Security Issues Associated with Routing in MANETs

Security attacks in mobile ad hoc networks are classified broadly as active and passive attacks[Siva Ram Murthy *et al.* (2007)], [Shilpi Burman Sharma *et al.* (2015)]. Active attacks can destroy or revise the live network and routing data causing malfunctioning of the network. Passive attacks are dangerous as they does not disturb network operation but they snoops network data without any changes. Different types of attacks in MANETs can be classified as; network layer attacks, transport layer attacks and application layer attacks. Attacks pertaining to the network layer are; wormhole attack, resource consumption attack, black hole attack, information disclosure and byzantine attack etc. Session hijacking is specific type of attack associated with the transport layer and the repudiation attack is generally occurs over the application layer. Other attacks associated with the MANETs are; multi-layer attacks and device tampering. Denials of service (DoS) and impersonation attacks are associated with the multi-layer attacks. Jamming, SYN flooding and distributed DOS (DDoS) attacks are multi-layer denial of service attacks generally referred as DoS attacks. Routing protocols in MANETs face several routing attacks which targets disruption of the network operation. Some of them include; rushing attack, packet replication, route cache poisoning, route table poisoning and routing table overflow. These routing attacks falls under network layer attacks in mobile ad hoc networks. In order to prevent the routing attacks, a secure routing protocol is needed for better operation of the network.

In MANETs, nodes have to perform as a host (source or destination) as well as router due to absence of centrally controllable network infrastructure. Thus, unavailability of dedicated routers poses several challenges in providing secure and error-free routing [Siva Ram Murthy *et al.* (2007)], [Shilpi Burman Sharma *et al.* (2015)]. Routing protocols in MANETs get affected by different ways of security attacks which disorders routing processes by altering established communication paths and by intruding invalid data packets along the path [Priyanka Yadav *et al.* (2017)]. Other reasons which make secure communication difficult are; random mobility of network nodes, limited obtainability of resources (bandwidth, memory and battery power) limited processing power. Therefore, a secure routing protocol require some basic requirements such as stability against routing attacks, correct path discovery guarantee, finding of malicious nodes and privacy of network topology. Some of the security aware routing protocols proposed for MANETs were; SA-AODV (Security Aware – Ad hoc On demand Distance Vector), SAR (Security aware Ad hoc Routing), ARAN (Authenticated Routing for Ad hoc Networks) and SEAD (Secure Efficient Ad hoc Distance vector) etc. Recent researches have proposed their new versions. Still there is large scope in addressing security challenges faced by the MANET routing protocols in order to ensure secure and safe operation of mobile ad hoc networks [Siva Ram Murthy *et al.* (2007), Priyanka Yadav *et al.* (2017)].

2.10 Factors that Affects performance of the MANETs

Mobile ad-hoc networks do not have any fixed infrastructure or base stations, these networks have limited transmission range, multiple hops may be needed for nodes of these networks for communicating throughout the ad-hoc network. Functionality of routing is incorporated in every host of the ad-hoc network. Thus, mobile ad-hoc networks are characterized as having a dynamic, multi-hop and constantly changing topology. Mobile ad-hoc networks can be used without any fixed infrastructure, their use is also being considered as part of wireless internet. The future of MANETs will depend on its ability of supporting existing and future applications of the internet and protocols. Dynamic environments of the modern day networks poses major protocol design challenges at the every layers of the network architectures, these challenges are ranging right from the issues of the physical layers of the networks to the access control of the network distribution medium to routing. Overall performance of the mobile ad-hoc network protocols depends on several factors. For instance, node velocity may cause failure of links between the source node and the mobile node, which will pour negative impact on the routing and QoS (Quality of Service) support.

Network density, control overheads and intensity of the traffic will have a considerable impact on the network scalability. There are several factors that affect performance of the mobile ad-hoc networks, some of them are: Transmit power, node pause time, node velocity, node density, mobility models, transmission region, number of source/sink pairs, type of traffic demands, and the core routing parameters of the protocol. These factors along with the inherent characteristics of the mobile ad-hoc networks may result in unpredictable variations in the overall performance of the network [Dmitri *et al.* (2002)]. Quantifying the effects of these factors will help the new design choices and trade-offs. For instance, node mobility is shown to have a greater impact on average control overhead than any other factor. This would suggest that the designing algorithms that adapt to node mobility would have the greater impact on network performance.

2.11 Problem Statement

Routing in ad hoc networks becoming challenging due to their dynamic topologies. Many researchers have motivated on the algorithmic complexity of ad-hoc routers. Some other researchers have proposed new routing solutions. Protocols of MANETs are optimized to reduce the number of hops from the source to the destination due to faster growth of wireless communication technologies. These technological advances are able to provide various kinds of advanced applications including multimedia applications to the common users. A mobile ad-hoc network has some limitations and inefficiencies that include numerous factors such as the characteristics of wireless links and their nature of time-varying. There are some obstacles in transmission like fading, path loss, blockage and interference which adds to vulnerable performance of wireless channels. Different issues resist the reliability of the wireless transmission. MANETs faces inadequate range of wireless transmission including the restricted radio bands that results in lesser data rates. In order to achieve optimal usage of bandwidth in MANETs, routing overheads needs to be reduced.

In ad-hoc networks, transmission faults effects in higher packet losses, the main issues that cause these packet losses are: collisions of hidden terminals, high bit error rate of wireless channels, interference, frequent path breaks caused due to mobility of the nodes and increased collisions due to the existence of unidirectional links and hidden terminals. Mobile ad-hoc network nodes experiences path changes due to their mobility, frequent path break occurs due to dynamic network topology. MANETs faces frequent network partitions, the random mobility of nodes often lead to the network partitions which affects the performance of the intermediate nodes. As discussed earlier, the key issues that affect the design, deployment and performance of MANETs are: Routing, scalability, multicasting, transport layer protocols, QoS provisioning, self-organization, security, energy management and addressing service discovery.

Presently available routing protocols for MANETs needs improvements in their performances and performances of the routing protocols can be improved by improving performance improving factors such as; the throughput, packet delivery ratio, end to end delay, packet and regulated (normalized) routing load. After studying earlier research works in detail, this research work was carried out to achieve possible improvements in performances of the standard AODV, DSDV, OLSR and DSR routing protocols through simulation based performance analysis.

2.12 Performance Improving Concerns in MANET Routing Protocols

A routing protocol designed for ad-hoc networks faces the major challenges like mobility of nodes, resource restrictions, and error-prone channel state, hidden and visible terminal problems [Siva Ram Murthy *et al*. (2007)]. Day by day, technology associated with the user applications are becoming advanced and existing routing protocols needs some kind of improvements in order to execute the advanced applications. These challenges need to be addressed for better and enhanced performance of the mobile ad-hoc networks.

2.12.1 Mobility Management

Due to mobility of nodes, mobile ad-hoc networks become highly dynamic in nature, due to which an on-going communication session suffers frequent path breaks. This disturbance occur either because of the movement of the intermediate nodes in the path or due to the movement of end nodes in the network. Such circumstances do not rise because of consistent links in wired networks in which all the nodes are fixed.

Mobile ad-hoc network routing protocols must be able to achieve effective and proficient mobility management.

2.12.2 Bandwidth Restriction

In wired networks, rich amount of bandwidth is available due to the introduction of fibre optics and due to the utilization of WDM (Wave length Division Multiplexing) technologies. But in an ad-hoc wireless network, the radio band is limited, and hence the data rates that a wireless network can offer are much lower than that of a wired network can offer. Because of this, the MANET routing protocols have to use the bandwidth optimally by keeping lesser overheads. Availability of limited bandwidth also enforces a restriction on routing protocols in maintaining the information related to the network topology. Due to the regular changes in network topology, maintaining reliable topological information in all nodes of the network comprises added control overheads which results in more wastage of bandwidth, this needs improvements.

2.12.3 Error-Prone Shared Transmission Radio Channel

In Mobile ad-hoc networks, the transmission nature of the radio channel postures an exclusive challenge. With reference to the terms link-error probability and link capacity, the wireless links poses time-varying characteristics. To improve these characteristics, mobile ad-hoc network routing protocols must liaise with the MAC (Medium Access Control) layer to find best quality links and the alternate routes. Data packet transmission in mobile ad-hoc networks often faces data packets and control packets collisions, this endorsed to the hidden terminal problem [Fullmer *et al.* (1997)].

2.12.4 Hidden and Visible Terminal Problems

The collision of data packets at a receiving node occur due to the simultaneous transmission from the sending nodes, which are not with in the straight transmission range of the sender, but they are within the transmission range of the receiver is refers to the hidden terminal problems. When any two nodes of the network transmit data packets at the same interval of time without knowing about each other’s transmission then the collision occurs.

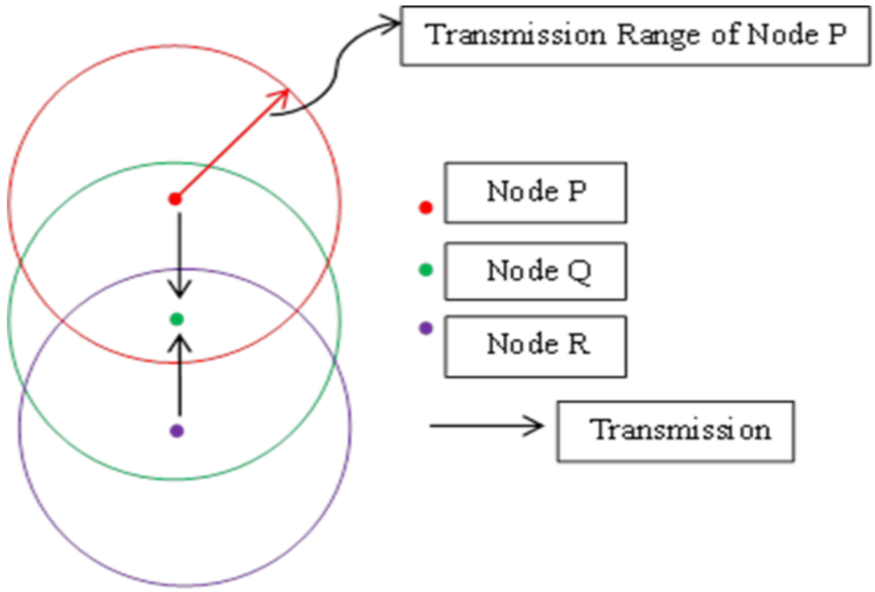

Fig.2.5.Hidden terminal problem

For instance, consider Fig.2.5. Here, if both node ‘P’ and node ‘R’ transmit to node ‘Q’ at the same time, their data packets gets collide at node ‘Q’. This is due to the fact that both the nodes ‘P’ and ‘R’ are hidden from each other, as they are not within the direct transmission range of each other and hence they do not know about the presence of each other. Fig.2.6 illustrates the hidden terminal problem as discussed in Fig.2.5.

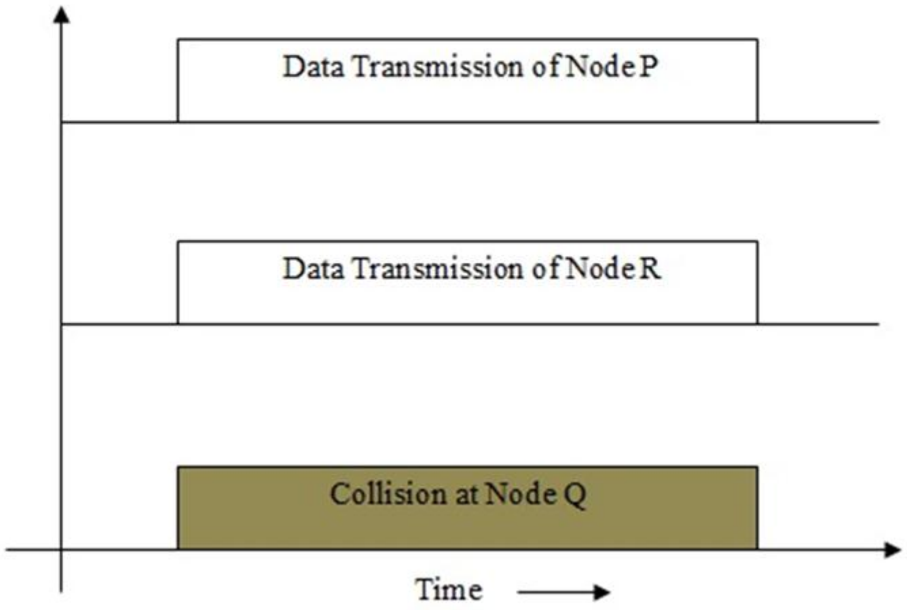

Fig.2.6.Illustration of hidden terminal problem

There are some solutions for this problem which includes MACA (Medium Access Collision Avoidance) [Karn *et al.* (1990)], MACAW (Medium Access Collision Avoidance for Wireless) [Bharghavan *et al.* (1994)], FAMA (Floor Acquisition Multiple Access) [Fullmer *et al.* (1995)] and DBTMA (Dual Busy Tone Multiple Access) [Deng *et al.* (1998)]. A node faces inability while transmitting to another node due to transmission session of the nearby node is referring to the visible terminal problem. Fig.2.7 illustrates that there are four nodes P, Q, R and S in a mobile ad-hoc network, if transmission from node Q to node P is in progress then the node R cannot transmit to node S, because node R concludes that its neighbour node Q is in transmitting mode and hence it should not interfere with the on-going transmission. This affects the reusability of the radio spectrum. In order to put node R in simultaneous transmission mode during transmission by the node Q, transmission frequency of node R must be different from its receiving frequency [Siva Ram Murthy *et al.* (2007)].

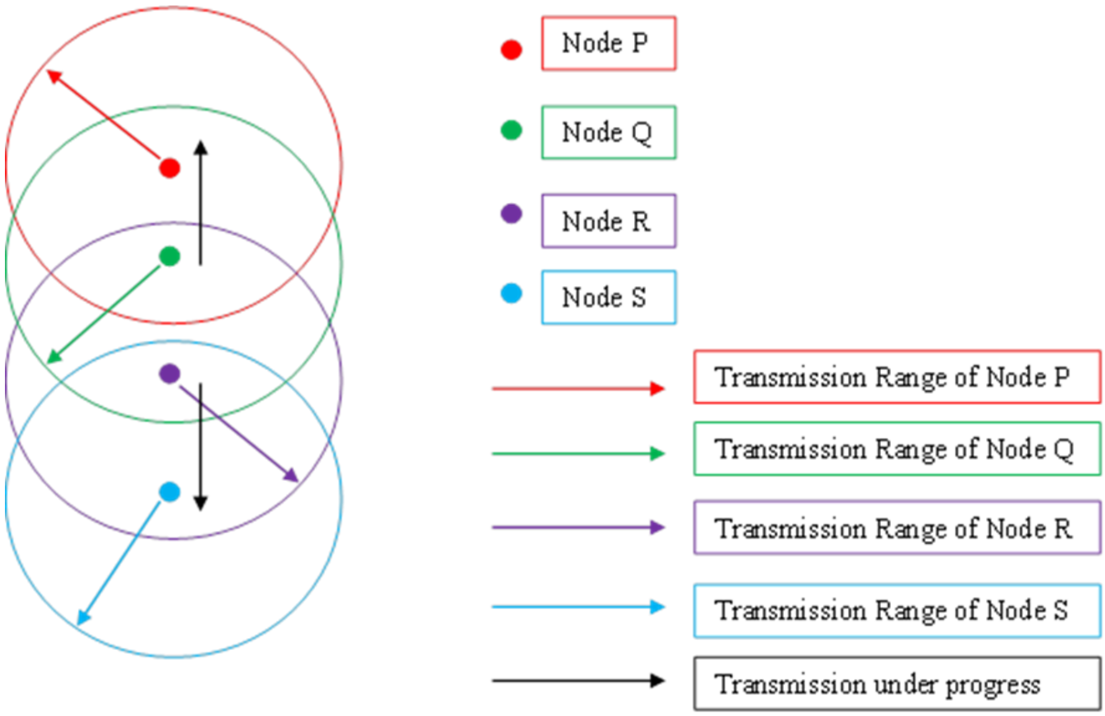

Fig.2.7.Illustration of exposed terminal problem

2.12.5 Resource Restrictions

The battery life and the processing power are the two essential and limited resources that shape the major restriction for the nodes in an ad-hoc wireless network.

In most cases, MANET devices are required to be portable and they also have size and weight restrictions along with the power source constraints. If we consider increasing battery power and the processing ability, then the nodes becomes bulky and less portable, therefore routing protocols must optimally manage these resources.

2.13 Performance Parameters

Performance metrics are the tools by which performance evaluation can be achieved, there are different performance metrics available for evaluating mobile ad-hoc network routing protocols. Some of them are; throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load. Some of other QoS parameters such as bandwidth, buffer, router CPU (Central Processing Unit) time, delay and jitter also affects the performance of wireless networks [Mohammad *et al.* (2010)]. Average values of these metrics are helpful in evaluating performance of mobile ad-hoc network routing protocols.

2.13.1 Throughput

Here, throughput refers to the network throughput; throughput can be defined as rate of effective delivery of messages or data packets over the communication channel. These data messages may be delivered over a logical or physical links. Throughput is generally measured in bits per second (bps) or kilobits per second (Kbps). Throughput is basically synonymous to consumption of digital bandwidth [Miao *et al.* (2016)]. Mathematical analysis of the throughput can be done by applying queuing theory also. In communication systems, throughput gets affected by different factors such as; processing power of the devices, primary analog physical medium and behaviour of end-user systems. When the overheads of different protocols are taken into account, valuable rate of the transmitted data may be expressively lesser than the maximum realizable throughput and the valuable rate of transfer of data is refers to good put. Throughput can also be defined as amount of data transmitted from the source node to the destination node through the network in a unit time expressed in Kbps. Higher values of throughput provides better and improved performance.

2.13.2 Packet Delivery Ratio

Packet delivery ratio is related to the analysis of packet data in a data communication network. Where, total packet generation at the source or sending node and its effective delivery at the desired destination node is the key issue. Packet delivery ratio can be defined as the ratio of total data packets received at the destination to that of total data packets sent from the source or sending node. Larger values of the packet delivery ratio provide better and enhanced performance. Packet delivery ratio is derived in % (Percentage).

2.13.3 End To End Delay

Average time interval between packets generated at the source node and effective delivery of these packets at the destination node is called end to end delay. Lesser values of end to end delay give us better and improved performance and it is derived in mille seconds (ms). In other words, simply delay can be defined as the time interval lapsed between the data departure from the source to its arrival at the destination. In communication systems, delay refers to the hold time between the signal departure from the source and arrival of the signal at the destination. Due to clock synchronization problems, measurement of one-way delays is challenging; therefore, round-trip (forward and return paths) delays are used in case of internet [Jiuchun *et al.* (2009)]. However, in data communication networks, delay encompasses various delays such as; packet queuing delay, propagation delay and transmission delay. In many applications, delay is a key metric in achieving network performance. In general, it is predictable that the higher throughput can be achieved at the cost of larger delays and that can be enhanced at the cost of the other. In wireless networks, queuing delay dominates the transmission delay and it is most effective delay.

2.13.4 Packet Loss

In wireless communication, information transmitted over the wireless link is refers to packets, these packets holds all the information about the sending source node and the destination node up to which communication is needs to be established. In several cases of data communication, generated packets at the source are successfully delivered at the destination, however, when there are some difficulties in delivery, and then packet loss occurs. Thus, losses in packet delivery signify the amount of data packets that gets affected and not arrive up to the destination in a specific interval of time. There exist many reasons that cause packet loss, in some cases, the signal may degrade over the time. In some other cases, hardware problems could cause the packet loss including larger demand volume and stale data packets. Different methods that reduce the chances of packet losses are; by providing individual channels and guaranteed bandwidth for specific data transmissions and by retransmission of data for loss recovery. In several cases, whenever the packet loss occurs, the sending source node resends the lost packet. Packet loss can be stated as difference between the total packets sent and the total packets received.

2.13.5 Normalized Routing Load

The ratio of number of routing packets transported to the total data packets received is called normalized routing load. Higher values of Normalized routing load provide large number of routing packets however; it leads to lesser efficiency in terms of bandwidth consumption [Qutaiba Razouqi *et al.* (2013)].

2.14 Performance Improving Techniques

Different approaches can be employed to achieve possible performance enhancements in mobile ad-hoc network routing protocols. These approaches could either be theoretical, mathematical and fine-tuning of existing protocols. There exist some optimization techniques by which performances of these routing protocols could also be achieved [Tarun Varshney *et al.* (2014)]. In this thesis, fine tuning approach was taken into account with the help of Network Simulator-3. Performance of a routing protocol depends upon various technical parameters associated with the network and the routing protocol. Fine tuning of a routing protocol refers to assigning of new attribute values to the standard protocol parameters through which it operates.

2.15 Simulation Tools

Many simulation tools are available for conducting simulation based experiments on routing protocols of MANETs. Different tools are available for different operating systems, among these tools, the well- known network simulation tools preferred by the network researchers are NS-2 (Network Simulator-2) and NS-3 (Network Simulator-3). Simulation based experiments of this thesis on performance analysis of mobile ad-hoc network routing protocols were conducted using NS-3. Simulation tools involves successful installation and testing of Network Simulator-3 (NS-3, Version: 3.13) on CENTOS Linux (an open source server graded Linux operating system) platform. "Network Simulator-3 is a discrete-event network simulator in which the simulation core and models are implemented in C++". NS-3 is assembled as set of library, which can be linked to C++ main program statically or dynamically.

The C++ main program in NS-3 defines simulation topology and it starts the simulator. Almost all the APIs (Application program Interfaces) of NS-3 have been exported to Python, in order to allow Python programs to import NS-3 modules. There are six layers in NS-3, these layers deals with different functions. Table-2.1 illustrates organization of software layers in NS-3. First layer contains the simulation core module, second layer deals with network modules, third layer compacts with internet and mobility modules. The fourth layer deals with the protocols, applications, devices and propagation etc. The fifth layer has helper modules and the final module is test bed, where all the simulation tests take place. As compare to NS-2 (Network Simulator-2), NS-3 has enhanced simulation capabilities. NS-3 is not rear attuned with the NS-2; NS-3 was developed from the scratch in order to replace NS-2 APIs. However, some modules of NS-2 have been ported to NS-3. NS-3 does not support NS-2 application program interfaces. NS-3, the discrete-event network simulator is developed mainly for research and educational use. NS-3 is an open-source network simulator attempts to continue open environment for researchers for sharing and contribution of software developed by them [IR 6].

Table-2.1: Organization of Software layers in NS-3

<table>
<tr><td colspan="5">Test Layer
(Here final testing takes place)</td></tr>
<tr><td colspan="5">Helper Layer
(This layer provides high-level wrappers for everything and it aims at scripting)</td></tr>
<tr><td>Protocols Layer
(It deals with protocol issues)</td><td>Applications Layer
(It deals with the applications)</td><td colspan="2">Devices Layer
(This layer deals with the devices)</td><td>Propagation Layer
(This layer deals with the propagation related issues)</td></tr>
<tr><td colspan="3">Internet Layer
(This layer deals with the traffic scenarios)</td><td colspan="2">Mobility Layer
(This layer manages mobility models such as static, random walk etc.)</td></tr>
<tr><td colspan="5">Network Layer
(Network Layer deals with node class, net device abstract base class, address types such as IPv4, MAC, etc., queues, socket abstract base class, IPv4/IPv6 abstract base classes and packet sockets. It also deals with packets, packet tags, packet headers, pcap/ASCII file writing.)</td></tr>
<tr><td colspan="5">Core Layer
(Core Layer deals smart pointers, dynamic system type attributes, call backs, tracing logging and random variables. It also handles events, schedulers and time arithmetic.)</td></tr>
</table>

2.16 Summary and Concluding Remarks

This chapter presented a brief review of some important features of mobile ad-hoc networks and the routing protocols of MANETS. This chapter covers various factors that affect the performances of the routing protocols in mobile ad-hoc networks along with the issues and challenges. Based on the literature survey presented in various sections of this chapter, some important observations are summarized below in order to justify the scopes of the thesis outlined in Chapter 1.

- Mobile ad-hoc networks are one of the categories of the wireless networks that uses multi-hop radio relaying and it has the capacity of operating without having support of any kind of fixed infrastructure or central control setup. MANETs are also called as infrastructure less networks. Mobile ad-hoc networks experiences breakage of links due to movement of nodes from one place to another. This pours major challenges in performance of the routing protocols. Several routing protocols were proposed by the research community and these are normally categorized as topology and position based routing protocols.

- Mobility models creates node movements closely relates to the movements like in a real network. Several such models are proposed by the research community in order to test the performance of the routing protocols in various node mobility scenarios. Realistic motion scenarios of the nodes are complex natured that is why these scenarios vary from one mobility model to another. This poses challenges in analysing mobile ad-hoc network routing protocols. Node mobility is shown to have a greater impact on average control overhead than any other factor. This would suggest that the designing algorithms that adapt to node mobility would have the greater impact on network performance.

- Several factors affect performance of the mobile ad-hoc networks, such as: transmit power, node pause time, node velocity, node density, mobility models, transmission region, number of source/sink pairs, type of traffic demands, and the core routing protocol parameters. These factors along with the inherent characteristics of the mobile ad-hoc networks may result in impulsive variations in the overall performance of the mobile ad-hoc network. Quantifying the effects of these factors will help the new design choices and trade-offs. Functionality of routing is integrated in every host of the ad-hoc network. Thus, mobile ad-hoc networks are characterized as having a dynamic, multi-hop and constantly changing topology. Different traffic generators are helpful in testing performances of routing protocols as they models the traffic in a predefine structure and schedule manner. Traffic generators deliver the communication demands of traffic consignments regardless position of agent which is attached at a particular interval and time.

- Mobile ad-hoc networks require solutions for some restrictions and inadequacies that include numerous factors such as the characteristics of wireless links which are time-varying natured. There are some transmission obstructions such as; fading, path loss, blockage and interference, these prompts vulnerable behaviour in wireless channels. Different issues resist the reliability of the wireless transmission. MANETs face limited range of wireless transmission including the limited radio bands that results in lesser data rates. In order to achieve optimum usage of bandwidth in mobile ad-hoc networks, routing overheads must be reduced. The major issues that affect the design, deployment and performance of MANETs are; deployment considerations, routing scalability, multicasting transport layer protocol, pricing scheme provisioning of QoS (Quality of Service), self-organization security energy management and addressing and service discovery.

- Routing protocols designed for mobile ad-hoc networks faces the key challenges like mobility of nodes, resource restrictions, and error-prone channel state, hidden and visible terminal problems. These challenges are need to be addressed for better performance of mobile ad-hoc networks. Above discussed challenges can be put under control by means of effective management and control of some factors like; mobility management, bandwidth restrictions, error-prone shared transmission radio channels, hidden and visible terminal problems and resource restrictions etc. Also, mobile ad-hoc network routing protocols must possesses certain ideal characteristics, by which performance of the routing protocols may be compared. The ideal routing protocol must have completely distributing characteristics and it must be adaptive to frequent topology changes. Restricted number of nodes must take part in route maintenance and computation; every network node should have quick access to the accessible routes. During stable topology, the ideal routing protocol must converge to optimal routes. An ideal routing protocol must have ability to deliver some QoS (Quality of Service) level according to demands made by the applications.

- MANET routing protocols can be generally classified into four categories based on the mechanisms such as; topology of routing, consumption of specific resources, mechanism of routing information and usage of time-based information for routing. Based on Mechanism of Routing Information, these routing protocols can be classified as; proactive or table driven, reactive or on-demand and hybrid routing protocols. Works in this thesis were focussed on performance analysis of

AODV, DSDV, OLSR and DSR routing protocols using NS3 (Network Simulator-3).

- Different types of security attacks in MANETs can be classified as; network layer attacks, transport layer attacks and application layer attacks. Attacks pertaining to the network layer are; wormhole attack, resource consumption attack, black hole attack, information disclosure and byzantine attack etc. Session hijacking is specific type of attack associated with the transport layer and the repudiation attack is generally occurs over the application layer. Other attacks associated with the MANETs are; multi-layer attacks and device tampering. Denials of service (DoS) and impersonation attacks are associated with the multi-layer attacks. Jamming, SYN flooding and distributed DOS (DDoS) attacks are multi-layer denial of service attacks generally referred as DoS attacks. A secure routing protocol require some basic requirements such as stability against routing attacks, correct path discovery guarantee, finding of malicious nodes and privacy of network topology.

- Most of the previous works were focused on performance analysis of standard MANET routing protocols by using different sets of standard routing protocols and comparing them with one another. These works can only justify the best performing routing protocol in some general network scenarios. In brief, there is enough scope for carrying out a systematic study of the analysis of mobile ad-hoc network routing protocols. Thus, the scopes of the thesis outlined in Chapter 1 dealing with the study and performance analysis of mobile ad-hoc network routing protocols are well justified.