CHAPTER 1

INTRODUCTION TO MOBILE AD HOC NETWORKS

1.1 Ad hoc Networks

Ever since the evolution of wireless devices, there has been a complete revival of the technology used to catalyse the functioning and growth of the communication era. Ad hoc networks are networks formed by a group of nodes intending to do a particular task.

The network is ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity. In addition to the classic routing, ad hoc networks can use flooding for forwarding data.

An ad hoc network typically refers to any set of networks where all devices have equal status on a network and are free to associate with any other ad hoc network device in link range. An ad hoc network is made up of multiple “nodes” connected by “links.” Links are influenced by the node's resources and behavioural properties, as well as link properties. Links can be connected or disconnected at any time; hence a functioning network must be able to cope with this dynamic restructuring, preferably in a way that is timely, efficient, reliable, robust, and scalable. The network must allow any two nodes to communicate by relaying the information via other nodes.
A “path” is a series of links that connects two nodes. Various routing methods use one or two paths between any two nodes; flooding methods use all or most of the available paths. A communication session is achieved either through single-hop transmission if the recipient is within the transmission range of the source node, or by relaying through intermediate nodes otherwise.

1.2 Mobile Ad hoc Networks

Mobile ad hoc networks are formed by the co-ordination of mobile wireless devices in the ‘ad hoc’ mode of operation. Mobile Ad hoc Networks (MANETs) are extensively used for on-the-move applications and remain as a promising technology. The network is formed using autonomous nodes used over links that are bandwidth constrained. The network topology may change rapidly and unpredictably over time because of the node mobility. All nodes are autonomous, who can take decisions regarding the operations among the nodes individually and in a decentralized manner.

As the routes are no longer static in MANETs, the signal strength varies and the network may disconnect at any time. A link that exists at one moment may not exist in the next moment since the link exists only when a node can receive a sufficiently strong recognizable signal from its neighbour. The strength of the received signal depends on the power of the transmitted signal, the antenna gain at both the sender and receiver, the distance between the two nodes, the obstacles between them, and the number of different paths the signals travel due to reflection.

Each node in a multi-hop MANET must continuously monitor the radio signals it receives in order to determine neighbours composing a localized view of the network topology to use with routing protocols. Owing to the advantages, MANETs are
preferred for applications like: Personal area networking in military environments, in civilian environments and emergency operations.

1.3 Architecture of MANETs

One of the main advantages of MANETs is the decentralized architecture, where each and every node is independent to make its own decisions. In order to understand the decentralized architecture of MANETs the centralized and decentralized architectures of a general system are described.

- Centralized System

Centralized systems have been in use for a long time such as in master and slaves based systems. The centralized systems directly control the operation of the individual units and flow of information from a single centre. All individuals are directly dependent on the central power to send and receive information, and to be commanded. The working arrangement of a centralized system is shown in Figure 1.1.

Figure 1.1 Centralized Architecture
In this system, individual nodes are directly controlled by the central authority or a central head node. The local nodes are forbidden to coordinate and work-together among themselves. Instead, each of them is obliged to follow the order from the centre. The greatest disadvantage is that a single point failure of the central authority can collapse the entire network operation.

- **Decentralized System**

  The concept of centralised systems was only developed after decentralised systems, because the first network created can possibly only contain two nodes after which the concept of network was established. In this architecture, the authority is decentralised and each individual node is capable of communicating with each other without involving any central authority. Figure 1.2 shows the decentralized architecture of MANETs. Each node can hence send, receive or forward data to any other node of its choice without involving any single authority.

![](image)

**Figure 1.2 Decentralized Architecture**
The greatest advantage of using a decentralized architecture in systems is the operation of the network continues even if when a few nodes fail in the network. The entire network operation is not based on a single entity at all.

1.4 Properties of MANETs

Mobile ad hoc networks can be defined by their various properties and operational requirements. Understanding the properties of MANETs has great significance in the design of routing protocols for the same. These properties or features are described, some of which add value to MANETs while the others cause disadvantages in MANETs.

- Ubiquitous mobile computing environment

The word “ubiquitous” can be defined as "present everywhere at the same time", “constantly encountered” and “widespread”. Applying this concept to technology, the term ubiquitous implies that technology is everywhere and can be used at all times. Ubiquitous computing is poised to revolutionize the way a user would compute and interact with other users. Thus users can access services, run programs, utilize resources, and harvest computing power anytime and anywhere. This new generation of ubiquitous computing enables the delivery of integrated services and multimedia-enabled applications that are no longer bound by time or location barriers.

Ubiquitous computing promotes the proliferation of embedded devices, smart gadgets, sensors and actuators. MANETs can be used anywhere and everywhere at all times even at motion and hence come under ubiquitous mobile computing category. This property of MANET enables its application into critical and tactical operations at large.
• **Seamless interaction**

MANETs can otherwise be called as a network of mobile routers. Since each node is capable of acting both as a client and a server, it performs dual operation while forwarding data. The communication can be achieved without any breakages as long as the nodes are continuously in range of each other and there are no interference issues. An audio file, video files and other software files can be transmitted without any interruption through ad hoc networking in MANETs.

• **Seamless connectivity**

It is possible to maintain continuous connectivity between the devices when they move with the nearby wireless nodes, sensor nodes, and embedded devices in automobiles while sharing information across the network. In descriptive terms, MANETs can be described as a chain of communicating nodes while there is data transfer from one user to another with seamless connectivity observed even during movement of nodes from place to place. However, at very few situations in large networks bandwidth availability is a question mark leading to some connectivity issues.

• **Neighbour discovery**

Neighbour discovery can be termed as one of the important characteristics of a MANET. It is usually performed at the media access control (MAC) layer of the protocol. In the seven-layer OSI model of computer networking, media access control (MAC) data communication protocol is a sub-layer of the data link layer (layer 2).

The MAC sub-layer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to
communicate within a multiple access network that incorporates a shared medium, the wireless medium in MANETs. If a node leaves a particular region, other nodes that no longer lie within its neighbourhood should be notified and should be able to take down their communication links with the leaving node. Hence the list of neighbours is regularly updated enabling in forming continuous routes across the network for communication.

- **Data routing abilities**

  Each mobile node in a MANET is an independent node, which could function as both a host and as a router. This enables in a single autonomous node to handle data packets arriving at its receiver terminal. Data can berouted from a source node to aneighbouring node by successful neighbour discovery and after taking the appropriate decision. The data routing abilities of a MANET differentiate it from any other network technologies suitting mobile communication paradigms.

- **Service Discovery in MANETs**

  Service discovery is a technology that enables a node to find other nodes that render services it requires. It is one of the crucial features that improve the usability of MANETs practically. A node discovers the service of a nearby node and communicates to a remote node in the MANET by using a service discovery protocol. This is achieved by a source node sending a request for a service which is successively forwarded by the other nodes. When these requirements match the services provided by other nodes, a service reply is sent in the reverse direction intimating the source node about the availability of service. Hence the required service is availed by the usage of MANETs.
• **Flexible network architecture**

MANETs come under Infrastructure-less wireless networks that are an important class of wireless networks best suited for scenarios where there is temporary and localized telecommunication demand. Such networks consist of wireless devices that can form a network autonomously without the need for pre-deployed telecommunication infrastructures such as base-stations and access points. In order to provide communication in case of the limited wireless connectivity range and resource constraints, MANET configures itself frequently.

Flexibility and variable routing paths enables fast establishment of networks thus improving communication on the move. It is possible to change the routing paths dynamically due to unavailability of nodes or bandwidth constraints in MANETs.

• **Ease of Establishment**

When a new network is to be established, the only requirement is to provide a new set of nodes with limited wireless communication range. With all the available nodes and their limited ranges, the communication can be begun among the nodes that are connected together as a chain of in-range nodes as shown in the figure 1.3.
**Capability Limitations of a Node**

A node has limited capability, that is, it can connect only to the nodes which are nearby and thus consumes limited power. A node can be limited in terms of the following parameters:

- Power
- Transmission Range
- Processing speed
- Memory associated with processor
- Frequency of operation
- Spectrum bandwidth availability
- Mobility of a node

Limited wireless connectivity range requires that a node should move in the vicinity of at least one nearby node within the wireless communication range, else the node should be provided with the access-point of wired communication.
• **Peer-to-Peer connectivity**

Peer-to-Peer (P2P) protocols allow peers to connect directly to each other without any interference from a central server. The architecture in MANETs enables Peer-to-Peer connectivity. Each and every node in a MANET can individually communicate and share information without the involvement of any central body. In a MANET, the applications are typically “peer-to-peer” rather than “client-server”. Moreover, a MANET is often built to support a specific application, thus the networking is application-driven. For these reasons, very often the ad hoc networking done in a MANET is referred to be peer-to-peer (P2P) networking.

• **Connections to other networks**

A newly established MANET can be included into other existing networks using suitable access points located at the vicinity of the intercepting area. Hence it is quite easy to interface and be attached or to detach from other networks using such access points.

A gateway may contain devices such as protocol translators, impedance matching devices, rate converters, fault isolators, or signal translators as necessary to provide system interoperability. It also requires the establishment of mutually acceptable administrative procedures between both networks. In other words, gateway can be termed as a network node equipped for interfacing with another network that uses different protocols. Hybrid networks can therefore contain MANETs as one functional network block in this fast pacing technology using suitable gateways.
Diverse in Heterogeneity

Heterogeneity refers to the various devices used as nodes in the MANET. An ad hoc operation of iPods, palm handheld computers, Smartphones, PCs, smart labels, smart sensors, and automobile-embedded systems is possible and the usability of MANETs increases exponentially with the available of such smart devices. Figure 1.4 shows some of the devices that can be connected in a MANET.

Figure 1.4 Diversity of Devices used in a MANET
1.5 Applications of MANETs

With all the above mentioned properties, there is proliferation of MANETs into every possible field although they were initially designed for military use. MANETs have been extended to

- Data Networks for support to the network for the exchange of data between mobile device
- Device Networks supports the wireless connections between various mobile devices so that they can communicate
- Free internet connection sharing across various devices.
- Sensor networks using ad hoc connections and MANETs at one end
- Vehicular Ad hoc Networks (VANETs) for vehicle communications
- InVANETs stand for Intelligent Vehicular Ad hoc networks for securing vehicular operations, avoiding accidents and road traffic management
- Personal Area Networks (PANs) for personal home/office networking
- Smart Phone Ad hoc Networks (SPANs) are used for networking with smart phones and other smart mobile devices which is a by product of MANETs

Some of the application areas and situations are listed here:

- Military operations, Border protection and Defence against terrorist attacks
- National event management and Security Forces
- Crowd control operations and Police Patrol control operations
- Disaster management, Emergency services and Relief management
- Video conferencing and Commercial Business meetings
- Commercial site monitoring and control
- Education networks for instant file and software transfers
- Medical ad hoc networks and bio-sensor management
- Civilian environments like taxicab, sports stadium, boat and small aircraft
- A MANET enabled version of JXTA peer-to-peer, modular, open platform is used to support use location and audio streaming over the JXTA virtual overlay network. Using MANET-JXTA, a client can search asynchronously for a user and a call setup until a path is available to reach the user. The application uses a private signalling protocol based on the exchange of XML messages over MANET-JXTA communication channels.

### 1.6 Issues and Challenges in a MANET

Although MANETs have a number of advantages and are being used in a variety of scenarios and real time situations, there are quite a few challenges encountered. It is very essential to understand these challenges before the design of any routing scheme in the network.

#### 1.6.1 Difficulties due to the wireless medium

There are a number of difficulties due to the wireless air medium, some of which are listed below:

- Weak connectivity and remote server latency
- Unreliable links to a gateway — failure of an intermediate node results in greater latency in communicating with the remote server
- Resource constraints — Limited bandwidth available between two intermediate nodes
- Node may have limited power and thus computations need to be energy-efficient
General losses may occur due to Multipath Propagation (Figure 1.5) and wireless signal interferences including environmental factors.

![Figure 1.5 Multipath Propagation in wireless network](image)

1.6.2 Channel contention

The bit errors are the main problem which arises because of the unreliable wireless channels. These channels cause high bit error rate and this is due to high interference, thermal noise, multipath fading effects, and so on. This leads to low packet delivery ratio. Since the medium is wireless in the case of MANETs, it may also lead to leakage of information into the surroundings.

1.6.3 Unreliable channel

Nodes in a MANET must communicate with each other on a common channel so as to provide the network topology. However, this introduces the problems of
interference and channel contention. For peer-to-peer data communication, these can be avoided in various ways.

One way is to attempt global clock synchronization and use a TDMA-based system where each node may transmit at a predefined time. This is difficult to achieve since there is no centralized control on the nodes. Other ways are to use a different frequency band or spreading code (as in CDMA) for each transmitter. This requires a distributed channel selection mechanism as well as the dissemination of channel information.

1.6.4 Mobility

Mobility of hosts, which causes topological changes of the underlying network, also increases the volatility of network information. In addition, the limitation of power leads users to disconnect mobile units frequently in order to limit power consumption. Range of a node keeps constantly fluctuating during mobility, which causes difficulties identifying the presence of a node in a locality. The mobility feature of MANETs alone causes a lot of failures in the links while routing. Movement of a node into the vicinity of high interference is also a cause for such failures.

1.6.5 Routing Challenges

A number of challenges are faced while routing is performed in MANETs. Only if a protocol is able to handle most of these challenges can there be any possible data transfer between the communicating nodes.

- Dynamic topologies: Nodes are free to move arbitrarily; thus, the network topology, which is typically multi hop, may change randomly and rapidly at
unpredictable times, and may consist of both bidirectional and unidirectional links.

- **Routing:** Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multi cast routing is another challenge because the multi cast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication.

- **Device discovery-** Identifying relevant newly moved in nodes and informing about their existence need dynamic update to facilitate automatic optimal route selection.

- **Bandwidth-constrained-variable capacity links:** Wireless links will continue to have significantly lower capacity than their hardwired counterparts.

- **Power-constrained and operation:** Some or all of the nodes in a MANET may rely on batteries or other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.

- For most of the light-weight mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.

- **Security and Reliability:** In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to e.g. nasty neighbour relaying packets. The feature of distributed operation requires different schemes of authentication and key management.

- Further, wireless link characteristics introduce also reliability problems, because of the limited wireless transmission range, the broadcast nature of
the wireless medium (e.g. hidden terminal problem), mobility-induced packet losses, and data transmission errors.

- Mobile wireless networks are generally more prone to physical security threats than are fixed-cable nets. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be carefully considered.

- Quality of Service (QoS): Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the traditional resource reservation to support the multimedia services.

- Inter-networking: In addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.

- Multicast: Multicast is desirable to support multiparty wireless communications. Since the multicast tree is no longer static, the multicast routing protocol must be able to cope with mobility including multicast membership dynamics (leave and join).

- IP-Layer Mobile Routing-An improved mobile routing capability at the IP layer can provide a benefit similar to the intention of the original Internet, "an interoperable internetworking capability over a heterogeneous networking infrastructure".
1.7 Medium Access Control in MANETs

Due to the various problems found in MANETs, achieving simple, efficient, fair, and energy-efficient medium access control, which is highly desirable and is challenging. MAC protocol plays an important role in the performance of the MANETs.

A MAC protocol defines how each mobile unit can share the limited wireless bandwidth resource in an efficient manner. The design of MAC protocol should also address issues caused by mobility of nodes and an unreliable time varying channel. Recently, a tremendous number of MAC schemes have been proposed for MANETs to address various relevant issues and tradeoffs in designing MAC protocols to deliver good performance in MANETs.

The popular Carrier Sense Multiple Access (CSMA) (Kleinrock 1975) MAC scheme and its variations such as CSMA with Collision Detection (CSMA/CD) developed for wired networks, cannot be used directly in the wireless networks, as explained below. In CSMA-based schemes, the transmitting node first senses the medium to check whether it is idle or busy. The node defers its own transmission to prevent a collision with the existing signal, if the medium is busy. Otherwise, the node begins to transmit its data while continuing to sense the medium. However, collisions occur at receiving nodes.

Due to the fact that signal strength in the wireless medium fades in proportion to the square of distance from the transmitter, the presence of a signal at the receiver node may not be clearly detected at other sending terminals, if they are out of range.
As illustrated in Figure 1.6, node B is within the range of nodes A and C, but A and C are not in each other’s range. Let us consider the case where A is transmitting to B. Node C, being out of A’s range, cannot detect carrier and may therefore send data to B, thus causing a collision at B. This is referred to as the ‘hiddenterminal problem’, as nodes A and C are hidden from each other.

Another case where B is transmitting to A needs to also be considered. Since C is within B’s range, it senses carrier and decides to defer its own transmission. However, this is unnecessary because there is no way C’s transmission can cause any collision at receiver A. This is referred to as the ‘exposed-terminal problem’, since B being exposed to C caused the latter to needlessly defer its transmission. MAC schemes are designed to overcome these problems.

Multiple Access with Collision Avoidance (MACA) was proposed for packet radio networks as an improvement over CSMA to eliminate the hidden terminal problem. The protocol introduces a handshake between a sender and receiver. This
handshake ensures that neighbouring nodes are aware of the upcoming transmission, and that they will refrain from sending for the duration of that transmission.

The sender initiates the handshake by transmitting a Request to Send (RTS) signal to the receiver to indicate its request to access the medium. Nodes in the vicinity of the sender are notified of the upcoming transmission through this RTS message. Upon receiving an RTS, the receiver replies with a Clear to Send (CTS) message indicating its readiness for reception. Nodes that are in the vicinity of the receiver are also notified of the transmission through the CTS. Once the RTS/CTS handshake is complete, the transmission proceeds with no risk of collisions. If there is a collision of two RTS messages, then both stations back off for some time.

By reducing the possibility of collisions and eliminating the hidden terminal problem for data transmissions, MACA offers an improvement over CSMA. In fact, when hidden terminals are present and the network traffic is high, the performance of MACA degenerates to that of ALOHA. Another weakness of MACA is that it does not provide any acknowledgement of data transmissions at the data link layer. If a transmission fails for any reason, retransmission has to be initiated by the transport layer. This can cause significant transmission data.

In order to overcome some of the weaknesses of MACA, MACAW was proposed to adapt MACA for the unreliability of the wireless medium (Bhargavan 1994), by making the receiver acknowledge successful data reception with an ACK message. This offers a delivery guarantee that is crucial in wireless networks. MACAW scheme that uses a five step RTS-CTS-DS-DATA-ACK exchange. MACAW allows much faster error recovery at the data link layer by using acknowledgement (ACK) that is returned from the receiving node as soon as data
reception is completed. The back off and fairness issues among active nodes were also investigated. MACAW achieves significant lower throughput compared to MACA.

Some other others MAC protocols focus on specific features such as power control: Power aware medium access control with signalling PAMAS (Singh 1998), PCM (Jung 2002), etc.; or the use of specialized technology like directional antennas: D-MAC (Ko 2000), Multi-Hop RTS MAC (Choudhury 2002), etc.. Most of these schemes, however, are not designed especially for networks with mobile nodes. On the other hand, the transaction time at the MAC layer is relatively short. The effect of mobility will become less significant as the available channel bandwidth continue to grow. Several international standards exist for MANETs, such as IEEE 802.11a, b, and g, HIPERNET, and Bluetooth. It is worth mentioning here that several new standards are still being developed. In particular, the IEEE 802.15 Personal Area Network (PAN) and the IEEE 802.16 Metropolitan Area Network (MAN) standards are targeted towards small and large-scale wireless networks respectively.

1.8 Communication Paradigm of a MANET

Communication in all wireless technologies is basically categorized into three types. However, all three types follow the same communication prototype in MANETs especially.

- Unicasting

A link is established between two wireless nodes intending to communicate. Data is transferred only between these two connected nodes, where one acts as a source and another acts as a destination. In MANETs multiple links are established among intermediate nodes in order to send data from a source to a destination as in Figure 1.7
• **Broadcasting**

Figure 1.8 shows an example for broadcasting in MANETs. Broadcasting clearly refers to the case where a single source sends out information to all other nodes in the network without excluding any node.
- **Multicasting**

  Multicasting is the process of sending data from a single source to multiple destinations through a number of intermediate nodes. This is called multicasting. Multicasting in MANETs is quite a challenging task due to the unreliability of links. Figure 1.9 shows how multicasting is performed in a MANET, where copies of the information are sent to three different destinations simultaneously.

![Multicasting in MANETs](image)

**Figure 1.9** Multicasting in MANETs

**Advantages**

- Delivery to destinations simultaneously
- Deliver the messages over each link of the network only once
- Only creates copies when the links to the destinations split

**Applications**

- Multimedia Conferencing: Audio/Video and whiteboard comprise the classic conference application. Having multiple datastreams with different priorities
characterizes this type of application. Co-ordination issues--such as determining who gets to talk when--complicate their development and usability. There are common heuristics and "rules of play", but no standards exist for managing conference group dynamics.

- Synchronized Resources: Shared distributed databases of anytype (schedules, directories, as well as traditional Information System databases).
- Concurrent Processing: Distributed parallel processing.
- Collaboration: Shared document editing.
- Distance Learning: This is multicasting distribution application with "upstream" capability that allows receivers to question the speaker(s).

In reality, all data transmission in the wireless paradigm follows broadcasting. The only difference is that the relay nodes forward data only to the nodes that are part of the route to the destination. The nodes use their intelligence to decide whether to forward or drop the information depending on the protocol that controls the entire communication process.

1.9 Need for Reliability in Multicasting

Having understood the significance of multicasting and MANET’s multicasting applications it is absolutely essential to investigate the need for reliability in this process. The word ‘reliability’ can mean many things about the delivery of message packets in a network:

- To each process
- In same order
- In timely manner
- No duplicates

Reliable multicasting can cause more network congestion than unicast group, because large amounts of data are transmitted to recipients distribute over WAN. It can
also cause more traffic than unreliable multicast group, because of additional control messages ensuring reliability. It is less complicated to reduce the number of link failures instead of inducing more traffic into the network by the incorporation of exclusive reliability mechanisms. This is especially recommended in multicasting mechanism because the multicast receivers can range from 1 node to as many nodes, not limited by any communication protocol.

1.10 Problem Description

One of the most challenging modes of communication among the three methods of communication is multicasting. This is because a user at the source end is contended only if it receives a message acknowledgement from all of the destinations that it initially plans to send data to. It takes greater time and resources in order to achieve multicasting hence the reliability is a question mark.

1.11 Research Motivations

One of the main reasons for the commencement of this research work is the lack of multicast communications that are breakage-free. A sad and very timely example is the South Asia Tsunami disaster. The ad hoc network may be a combination of heterogeneous technologies – from satellites to ground ad hoc radios and improvised cellular and mesh network services. Different teams are formed – a few teams will cooperate in a particular mission. For instance, three or four different teams may search for survivors; others will be in charge of distributing food and supplies; there will be medics teams providing first aid and medications; engineering teams for reconstruction; police teams preventing looting, etc). These teams move and operate as groups. Hence there is a requirement for reliable multicasting strategies for quality communication.
1.12 Objectives of Research

Pertaining to the main objective of the multicast algorithms design with reduced link failures, there are four objectives for this research work:

- To propose a Link Aware On demand Multicast Routing (LAOMR) Scheme to adopt with dynamic environment of MANET.
- To design an Efficient Link Based Route Selection for Multicasting (LBRSM) in Mobile Ad Hoc Networks.
- To improve Link Stability in MANET using Linked-Friend Based Routing for increasing the network performance (LSFBFR).
- To design a Familiar Route Retrieval mechanism for efficient Multicasting in MANETs.

1.13 Software Tool used

The Network Simulator (NS-version2) is used for the analysis and design of the mechanisms proposed in this research work. Network Simulator (NS) is a simulation tool targeted at both wired and wireless (local and satellite) networking research. NS is a very promising tool and is being used by universities and researchers. This tool can be used in the unix operating system at large and can be used to analyze and design both wired and wireless networks operating at different IEEE standards. A simple but limited method is to combine the existing components with OTcl scripts; a complex but powerful method is to implement new components into NS2 using C++. The results consist of any of these three parts: Command line outputs, Network Animator (NAM) and to graph plots (using Xgraph/GNUplot) the simulation results are presented.

Network Simulator (NS), a discrete event simulator targeted at networking research is widely used in universities and companies by researchers. It implements
network protocols such as FTP and Telnet, routing algorithms such as SPF and DV, and 'lower' layers such as logic link (LL) and media access control (MAC). NS began as a variant of the REAL network simulator in 1989. In 1995 NS development was supported by DARPA through the VINT project at LBL, Xerox PARC, UCB, and USC/ISI. Currently NS development is support through DARPA with SAMAN and through NSF with CONSER. NS has always included substantial contributions from other researchers, including ACIRI, UCB, CMU, and Sun Microsystems. Nam began at LBL. The Nam development effort was an ongoing collaboration with the VINT project.

The simple way NS2 can be used is for studying the property of a well-known protocol. In this case, a script language OTcl is used to glue the network components (nodes, links, agents, applications, etc) provided by NS2, configure the parameters (band-width, delay, routing protocol, etc) and launch activities (data transfer, topology change, etc). NS2 will read these configurations; simulate each network event, and record events and statistics in to trace files. After the simulation, Nam can demonstrate the events in a visualized way. For the simple usage of NS2, an understanding to the simulation framework is necessary. An example NAM output is shown in figure 1.10 below.
When NS2 is used to simulate a new protocol, e.g., an ad hoc wireless routing protocol, the simple way is not enough. The advanced way is to hack the source of NS2 with C++, define new network components, rebuild the whole system and run the customized version of NS2. For the advanced usage of NS2, knowledge of the simulator implementation is required.

The Elements of ns-2 are listed below:

- Create the event scheduler
- [Turn on tracing]
- Create network
- Setup routing
- Insert errors
- Create transport connection
- Create traffic
- Transmit application-level data

The analysis and design of all the existing and the methods proposed here are performed using the network simulator NS-2.35. The mobility models that can be implemented are City Selection and Random Way Point mobility models. In order to analyse the protocols in the most random conditions, simulations are only performed using the Random Way Point mobility model. Graphs are obtained using the Xgraph plots to compare and prove the efficiency achieved at each stage of this research work.

1.14 Organization of Thesis

Chapter 1: It gives an Introduction to the Mobile Ad hoc Networks, architecture, routing types and challenges faced while routing.

Chapter 2: A detailed literature survey has been presented pertaining to the existing research in various routing types in this chapter.
Chapter 3: It presents the design of a Link Aware On-demand Multicast Routing (LAOMR) Scheme to adopt with dynamic environment of MANET

Chapter 4: An Efficient Link Based Route Selection for Multicasting (LBRSM) in Mobile Ad Hoc Networks is presented here.

Chapter 5: It presents an improvement in the Link Stability of MANET using Linked-Friend Based Routing for increased network performance.

Chapter 6: It presents the design of a Familiar Route Retrieval mechanism for efficient Multicasting in MANETs.

Chapter 7: It provides the comparison analysis of all proposed methods.

Chapter 8: A Conclusion of research work and the future scope is described in this Chapter.

1.15 Summary

An introduction to the Mobile ad hoc networks, its architecture and working is presented. The types of routing in MANETs and the challenges faced have been presented with an aim to eliminate some of these issues. Multicasting issues and link breakages have been understood before any further research is begun. From the investigation made, it can be concluded that the suggestion of link failures reduction provides greater performance than exclusive reliability inducing mechanisms for MANETs. However, a survey of the existing literature and protocols is essential for the design of multicast routing protocols to reduce link failures.