Chapter I

Introduction

Distributed, dynamic, self organizing architecture are the characteristics of an Ad hoc network. An Ad hoc network consists of a set of mobile devices, equipped with radio transceivers, which communicate with each other, either directly or in multihop fashion, without the need for a fixed infrastructure. Each node in the network is capable of independently adapting its operation based on the current environment according to the specified protocol. This helps the construction of temporary networks with no wires, no communication infrastructure and no administrative intervention.

This chapter is introducing wireless networks, classifications of wireless networks, introduction of mobile Ad hoc networks (MANETs), special features of MANET and MANET routing. In this chapter we also bring out the main contribution of the thesis and present an outline of the rest of the thesis.

1.1 Wireless Networks

The term wireless networks refer to technology that enables two or more computer to communicate using standard network protocols, without cabling.

There are two kinds of Wireless Network. They are as follows:-

a) Reliable Infrastructure Wireless Networks [1]: These types of wireless networks built on top of a wired network and wireless nodes are able to act as bridges in a wired network. These kind of wireless nodes are called base-stations. An example of this wireless network is the cellular-phone networks where a phone connects to the base-station with the best signal quality. When the phone moves out of range of a base-station, it does a “hand-off” and switches to a new base-station within reach.
b) Wireless Local Area Networks (WLAN): In these kinds of networks, there is no infrastructure at all except the participating mobile nodes. This is called an infrastructure less network or an Ad hoc network.

Wireless networks are classified into three different types according to relative mobility of hosts and routers. They are as follows:-

1.1.1. Fixed wireless network: Fixed hosts and routers are use by wireless channels to communicate with each other and form a fixed wireless network. A wireless network is formed by fixed network devices using directed antennas.

![Figure 1-1. An example of a fixed wireless network](image)

1.1.2. Wireless network with fixed access points: Mobile hosts are use in wireless channels to communicate with fixed access points, which may act as routers for those mobile hosts, to form a mobile network with fixed access points i.e. a number of mobile laptop users in a building that access fixed access points.
1.1.3. Mobile Ad hoc networks: All nodes in the network are mobile and nodes are communicating which each other without the use of fixed infrastructure, that will form an Ad hoc network and mobile nodes are known as mobile hosts. Some of these mobile hosts are willing to forward packets for neighbors. These networks have no fixed routers; every node could be a router. All nodes are capable of moving and can be connected dynamically in an arbitrary manner. The responsibilities for organizing and controlling the network are distributed among the terminals themselves. The entire network is mobile, and the individual terminals are allowed to move freely. In this type of networks, some pairs of terminals may not be able to communicate directly with each other and have to rely on some other terminals so that the messages are delivered to their destinations. Such networks are often referred to as multi-hop or store-and-forward networks. The nodes of these networks function as routers, which discover and maintain routes to other nodes in the networks. These nodes may be located in or on airplanes, ships, trucks, cars, perhaps even on people or very small devices.
1.2 Mobile Ad hoc Network Definitions

1.2.1 MANET Definition

It is very difficult to pinpoint what is meant by an Ad hoc network. In today’s scientific literature, the term is used in many different ways. There are many different definitions, which describe Ad hoc networks, but we just present two of them. The first one is given by Internet Engineering Task Force (IETF) group and the other one is given by Murphy [2].

1.2.2 IETF Definition of Ad hoc Network

A Mobile Ad hoc Network (MANET) is a self-configuring (autonomous) system of mobile routers (and associated hosts) connected by wireless links - the union of which form an arbitrary topology. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet operating as a hybrid fixed/Ad hoc network.

In a MANET, no such infrastructure exists and the network topology may dynamically change in an unpredictable manner since nodes are free to move.
As for the mode of operation, Ad hoc networks are basically peer-to-peer multi-hop mobile wireless networks where information packets are transmitted in a store-and-forward manner from a source to an arbitrary destination via intermediate nodes.

1.2.3. Murphy Definition of Ad hoc Network

According to [2], an Ad hoc network is “a transitory association of mobile nodes which do not depend upon any fixed support infrastructure. Participants at a conference and disaster relief workers may find it necessary to interact with each other in this manner when the static support infrastructure is not available. An Ad hoc network can be visualized as a continuously changing graph. Connection and disconnection is controlled by the distance among the nodes and by willingness to collaborate in the formation of cohesive, albeit transitory community”.

Additional infrastructure is not required with Ad hoc network. It is the distance among nodes, or rather their adjacency, that defines the boundaries of the network. That means, the only arranging of two or more mobile nodes within a certain boundary defines a new network in an Ad hoc manner. Now, if the nodes were not mobile, an Ad hoc network would not be different from LAN (Local Area Network). So, it is also the mobility of nodes, causing variations in their distance that gives such networks their Ad hoc nature. The actual boundary defining an Ad hoc network really depends on the technology being used. Some Ad hoc network solutions are limited to Personal Area Network (PAN). The Bluetooth technology, for instance, is allowed only for PAN (up to about 10 meters) [3].

The collocation of several nodes within a certain distance is necessary but not sufficient condition to form an Ad hoc network. In addition, collocated nodes needs to be willing to collaborate. By definition of Ad hoc networks, this
willingness is expressed at the network level. The decision to collaborate or not is expressed by going online or offline.

1.3 Classification of Ad hoc Networks
There is no recognized classification of Ad hoc networks in the literature. However, a classification on the basis of the network types can be executed. In the following, Ad hoc networks are classified according to three different aspects [4].

1.3.1 Classification According to Communication
This simple classification is based on the formation and type of communication. The classification according to communication is as follows:

1.3.1.1 Single-hop Ad hoc Network
In the single-hop Ad hoc network, nodes are in their reachable area and can communicate directly. Single-hop Ad hoc networks are the simplest type of Ad hoc networks where all the nodes are in their mutual range that means the individual nodes can communicate directly, without any help of other intermediate nodes. This type of networks also known as plug and play networks, since it concerns mainly about the simple and fast structure from temporary connections. In the Single-hop Ad hoc network the mobility does not play a role. The individual nodes have to be mobile; they must remain within the range of all nodes, which means the entire network could move as a group, which would not modify anything in the communication relations.

1.3.1.2 Multi-hop Ad hoc Network
This type of Ad hoc network differs from the first type. In that type, some nodes are far and cannot communicate directly. Therefore, the traffic of these communication end-points needs to be forwarded by other intermediate nodes. With this class, one assumes that the nodes are mobile. The basic difficulty of the networks of this class is the node mobility that causes continue modification of network topology. The general problem in networks of this class is the
assignment of a routing protocol. High performance routing protocols must be used to the fast topology modification.

1.3.1.3 Mobile Multi-hop Multimedia Ad hoc Network (3M-Network)
This type is an extension of the second type with the difference is that, the communication traffic consists here mainly of real time data such as audio and video. The networks of this class are also defined as 3M-Network [5] [6]. The quality requirements play the main role in this class of networks.

1.3.2 Classification According to Topology
Ad hoc networks can be classified according to the network topology. The individual nodes in an Ad hoc network are divided into different types with special functions. There are two different classes: flat and hierarchical.

1.3.2.1 Flat Ad hoc Networks
In flat Ad hoc networks, all nodes carry the same responsibility and there is no distinction between the individual nodes. All nodes are equivalent and can transfer all functions in the Ad hoc network. Control messages are to be transmitted globally throughout the network, but they are appropriate for highly dynamic network topology. The scalability decreases when the number of nodes increases significantly.

1.3.2.2 Hierarchical Ad hoc Networks
Hierarchical Ad hoc networks consist of several clusters, each one represents a network and all the nodes are linked together. The nodes in hierarchical Ad hoc networks can be differentiated into two types:
1. Master nodes: administer the cluster and are responsible for passing the data on to other cluster.
2. Normal nodes: Communicate within the cluster directly and with nodes in other clusters with the help of the master node. Normal nodes are also called slave nodes.
One assumes that the majority of communication (control messages) takes place within the cluster and only a fraction between different clusters. During communication within a cluster forwarding of communication traffic is not necessary. The master node is responsible for the switching of a connection between nodes in different clusters.

The flat architecture has the following advantages over the hierarchical:

1. Increased reliability and survivability.
2. No single point of failure.
3. Alternative routes in the network.
5. Better coverage, i.e. reduced use of the wireless resources.
6. Route diversity, i.e. better load balancing property.
7. All nodes have one type of equipment.

For reaching every message to its destination no single point failure in of great importance. This means that if one node goes down, the rest of the network will still function properly. In the hierarchical approach this is other way round. If one of the cluster heads goes down, that section of the network won’t be able to send or receive messages to other sections for the during the downtime of the cluster head. Hierarchical architectures are more suitable for low mobility case. Although flat architectures are more flexible and simpler than hierarchical ones, hierarchical architectures provide more scalable approach.

1.3.3 Classification According to Node Configuration

Further classification of Ad hoc networks can be executed on the basis of the hardware configuration of the nodes [7]. The configuration of the nodes in a mobile Ad hoc network is important and can depend very strongly on the actual application. Classification according to node configuration is as follows:
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1.3.3.1 Homogeneous Ad hoc Networks
In homogeneous Ad hoc networks, all nodes possess the same characteristics regarding the hardware configuration consist of processor, memory, display and peripheral devices. Most well known representatives of homogeneous Ad hoc networks are wireless sensor networks. In homogeneous Ad hoc networks, applications can be proceed from certain prerequisites; for example, the localization is considerably facilitated by the presence of control components in each node.

1.3.3.2 Heterogeneous Ad hoc Networks
In heterogeneous Ad hoc networks, the nodes differ according to the hardware configuration. Each node has different characteristics, resources and policies. In Ad hoc networks of this class, all nodes cannot provide the same services.

1.3.4 Classification According to Coverage Area
We can classify Ad hoc networks, depending on their coverage area, into several classes: Body (BAN), Personal (PAN), Local (LAN), Metropolitan (MAN) and Wide (WAN) area networks [8]. Wide and Metropolitan area Ad hoc networks are mobile multi-hop wireless networks presenting many challenges that are still being solved (e.g., addressing, routing, location management, security, etc.) and their availability is not on immediate horizon. On the other hand, mobile Ad hoc networks with smaller coverage can be expected to appear soon. Specifically, Ad hoc single-hop BAN, PAN and LAN wireless technologies are already common in the market; these technologies constitute the building blocks for constructing small multi-hop Ad hoc networks that extend their range over multiple radio hops A body area network is strongly correlated with wearable computers. A wearable computer distributes on the body of its components (e.g., head-mounted displays, microphones, earphones, etc.), and the BAN provides the connectivity among these devices. The communication range of a BAN corresponds to the human body range, i.e., 1–2 m. wiring a body is cumbersome.
Wireless technologies constitute the best solution for interconnecting wearable devices.

Personal area networks (PAN) connect mobile devices carried by users to other mobile and stationary devices. BAN is devoted to the interconnection of one-person wearable devices. PAN is a network in the environment around the persons. A PAN communicating range is typically up to 10 m. The most promising radios for widespread PAN deployment are in the 2.4 GHz ISM band. Spread spectrum is typically employed to reduce interference and bandwidth reuse.

Wireless LANs (WLANs) have a communication range typically of a single building, or a cluster of buildings, i.e., 100–500 m. A WLAN should satisfy the same requirements typical of any LAN, including high capacity, full connectivity among attached stations and broadcast capability. However, to meet these objectives, WLANs need to be designed to face some issues specific to the wireless environment, like security on the air, power consumption, mobility and bandwidth limitation of the air interface.

Two different approaches can be followed in the implementation of a WLAN: an infrastructure-based approach and an Ad hoc networking one. An infrastructure-based architecture imposes the existence of a centralized controller for each cell, often referred to as Access Point. The Access Point (AP) is normally connected to the wired network, thus providing the internet access to mobile devices. In contrast, an Ad hoc network is a peer-to-peer network formed by a set of stations within the range of each other, which dynamically configure themselves to set up a temporary network. In the Ad hoc configuration, no fixed controller is required, but a controller may be dynamically elected among the stations participating in the communication. The success of a network technology is connected to the development of networking products at a competitive price. The Ad hoc network size in terms of the number of active
nodes is the other metric used to classify MANETs. We can classify the scale of an Ad hoc network as small scale (i.e., 2–20 nodes), moderate scale (i.e., 20–100 nodes), large scale (i.e., 100+ nodes) and very large-scale (i.e., 1000+ nodes).

1.4 Properties of Mobile Ad hoc Networks

MANETs have the following special features that should be considered in designing solutions for these kinds of networks.

1. Dynamic Topology

Due to the node mobility, the topology of mobile multi-hop Ad hoc networks changes continuously and unpredictably. The link connectivity among the terminals of the network dynamically varies in an arbitrary manner and is based on the proximity of one node to another node. It is also subjected to frequent disconnection during node’s mobility. MANET should adapt to the traffic and propagation conditions as well as to the mobility patterns of the mobile network nodes. The mobile nodes in the network dynamically establish routing among themselves as they move about, forming their own network on the fly. Moreover, a user in the MANET may not only operate within the Ad hoc network, but may require access to a public fixed network.

2. Bandwidth

MANETs have significantly lower bandwidth capacity in comparison with fixed networks. The used air interface has higher bit error rates, which aggravates the expected link quality. Current technologies suitable for the realization of MANETs are IEEE 802.11(b,a) with bandwidth up to 54Mbps and Bluetooth providing bandwidth of 1Mbps. The nature of high bit-error rates of wireless connection might be more profound in a MANET. One end-to-end path can be shared by several sessions. The channel over which the terminals communicate is subjected to noise, fading and interference, and has less bandwidth than a wired network. In some scenarios, the path between any pair of users can
traverse multiple wireless links and the links to themselves can be heterogeneous.

3. Energy
All mobile devices will get their energy from batteries, which is scarce resource. Therefore the energy conservation plays an important role in MANETs. This important resource has to be used very efficiently. One of the most important system design criteria for optimization may be energy conservation.

4. Security
The nodes and the information in MANETs are exposed to some threats like in other networks. Additionally to these classical threats, in MANETs there are special threats, e.g. denial of service attacks. Also mobility implies higher security risks than static operation because portable devices may be stolen or their traffic may insecurely cross wireless links. Eavesdropping and spoofing should be considered.

5. Autonomous
No centralized administration entity is required to manage the operation of the different mobile nodes. In MANET, each mobile terminal is an autonomous node, which may function as both a host and a router. So usually endpoints and switches are indistinguishable in MANET.

6. Distributed Operation
Since there is no background network for the central control of the network operations, the control and management of the network is distributed among the terminals. The nodes involved in a MANET should collaborate among themselves and each node acts as a relay as needed, to implement functions e.g. security and routing.

7. Multi-hop Routing
Basic types of Ad hoc routing algorithms can be single-hop and multi-hop, based on different link layer attributes and routing protocols. Single-hop
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MANET is simple in comparison with multi-hop MANET in terms of structures and implementation. When delivering data packets from a source to its destination out of the direct wireless transmission range, the packets should be forwarded via one or more intermediate nodes.

8. Light-Weight Terminals
In most cases, the MANET nodes are mobile devices with less CPU processing capability, small memory size and low power storage.

9. Infrastructure less and Self Operated
A mobile Ad hoc network includes several advantages over traditional wireless networks, including ease of deployment, speed of deployment and decreased dependence on a fixed infrastructure. MANET is attractive because it provides an instant network formation without the presence of fixed base stations and system administrators.

1.5 Applications of Mobile Ad hoc Network
Ad-hoc networks are suited for use in situations where an infrastructure is unavailable or to deploy one is not cost effective. One of many possible uses of mobile ad-hoc networks is in some business environments, where the need for collaborative computing might be more important than outside the office environment. For example, it can be used in a business meeting outside the office to brief clients on a given assignment. Work has been going on to introduce the fundamental concepts of game theory and its applications in telecommunications. Game theory originates from economics and has been applied in various fields. Game theory deals with multi-person decision making, in which each decision maker tries to maximize his utility. The cooperation of the users is necessary to the operation of ad-hoc networks; therefore, game theory provides a good basis to analyze the networks.

A mobile ad-hoc network can also be used to provide crisis management services applications, such as in disaster recovery, where the entire
communication infrastructure is destroyed and resorting communication quickly is crucial. By using a mobile ad-hoc network, an infrastructure could be set up in hours instead of weeks. Another application of a mobile ad-hoc network is Bluetooth, which is designed to support a personal area network by eliminating the need of wires between various devices, such as printers and personal digital assistants. The famous IEEE 802.11 or Wi-Fi protocol also supports an ad-hoc network system in the absence of a wireless access point. Another application of mobile Ad hoc network in Tsunami disaster relief operations wherein timely communication is very important factor, the relief workers come in the area and without the need of any existing infrastructure, just switch on their handsets and can start communicating with each other while moving and carrying out rescue work. In this case of rescue problems, for example in scenes of natural disasters, an Ad hoc network could be formed by communication devices in fire brigades, helicopters, ambulances, policies and also people with laptop computers or mobile phones in hospitals, pharmacies and so on, all together work in a collaborative way to provide effective solutions to the problem.

Figure 1-4. Representation of a MANET to solve rescue problems
1.6 Routing Definition and Basic Functions

A routing protocol is the mechanism by which user traffic is directed and transported through the network from the source node to the destination node. An objective of routing includes maximizing network performance from the application point of view (application requirements) and minimizing the cost of networks itself in accordance with its capacity. The application requirements are hop count, delay, throughput, loss rate, stability, jitter, cost, etc. The network capacity is a function of available resources at each node, density (i.e. number of nodes), frequency of end-to-end connection (i.e. number of communications) and frequency of topology changes (mobility rate). Following are the basic routing functionalities for mobile ad hoc networks:

1. It includes path generation which generates paths according to the assembled and distributed state information of the network and of the application.
2. Path selection which selects appropriate paths based on network and application state information.
3. Data forwarding which forwards user traffic along with the selected route.
4. Path Maintenance is responsible for maintaining the selected path.

Consequently routing is bounded by traffic requirements and network capacity. This is illustrated in Figure 1.5

Routing in MANETs is a difficult problem due to the bandwidth, energy constraints and rapidly changing topologies. In mobile ad hoc routing, each node acts as a router and a number of nodes cooperate. Routing is multi-hop, so that data packets are forwarded from the source by a number of nodes before reaching the destination.
1.6.1 Classification of Routing Algorithms

Routing algorithms are classified as follows [9]:

1. Centralized versus Distributed
2. Static versus Dynamic.
3. Proactive versus Reactive
4. Unicast versus Multicast

In centralized routing algorithms, a main controller is responsible for updating all the nodes’ routing tables and/or to make every routing decision. Centralized algorithms can be used only in particular cases and for small networks.

In distributed routing algorithms, the computation of routes is shared among the network nodes, which exchange the necessary information. The distributed paradigm is currently used in the majority of network systems.

In static routing systems, the path taken by a packet is determined only on the basis of its source and destination, without regard to the current network state. This path is usually chosen as the shortest one according to cost criterion.
In dynamic routing systems, the routing policy can adapt to time and varying traffic conditions. As a drawback, they can cause oscillations in selected paths. This fact can cause circular paths, as well as large fluctuations in measured performance.

In a proactive routing protocol, all the routes to each destination are kept in an up-to-date table. Changes in the network topology are continually updated as they occur. The differences between the protocols are in how the changes are spread through the network and how many tables each node maintains.

In the reactive approach, a connection between two nodes is only created when it is asked by a source. When a route is found, it is kept by a route maintenance procedure until the destination no longer exists or is not needed anymore.

In case of multicast routing, a single packet is sent simultaneously to multiple recipients, but in unicast routing, a single packet is only sent to one recipient for every transmission. Thus, the multicast method is a very efficient and useful way to support group communication when bandwidth is limited and energy is constrained.

1.6.2 Introduction of Routing in MANETs

In MANET, there is no central server through which information can be exchanged within the network. A particular form of routing protocols is necessary in case of ad hoc networks. While two hosts wishing to exchange packets may not be within wireless transmission range of each other (i.e. not be able to communicate directly), but it could communicate with help of other mobile nodes which are also participating in the ad hoc network and are willing to forward packets for them. For example, Figure 1.6 illustrates a mobile ad hoc network with three wireless mobile hosts. Node 3 is not within the range of node 1’s wireless transmitter (indicated by the circle around node 1) and vice versa. If node 1 and node 3 wish to exchange packets, they must procure the services of
node 2 to forward packets for them, since node 2 is within the range overlap between node 1 and node 3.

Each time a packet is transmitted to a neighboring node, it is said to have made a hop. In the above example, when node 1 sends a packet to node 3, the packet makes two hops: first from node 1 to node 2, and second from node 2 to node 3.

**Figure 1.6** Exchange packets in a three mobile nodes ad hoc network

The situation in Figure 1.6 becomes more complicated with the addition of more nodes. The addition of just one node, as illustrated in Figure 1.7, results in multiple paths existing between nodes 1 and 3; packets may travel the path 1 - 2 - 3, 1 - 4 - 3, or even 1 - 4 - 2 - 3. An ad hoc routing protocol must be able to decide on a single "best" path between any two nodes.

**Figure 1.7.** Exchange packets in a four mobile nodes ad hoc network
Sometimes in a network of mobile nodes, parts of the network may become isolated and separate. This effect is called network partitioning and is illustrated in Figure 1.8. When network partitioning occurs, nodes can continue to exchange information within the same partition, but it is impossible for information to flow between separated partitions.

**Figure 1.8. Ad hoc network partitioned into two separate networks**

Another unique situation of wireless networks is illustrated in Figure 1.9. In this example, node 1 has a large enough range to transmit packets directly to node 3. However, node 3 has a much smaller range and must enlist the help of node 2 in order to return packets to node 1. This makes the link between node 1 and node 3 appears as a one-way or unidirectional link. Most conventional routing protocols require bi-directional links.

**Figure 1.9. Ad hoc network with a one-way link**
In summing up, routing protocols for ad hoc networks face several challenges. Ad hoc networks require multi-hop forwarding to facilitate information exchange. Wireless links are non uniform and can cause unidirectional links. By their nature, mobile nodes tend to "wander around", changing their network location and link status on a regular basis, sometimes partitioning the network. Also, new nodes may unexpectedly join the network or existing nodes may leave or be turned off. It is the goal of ad hoc routing protocols to provide network connectivity despite of these challenges.

Ad hoc routing protocols must minimize the time required to converge after these topology changes. A low convergence time is more critical in ad hoc networks because temporary routing loops can result in transmitting packets in circles, further consuming valuable bandwidth.

1.7 Challenges in Mobile Ad hoc Network Routing

Following are the some of the important factors that make routing in mobile ad hoc networks with wireless links challenging:

1. Frequent Topology Changes

All nodes in a MANET are mobile; this means that the topology is dynamic and routes that existed may not exist some time later due to the movement of the intermediate nodes. To overcome this problem, the protocol should be flexible to topology changes. Reactive protocols that try to repair disconnected paths incur large control overhead and packets are lost during the reconstruction phase. Proactive protocols constantly update their routes but the constant overhead generated proves to be expensive in cases where the movement among the nodes is limited.

2. Frequent and Unpredictable Connectivity Changes

MANETs are expected to be used in hostile environments such as battlefields and emergency operations. In isolation, any routing protocol should not only be able to deal with frequent topology changes but also with unpredictable
connectivity changes for instance due to changing weather patterns or varied geographies. Wireless links behave unpredictably in these situations.

3. Bandwidth Constrained and Variable Capacity Links
MANETs use wireless links that offer limited bandwidth for transmission. Further, these links may be of variable capacity. This presents one of the most important challenges to any routing protocol - keeping the bandwidth usage to a minimum even while responding reactively to changes in topology or proactively maintaining routes. Further, this also presents challenges in terms of the optimization of network routes in the MANET environment.

1.8 Routing Protocols Issues
One of the issues with routing in ad hoc networks concerns about whether nodes should keep track of routes to all possible destinations, or instead keep track of only those destinations that are of immediate interest. A node in an ad hoc network does not need a route to a destination until that destination is to be the recipient of packets sent by the node, either as the actual source of the packet or as an intermediate node along a path from the source to the destination.

Several routing protocols have been proposed for mobile ad hoc network regarding application requirements and network properties. A comparison of different existing approaches and examination of the main strengths of each tendency can be found in [10][11][12].

In [6] the routing design issues for mobile ad hoc network are classified according to four criteria as indicated in Figure 1.20:
1. Routing Philosophy: Table-driven versus on-demand versus hybrid approach.
2. Routing Architecture: Flat versus hierarchical versus aggregate architecture.
1.8.1 Routing Philosophy

In proactive or table-driven routing protocols, each node continuously maintains up-to-date routes to every other node in the network. Routing information is periodically transmitted throughout the network in order to maintain routing table consistency. Thus, if a route has already existed before traffic arrives, transmission occurs without delay. Otherwise, traffic packets should wait in queue until the node receives routing information corresponding to its destination. However, for highly dynamic network topology, the proactive schemes require a significant amount of resources to keep routing information up-to-date and reliable. Proactive protocols suffer the disadvantage of additional control traffic that is needed to continually update out of date route entries.

Since the network topology is dynamic, when a link goes down, all paths that use that link are broken and have to be repaired. If no application is using these paths,
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then the effort taken for repair may be wasted. This wasted effort can cause inadequate bandwidth resources to be wasted and can cause further congestion at intermediate network points. Proactive protocols are scalable in the number of flows and the number of nodes but are not scalable in the frequency of topology change. Thus, this strategy is appropriate for a network with low mobility.

Certain proactive routing protocols are Destination- Sequenced Distance Vector (DSDV), Wireless Routing Protocol (WRP), Global State Routing (GSR) and Cluster head Gateway Switch Routing (CGSR).

2 On-Demand Routing Protocols (Reactive)

In contrast to proactive approach, reactive or on demand protocols, a node initiates a route discovery throughout the network, only when it wants to send packets to its destination. For this purpose, a node initiates a route discovery process through the network. This process is completed once a route is determined or all possible permutations have been examined. Once a route has been established, it is maintained by a route maintenance process until either the destination becomes inaccessible along every path from the source or until the route is no longer desired. In reactive schemes, nodes maintain the routes to active destinations. A route search is needed for every unknown destination. Therefore, theoretically the communication overhead is reduced at expense of delay due to route research. Moreover, the rapidly changing topology may break an active route and cause subsequent route searches [13]. Reactive protocols may not be optimal in terms of bandwidth utilization because of flooding of the route discovery request, but they remain scalable in the frequency of topology change. Such protocols are not scalable in the number of nodes; however, they can be made scalable if a hierarchical architecture is used. Further reactive protocols are not scalable in the number of flows. Thus, reactive strategies are suitable for networks with high mobility and relatively small number of flows. Some reactive protocols are Cluster Based Routing Protocol (CBRP), Ad hoc On-Demand Distance Vector (AODV),
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Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Associatively-Based Routing (ABR), Signal Stability Routing (SSR) and Location Aided Routing (LAR).

3 Hybrid Protocols

Finally in hybrid protocols, each node maintains both the topology information within its zone and the information regarding neighboring zones that means proactive behavior within a zone and reactive behavior among zones. Thus, a route to each destination within a zone is established without delay, while a route discovery and a route maintenance procedure is required for destinations that are in other zones. The zone routing protocol (ZRP), zone-based hierarchical link state (ZHLS) routing protocol and distributed dynamic routing algorithm (DDR) are three hybrid routing approaches.

The hybrid protocols can provide a better trade-off between communication overhead and delay, but this trade-off is subjected to the size of a zone and the dynamics of a zone. Furthermore, hybrid approaches provide a compromise on scalability issue in relation to the frequency of end-to-end connection, the total number of nodes and the frequency of topology change. Thus, the hybrid approach is an appropriate candidate for routing in a large network.

1.8.2 Routing Architecture

1. Flat Architecture

In flat architecture, all nodes carry the same responsibility. Flat architectures do not optimize bandwidth resource utilization in large networks because control messages have to be transmitted globally throughout the network, but they are appropriate for highly dynamic network topology. The scalability decreases when the number of nodes increases significantly.

2. Hierarchical Architecture

On the contrary, in hierarchical architecture, aggregated nodes into clusters and clusters into super-clusters conceal the details of the network topology. Some
nodes, such as cluster heads and gateway nodes have a higher computation communication load than other nodes. Hence, the mobility management becomes complex. The network reliability may also be affected due to single points of failure associated with the defined critical nodes. However, control messages may only have to be propagated within a cluster. Thus, the multilevel hierarchy reduces the storage requirement and the communication overhead of large wireless networks by providing a mechanism for localizing each node. In addition, hierarchical architectures are more suitable for low mobility case. Although flat architectures are more flexible and simpler than hierarchical one, hierarchical architectures provide more scalable approach.

3. Aggregate Architecture

Finally, aggregate architecture aggregates a set of nodes into zones. Therefore, the network is partitioned into a set of zones. Each node belongs to two levels topology: low level (node level) topology and high level (zone level) topology. Also, each node is characterized by two ID numbers: node ID number and zone ID number. Normally, aggregate architecture is related to the notion of zone. In aggregate architecture, we find both intra-zone and inter-zone architectures which in turn can either support flat or hierarchical architecture.

1.9 Contributions of thesis (Research Goal)

The thesis aims to provide analytical frameworks for the evaluation of the network performance under different routing protocol. Different simulations have been carried out using Opnet 14.5 software to get information related to following issues:

1. Comparative study between different Ad hoc routing protocol by evaluating End-to-End delay and throughput using simulation model.
2. Evaluation of End-to-End delay and throughput using different mobility models. The aim of using different mobility models is to investigate the
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effect of mobility on performance of Ad hoc wireless network with reference to the throughput and delay.
3. Evaluations of performance of different Ad hoc wireless networks under different inter arrival time probability distribution with reference to the throughput and delay.
4. Getting optimize performance of Ad hoc wireless network with reference to End to End delay and throughput using simulation models.

The thesis will discuss results obtained after the simulations and will provide information which can be used to enhance performance of wireless network systems.

1.10 Organization of Thesis

The work carried out will be described in six chapters. It covers ‘Introduction chapter’ and final chapter of ‘conclusions and scope for future work’. The introduction chapter covers all basic terms as is explained. The remaining chapters are organized as,

Chapter II: This chapter provides a review of literature relevant to this research. Practically, the literature review contains an overview of routing problem in MANET.

Chapter III: This chapter gives detail parameters used for simulation model and by using performs of simulation model, comparative study of Ad hoc wireless network under different protocol.

Chapter IV: This chapter present and discuss the results of different experiments that have been executed by simulation. The model has been developed for different traffic conditions described by statistical distribution.

Chapter V: This chapter will discuss comparative performance of network with and without mobility conditions.

Chapter VI: This chapter summarizes the most important results of the thesis and gives an outlook for future research.
References


