CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO AD-HOC NETWORKS

Mobile Ad-hoc networks (MANET) are autonomous networks consisting of nodes that are free to move randomly and organize themselves arbitrarily. Thus the network’s wireless topology may change rapidly and unpredictably. In other words, a MANET may simply be defined as a collection of mobile hosts that maintain interconnection without the intervention of centralized access point. Every node in the network functions as an end application node as well as a router and forwards packets on behalf of other nodes. In order to achieve this, each node must participate in an ad-hoc routing protocol that allows it to discover multi-hop paths through the network to any other node. Such a network may operate in a standalone fashion, or be connected to a larger Internet.

Two important properties of an ad-hoc network are that it is self-organizing and adaptive. ‘Self organizing’ implies that a network can be formed on the fly and then change its topology without the presence of system administration entities. The term ‘adaptive’ simply implies that an ad-hoc network can take different forms and has highly variable mobile characteristics such as power, transmission conditions, traffic distribution variations, and load balancing. In order to bring forth such an infrastructure, the participating devices must be capable of detecting the presence of other devices and perform necessary handshaking to allow communications and sharing of information and services. Ad-hoc wireless networks offer unique
benefits and versatility for certain environments and certain applications. Since there is no fixed infrastructure, such networks can be deployed anywhere and at any time on the fly. Since these networks are not governed by the limitations imposed by a wired topology, they tend to be inherently more fault resilient. All nodes are mobile and there is no fixed management entity involved in the addition and deletion of nodes from the network. Due to these inherent advantages, this network technology generates a lot of interest in the research community and it was perceived that several agencies such as military, police, and rescue could gain from its usage. In recent years, home or mall office networking and collaborative computing with laptop computers in a small area have emerged as other major potential areas, where MANET could be useful. However there are numerous challenges such as effective routing, security, power management, mobility management, and QoS related issues that must be overcome to realize the practical benefits of ad-hoc networking.

**Ad-hoc Networks: Characteristics and Design Challenges**

The following characteristics adequately depict an ad-hoc networking environment.

1. **Autonomous Terminal**: In MANET, each mobile node can either run in an autonomous node or it can act as both a host and a router. Therefore it is not possible to clearly distinguish between an endpoint mobile node and routers.

2. **Distributed Operation**: There is no fixed centralized authority to manage and control ad-hoc networks. Therefore these functions are distributed amongst individual nodes in the network. This implies that a high degree of collaboration is
necessary between the participating nodes to realize such a network.

3. **Routing**: MANET has provisions for single hop as well as multi hop routing depending upon different link layer attributes and routing protocols. Single Hop routing is simpler with the cost of lesser functionality and applicability. Packets are only delivered to directly connected nodes (nodes within the range of each other). In multi hop routing, when delivering packets from a source to a destination out of the direct wireless transmission range, the packets should be forwarded via one or more intermediate nodes.

4. **Dynamic Network Topology**: In MANET, nodes can be extremely mobile as a result of which the topology of the network changes frequently and dynamically. Such movements are unpredictable and may result in frequent disconnections. The challenge is to adapt to traffic and propagation conditions as well as the mobility patterns of the mobile network nodes. Each node must be able to collaborate with other nodes even when it moves to new location. There may be a scenario where a participating node may wish to have access to services outside a MANET: other MANETS or a public fixed network or the Internet.

5. **Unpredictable Link Capacity**: The presence of high bit error rates of wireless connection coupled with unpredictable topology changes subject a communication channel to noise, fading, and interference. Even worse, the path between any pair of endpoint nodes may traverse multiple wireless links and the link themselves can be heterogeneous.
6. **Lightweight Terminals:** In most cases, the MANET nodes are mobile devices with less CPU processing capacity, small memory size, and low power storage. The inherent advantages of a MANET architecture are the ability to self configure coupled with a highly adaptive nature.

**Applications of Ad-hoc Networks**

Any commercially successful network application can be considered a candidate for useful deployment with nodes that can form ad-hoc networks. Some potential applications for which an ad-hoc network infrastructure will be beneficial are identified in this section.

- **Military Tactical Networks:** The principle requirement in a military environment is that the participating battlefield units be able to communicate anywhere and at anytime in the absence of a fixed infrastructure. The units must be capable of performing routing and other network management functions to sustain such networks.

- **Collaborative networking:** A typical example of such a scenario is when a group of people needs to have a conference or a meeting and there are no fixed infrastructure services available. If these devices are ad-hoc enabled, they could dynamically set up a network without a great deal of configuration.

- **Sensor Networks:** Recent attention has been focused on ideas involving the possibility of coordinating activities and reports of a large collection of tiny sensor devices. These communication enabled sensor nodes collectively form an ad-
hoc network. Each node contains a specific sensor such as a movement or a heat sensor. When a sensor is activated, it relays the obtained information through the ad-hoc network to some central processing node where further analysis and actions can be formed. Such networks can be used in a wide variety of situations ranging from military to surveillance. Such sensor-based nodes forming ad-hoc networks have tighter constraints in terms of size, power, and processing capabilities.

- **Personal Area Networks**: The idea of a Personal Area network (PAN) is to create a much localized network populated by some network nodes such as PDA, laptop etc. that are closely associated with a single person. As an example, one can connect the PDA to a cell phone and use the phone to gain access to the Internet. Also there may be situations when several PANs may need to interact with each other. For instance, when two people interact it is likely that their PANs may need to interact with each other too. The protocol that is best equipped to handle communication in such an environment is Bluetooth. It is an emerging short-range radio technology-based protocol that facilitates wireless communication between PDAs.

- **Disaster Area networks and Emergency services**: In situations when existing network infrastructure is destroyed or is unavailable, ad-hoc networks can be used to quickly deploy a communication network. In a disaster area, such networks can be used to improve the communication among rescue
workers and other personnel and thereby support relief operations.

- **Home networking**: An example here would be a laptop, which is taken to and way from home to the office work environment and on business trips but yet maintaining its connection with the home PC. In ‘the home of the 21st century project that is being implemented in the George Washington University’s campus at Ashburn, Virginia, this idea is being taken one step further by forming a wireless network with other network-compatible devices such as motion detectors and security cameras.

### 1.1 BACKGROUND AND MOTIVATION

As said, an ad hoc mobile network is a collection of mobile nodes that are dynamically and arbitrarily located in such a manner that the interconnections between nodes are capable of changing on a continual basis. In order to facilitate communication within the network, a routing protocol is used to discover routes between nodes. The primary goal of such an ad hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in time.

In MANET, intermediate nodes are required to route packets between source and destination if they (the source and destination) are not directly connected. For example in a distance vector routing protocol, each node participating in the route calculation stores a routing table and shares it with all neighboring nodes. If the network has a flat topology (that is, all nodes are treated equally), the size of the routing table is proportional to the number of nodes in the entire network. Further, as network size increases, communication costs tend to consume a larger portion of the bandwidth.
Furthermore, as the rate of the network topology change increases, the exchange of routing tables between neighboring nodes must be more frequent to keep routing information up to date. Other network parameters such as network node density and traffic load can also impair network scalability. Several studies have shown the difficulty for a single routing protocol to scale with respect to mobility, traffic load and network size. There are many open issue in ad hoc networks like providing scalability, energy efficient routing, QoS for mobile node and security.

In order to provide network scalability, clustering is used. Clustering is a technique that partitions a network into different groups or clusters, creating a logical hierarchy in the network. Control overhead is an important metric for measuring the performance of a clustering algorithm since bandwidth is a limited and valuable resource in MANET. There are several clustering schemes such as Mob D Hop, Max Min, Lowest ID (LID), Highest connectivity clustering (HCC) etc. A detailed classification of clustering schemes are given in Section 3.2.

Efficient energy conservation plays an important role in the performance of MANET routing because mobile nodes in the networks are battery-operated. Many theoretical studies show that energy consumption in MANET can be significantly reduced using energy aware routing protocols compared to fixed power minimum-hop routing protocols. Two approaches are broadly suggested for energy aware routing protocols that are transmission power control approach and load sharing approach.

The transmission power control approach protocols determine the optimal routing path that minimizes total transmission energy required to deliver data packets from a source to a destination.
The load distribution approach protocols focus on balancing energy usage among the nodes by avoiding over utilized nodes while selecting a routing path.

This research work aims at constructing hierarchical MANET and developing energy conserving routing protocols to such networks.

1.2 LITERATURE SURVEY

The protocol stack designed for a Mobile Ad hoc Network (MANET) has to deal with the complex problems inherent to the wireless channel due to mobility of nodes. Several studies have shown the difficulty for a single routing protocol to scale with respect to mobility, traffic load, and network size. Royer and Toh (1999) has given a review of current routing protocols and Josh Broch et al (1998) have described about the performance of routing protocol and challenges. Therefore, an ad hoc routing protocol, which can adapt its behavior to the network dynamics, will outperform classical routing schemes. In ad hoc networks, protocols have to adjust their behavior to network condition such as link quality or energy considerations.

Routing protocols design for MANETs is very active research area and many proactive, reactive and hybrid routing protocols have been proposed. Proactive protocols find routes between all sources-destination pairs regardless of the actual need for such routes. The more traditional proactive protocol can reduce the needed time to get a route by including a high routing load over the network. The various proactive protocols are Highly Dynamic Destination sequenced Distance Vector routing protocol (DSDV) by Perkins and Bhagwat (1994), Fisheye State Routing - FSR by Mario Gerla (2000) etc.
Reactive protocols, on the other hand, are based on the reduction of the routing load by initiating new routing activities only in the presence of data packets in need of a route. Reactive routing is also known as on-demand routing explained by Johnson (1994). Examples are Dynamic Source Routing (DSR) by Johnson and Maltz (1996), Ad hoc on Demand Distance Vector Routing protocol (AODV) by Perkins and Royer (1999), an Adaptive Distance Vector routing by Boppana and Konduru (2001), Temporally Ordered Routing Algorithms (TORA), by Park and Corson (2001), Das et al (2000) has compared two on demand routing protocols.

Routing protocol which combines the advantages of both proactive and reactive schemes is called hybrid routing protocol one such is Zone Routing Protocol (ZRP). Haas et al (2002) have explained about Zone Routing Protocol.

1.2.1 Clustering and Hierarchical Routing

Hong et al (2002) have pointed out that it has been proven that current routing protocols works well in small size networks (e.g. fewer than 100 nodes). However recent study also reported that the ‘flat’ ad hoc network structure has

(i) Limited capacity

(ii) As the size of network increases, the overall network capacity decreases and the performance of routing protocol degrades quickly.

However the large-scale ad hoc networks are more and more desired in many application scenarios, especially the mobile military networks. An emerging promising solution to remove the performance
bottleneck of an ad hoc network in large scale is to build hierarchical network architecture.

Ko and Vaidya (1997) have proposed routing schemes for physically Hierarchical Ad Hoc Networks with different transmission capacities and mobility rates. Gerla and Hong (2000) described about Integrated Hierarchical Routing for Heterogeneous Multi-hop Networks.


The clustering algorithms are classified based on their objectives. According to this criterion, the proposed clustering schemes for MANETs can be grouped into five categories.

(i) **DS-Based Clustering**

Wu and Li (1999) proposed a distributed algorithm to find a CDS in order to design efficient routing schemes for a MANET. Chen and Liestman (2002) pointed out that although a CDS provides explicit
information for inter-cluster routing, the number of clusters produced by the CDS clustering is rather large and the formed cluster structure is likely highly overlapping.

(ii) **Low-Maintenance Clustering**

Kwon et al (2003) proposed a scheme that tries to eliminate the control overhead for clustering completely by constructing and maintaining cluster architecture based on data traffic forwarding. Chiang et al (1997) proposed LCC (Least Cluster Change) which is considered to be a significant enhancement of Lowest ID Clustering (LIC) presented by Anthony Ephremides et al (1987) or Highest Connectivity Clustering (HCC) presented by Gerla and Tsai (1995). Yu and Chong (2003) proposed 3hBAC (3-hop Between Adjacent Cluster heads), which forms a 1-hop non-overlapping cluster structure with three hops between neighboring cluster heads. Lin and Gerla (1997) proposed an adaptive clustering scheme to form non-overlapping cluster architecture without clusterheads because clusterheads bear extra work compared with ordinary member nodes and likely will become the bottlenecks of a network.

(iii) **Mobility-Aware Clustering**

Basu et al (2001) suggests in MOBIC that cluster formation, especially clusterhead election, should take mobility into consideration. It points out that clusterhead election is a local activity so that a clusterhead should be determined only by its neighbors and itself. DDCA (Distributed Dynamic Clustering Algorithm) developed by McDonald and Znati (2001) attempts to partition a number of mobile nodes into multi-hop clusters.
(iv) **Energy-Efficient Clustering**

Amis and Prakash (2000) suggest **IDLBC** (ID Load Balancing Clustering) in which clusters are formed by diffusing node identities along the wireless links. Wu et al (2002) proposed an energy-efficient clustering scheme based on the DS (Dominating Set) marking algorithm. Ryu et al (2001) proposed a clustering scheme for energy-conservation in a MANET.

(v) **Load-Balancing Clustering**

Ohta et al (2003) developed **AMC** which maintains a multihop cluster structure based on load-balancing clustering.

According to Amis and Prakash (2000), **DLBC** (Degree-Load-Balancing Clustering) periodically runs the clustering scheme in order to keep the number of mobile nodes in each cluster around a system parameter, ED, which indicates the optimum number of mobile nodes that a clusterhead can handle.

Hierarchical techniques have been known to afford scalability in networks. Clustering is widely used to build and maintain hierarchical topology. John Sucec and Ivan Marsic (2002) and John Sucec and Ivan Marsic (2004) have pointed the clustering overhead for hierarchical routing in MANET. Gonzalez et al (2005) proposed a hierarchical proactive routing which is derived from OLSR. Song Guo and Yang (2002) developed BSR (Backup Source Routing) to establish and maintain backup paths.

Ryotaro ODA et al (2007) extended the on-demand routing protocol AODV to hierarchical network as Hi-AODV. Qin (2006) analyzed and pointed out that the throughput of a hierarchical network is smaller than that of a flat network.

Tsai et al (1989) and Farid Jaddi and Beatrice Paillassa (2005) have pointed out adaptive hierarchical routing protocol that can adapt to changing network density and node mobility.

### 1.2.2 Power Aware Routing in MANET

Mobile ad hoc networks are power constrained since nodes operate with limited battery energy. Recently researchers started considering power aware design of network protocols to maximize the lifetime of the networks. Jones et al (2001) have given a summery of recent work addressing energy efficient and low-power design within all layers of the wireless network protocol stack.

Power conservation techniques are broadly classified into transmission power control approach, load sharing approach. In ad hoc networks, the network topology changes frequently due to node movement. Therefore on-demand routing protocols such as AODV and DSR which adapts to the change in network topology are enhanced to be energy efficient. Ya Xu et al (2000), Xu Li et al (2003), Garcia et al (2003), Sabitha Ramakrishnan et al (2005), and Yuhong Luo et al (2006), have proposed energy efficient routing protocol based on Dynamic Source Routing (DSR) protocol.

At the routing layer, Subbarao (1999) suggested a minimum power routing scheme that has been designed using the table-driven approach. Ram Ramanathan and Regina Hain (2000) brings about power savings by setting
the transmit power of all nodes to control the topology of a multi-hop wireless network.

Roduplu and Meng (1999) provided a distributed position based network protocol that minimizes energy consumption in mobile wireless networks. The power consumption model consists of large scale and small scale channel variations, path loss, transmit power, receive power, and the power required to process the signal. This implementation is well-suited for networks that consist of stationary nodes. The authors do not present results about signaling overhead due to mobility. The energy model assumes negligible costs for packet reception and processing.

Jae-Hwan Chang and Leandros Tassiulas (2000) proposed algorithms to select routes and corresponding power levels in a static wireless ad hoc network such that the system lifetime (in terms of battery life) is maximized. Xu et al (2001) suggested location information based energy conserving routing algorithm that works above the ad hoc routing agent protocol to bring about energy conservation in the network by powering down intermediate nodes while still maintaining connectivity.

Li et al (2001) developed an online approximate power aware routing algorithm to maximize the lifetime of the ad hoc network, which involves choosing between the minimal power consumption path and the path that maximizes the minimum residual power in the network. Chen et al (2001) suggested a distributed coordination technique for a multi-hop ad hoc wireless network that reduces energy consumption without significantly reducing the capacity and connectivity of the net-work. Energy savings are achieved by keeping certain chosen coordinator nodes active while the other nodes in the network are in a power save mode. Elbatt et al (2000) proposed a table-based scheme that strives to maximize the end-to-end throughput by fixing transmit power levels for nodes in a cluster. Brown et al (2001) studied the fairness of
different power aware routing objectives. Garcia et al (2003) proposed a novel DSR based energy efficient routing algorithm which prevents nodes from a sharp drop of battery power.

Das et al (2001) presented a critique between the two on-demand ad hoc routing protocols by stressing the differences in their dynamic behaviors that lead to the factors that affect their performance. They also discussed the interpretation of the simulation results carried out to compare the performance of these protocols based on the packet delivery fraction, average end-to-end delay of data packets, normalized routing load, and normalized MAC load. The simulation results indicated that DSR outperforms AODV in less “stressful” (lower load and or mobility and smaller number of nodes) situation when delay and throughput were considered. However in case of a more “stressful” situation, AODV outperforms DSR. This observation did highlight the fact that it was critical to develop a cross layered protocols that handled interactions across protocol layers.

Narayanswamy et al (2002) presented a protocol for power control in ad hoc networks by providing a solution to satisfy three objectives of maximizing the traffic carrying capacity of the entire network, extending battery life by using low power routes, and reducing contention at the MAC layer. The protocol called, COMPOW, aims to operate all nodes at a common power level which is selected to be the smallest power level at which the network remains connected.

At the link layer, Sivalingam at al (2000) suggested using a scheme that uses a small packet size for registration and bandwidth request and thus reduces the energy consumption.

The PAMAS protocol proposed by Suresh Singh and Raghavendra (1998) focuses on designing protocols to reduce energy consumption to
increase the life of each mobile, thus increasing network life as well. This is carried out by defining metrics such as Energy Consumed per packet, Time to network partition, Variance in power levels across mobiles, Cost per packet, and Maximum mobile cost.

Laura Marie Feeney and Martin Nilsson (2001) described a series of experiments carried out to model the energy consumption of wireless Ethernet cards operating in an ad hoc environment. The author classifies the different energy consumption costs based on broadcast traffic, point-to-point traffic, discard traffic, promiscuous mode operation, and idle mode operation.

1.2.3 Hybrid Routing Protocol

Zone Routing Protocol (ZRP) is a hybrid routing protocol that uses local proactive routing and global reactive routing, thus can achieve a higher level of efficiency. For the comprising a large number of nodes, hierarchical network structure is an effective way to organize the network.

Hongyan Du et al (2003) proposed Zone-Based Routing (ZBR) protocol where the network area is divided into fixed non overlapping square zones. There is a zone head in each zone that acts as a router in the network and maintains information of its member nodes.


proposed load balancing of Adaptive Zone Routing Protocol (AZRP) that adaptively resizes the zone radius on concentrating the changes of network traffic in a particular direction. Research has been carried out at each layer of the OSI stack to minimize energy consumption. Sheetalkumar Doshi and Brown (2002), Xu Li et al (2004) and Murugan et al (2005) have proposed energy efficient routing protocols.

1.3 OBJECTIVES OF THE THESIS

The major objectives of this thesis are as follows;

(i) To analyze the performance of DSR protocol in flat MANET and then to analyze the proposed HDSR protocol in a two level hierarchical MANET.

(ii) To implement energy efficiency to the proposed HDSR protocol and to analyze the energy saving.

(iii) To control the transmission power of packets depending on the distance between two nodes in routing packets using zone routing protocol and thus providing power saving.

1.4 ORGANIZATION OF THE THESIS

This thesis is organized in five chapters.

Chapter 1 is introductory and it explains the fundamentals of routing in MANET. A brief literature survey of the work done in the field of power aware routing in hierarchical MANET is presented.
In chapter 2, the classification of routing protocols and the recent developments such as hierarchical state routing, power aware routing are presented.

Chapter 3 explains clustering algorithm which is used to form two level hierarchical networks. A well-known routing algorithm Dynamic Source Routing (DSR) is modified for a hierarchical network and it is referred as Hierarchical Dynamic Source Routing (HDSR). It is proved that the control overhead and end-to-end delay are reduced in a hierarchical network compared with a flat network using network simulator.

In chapter 4, the proposed HDSR protocol is modified for power efficient using load sharing approach and then it is analyzed using simulator. Simulation result shows that the network lifetime is improved. Another approach that is transmission power control which is used for energy aware routing protocol. This is used in Zone Routing Protocol (ZRP). The simulation results are compared and proved to be power efficient.

Chapter 5 concludes and the possible future work is also explored.