CHAPTER 1

INTRODUCTION

1.1 Introduction to Mobile Ad hoc Networks

The tremendous and continuous proliferation of the market of wireless-enabled portable devices facilitates the major impetus towards the development of large Mobile Ad hoc NETworks (MANET) [20, 103]. The word “ad hoc” is defined in English as “improvised and often impromptu”. It implies in computer networking context as being dynamic, temporary, autonomous and with no fixed infrastructure. As the word “ad hoc” implies in computer networking, the mobile ad hoc network is a wireless network comprising of mobile computing devices without any fixed infrastructure that is deployed as a temporary network for instant communication.

The network contains mobile nodes which are free to move randomly and are connected among them through wireless links. Each node has a wireless interface and communicates with each other through infra red or radio waves and exchanges information with other nodes that resides within its transmission range. Due to the lack of centralized management of nodes, the mobile ad hoc network does not require any base station leading to the ease of deployment of network at the times of utmost emergency. The limited CPU capacity, storage capacity, battery power and bandwidth are the important characteristic of the mobile ad hoc networks. Due to the limited transmitting range of the nodes, multiple hops are needed to reach other nodes in the network. Thus, MANETs are also called as multi-hop network that allows traveling of messages through several links. Each node acts as a host as well as a router in the
mobile ad hoc network. The mobile ad hoc network plays a critical role in places where there is lack of wired backbone or finances to build the network. This multi-hop network architecture should be able to dynamically adapt itself with the changing configurations of the network.

1.1.1 MANET Features

The MANET has the following features

- **Autonomous Terminal**- Each mobile node acts autonomously as a host as well as the router in the network.

- **Distributed Operations**- Due to the lack of fixed or centralized infrastructure, the mobile nodes collaborates among themselves to control and manage the activities of the network.

- **Dynamic network topology**- Due to the mobile nature of the nodes, network topology changes rapidly and unpredictably and the connectivity among the nodes varies with time. The mobile nodes in the MANET should adapt dynamically by establishing dynamic routes among themselves.

- **Unpredictable link capacity**- The channels that mobile nodes communicate are prone to noise, fading and interference leading to high error bit rates and has lesser bandwidth than the wired networks.

- **Light weight terminals**- The mobile nodes in MANET has less CPU processing capability, limited memory power with less power storage and transmission power.
1.1.2 MANET Applications

The applications of MANETs are diverse, ranging from large scale, mobile, highly dynamic networks [28, 58, 22] to small, static networks that are constrained by power sources. Some of the vital applications are as follows:

- **Military Applications** - The basic technique of ad hoc network originates from this military field as shown in Figure 1.1. The Military equipments contain computer equipment that facilitates to build ad hoc network in order to maintain and exchange information among the soldiers, vehicles and military information head quarters.

![Figure 1.1 Military Applications](image-url)
- **Crisis Management Services** - The Ad hoc networking is used in emergency/rescue operations for disaster relief efforts where there is lack of fixed infrastructure and rapid deployment of communication network is needed. The examples include fire, flood, earth quake, law enforcement etc.

- **Local Level** - The MANET bears great application potential from the documents sharing at the conferences to the infrastructure enhancements. The examples of local level applications include business associates wishing to share files in an airport terminals or a class of students interacting with each other during the time of lectures and also in other areas like mobile conferencing, sensor dust, home networks and civilian environments like taxi cab, meeting rooms, sports, stadium, boats and small aircraft.

- **Personal Area Network (PAN)** - The PAN is the potentially promising application field of MANET for pervasive computing that eases the intercommunication between various short range mobile devices like PDAs, laptops and cellular phones.

- **Business Environments** - The mobile ad hoc network is used where the need for collaborative computing is more important outside the office environment than inside, such as in a business meeting outside to brief clients on a given assignment.

- **Bluetooth** - It is designed to support Personal Area Network by eliminating the need of wires between various devices such as printers and personal digital assistants. The famous IEEE802.11 or Wi-Fi protocol supports ad hoc network system in the absence of wireless access point.

- **Automation** - Automation could definitely profit from ad hoc technology. Service robots will be of greater mobility with advanced mobile
communication techniques. These technologies help to coordinate the works and improve the efficiency, making them independent of a fixed communication environment.

- **Ubiquitous Computing** - Currently, the mobile internet have been established and the next step is the massive growth of embedded microchip applications and their connectivity. Since ad hoc networking without fixed infrastructure are friendly than fixed solutions, ad hoc networking plays an important role in ubiquitous computing considerations.

### 1.2 Clustering in Mobile Ad hoc Network

The basic performance guarantee in a large dynamic MANET is to ensure the crucial aspect of scalability by the effective determination of clusters. When non-clustered architecture is used, each node would have to maintain immense topology knowledge with relevant characteristics viz. link, capacity, address that paves the way to the immense growth of the routing tables and location registers. A clustered architecture, however limits the view of each network entity to a fraction of total network. In addition, it reduces the signaling traffic exchanged between network entities and the information stored inside them because the detailed topology information is exchanged among the local cluster members, and only the aggregate information is distributed between the neighboring groups.

In clustered network organization [76], the clusters are formed by grouping the mobile nodes under the supervision of one special role node termed as cluster head. The cluster heads are vested with special supervising functions and they act as local coordinators by performing information aggregation of topology and managing intra-
cluster communication between the nodes in their proximity. Figure 1.2 shows the typical clustered ad hoc network architecture.

![Figure 1.2 Clustered Ad Hoc Network Architecture](image)

*Figure 1.2 Clustered Ad Hoc Network Architecture*

- \( H \) - Cluster head (Intra-Cluster Communication)
- \( G \) - Gateway (Inter-Cluster Communication)
- \( N_{ij} \) - \( j^{th} \) Cluster Member of \( i^{th} \) cluster head
- \( C \) - Cluster
- \( T \) - Transmission Range

The mobile nodes are grouped into clusters under the supervision of one cluster head are shown with the dotted lines and the mobile nodes associated with the cluster head are termed as cluster members or ordinary nodes, without any inter-cluster links. Gateway nodes are the non-cluster head nodes situated at the fringe of a cluster facilitating inter-cluster communication with its neighborhood clusters [72]. Efficient clustering imposes minimum clustering overheads, limits the number of clusters and their overlapping in the network.
1.2.1 Benefits of Clustering

Clustering is always of significant importance for network management, hierarchical address assignment, medium access control, Quality of Service (QoS), radio resource management, topology updates. In addition to it, it has the following benefits:

1. It improves the system capacity [57] by implementing spatial reuse of resources that is done by managing wireless transmission among the member nodes of a cluster.
2. It reduces the amount of routing information propagated in the network and routing delay [48, 49, 1, 19] due to the formation of virtual backbone [46, 43, 95] with the set of cluster heads and cluster gateways that facilitates inter-cluster routing in the network.
3. A clustered architecture limits the amount of information to represent the state of the network.
4. It reduces the amount of topology update messages [38] by updating the topology information within the cluster when there is change of position of its associated members in the network.

1.3 Motivation of the work

The extensive benefits of clustering in mobile ad hoc networks motivates researchers to focus on clustering techniques so as to develop more efficient clustering protocols for improving the stability and performance of the network. Each clustering protocol uses different methodologies to accomplish stability of the network. However, no clustering protocols were able to provide excellent stability.
The selection of stable cluster heads is a multi-criteria decision making problem. The Analytical Hierarchy Process [79, 105] is a simple and powerful tool that solves multi-criteria decision making problems in a more effective way. Therefore an attempt has been made to design efficient protocols to select stable cluster heads based on Analytical Hierarchy Process Methodology which in turn provided an efficient stable clustering for mobile ad hoc networks.

1.4 Problem statement

The extensive literature survey in the field of clustering in mobile ad hoc networks enabled to identify the problems that exist in the clustering protocols and to define them precisely and clearly as follows:

1. To provide stable network by increasing the cluster head lifetime and reducing cluster head changes, re-affiliations and re-clustering of the network

2. To minimize number of clusters and to reduce the communication overheads and transmission delay in the network.

1.5 Contribution

In this dissertation, the four novel clustering protocols viz. Analytical Hierarchy Process Clustering protocol, Beta-AHPC protocol, Mobile Agent based Analytical Hierarchy Process Clustering protocol and optimized AHPC protocol have been designed to provide stable clustered architecture with improved performance of the network. The following contributions were made.

- A novel clustering protocol, Analytical Hierarchy Clustering Protocol (AHPC) has been designed and implemented. Adequate experiments have been
performed to analyze the performance of AHPC protocol. This protocol provides stable cluster heads which basically reduces frequent cluster head changes, dominant set updates, re-affiliations, re-clustering thereby increasing the cluster head lifetime which eventually provides stable network.

- The novel Beta-AHPC protocol has been designed using Beta probabilistic model to reduce the number of clusters in the network.

- The AHPC protocol has been further enhanced using mobile agent concepts and another novel protocol named Mobile Agent based Analytical Hierarchy Process Clustering protocol (AHPCM) has been designed. This protocol also provides stable network. In addition, it reduces the communication overhead and delay thereby improving the performance of the network.

- Genetic algorithm has been used as the optimization technique to optimize the cluster head selection process of AHPC protocol to obtain optimum number of clusters thereby further enhancing the cluster head lifetime and stability of the network.

1.6 Organization of the Thesis

The rest of the thesis is organized as follows: The Chapter 2 provides an extensive literature survey of various clustering protocols and a comparative study of different groups of clustering protocols against vital performance metrics is presented. The Chapter 3 explains the architectural design of novel AHPC protocol. In addition, the AHP methodology has been explained extensively. The Chapter 4 provides the experimental analysis of the AHPC protocol in which the performance of AHPC protocol was evaluated using significant performance metrics. The Chapter 5 provides the mathematical analysis of AHPC protocol that includes stability analysis, control
overhead analysis, time and message complexity analysis of AHPC protocol. The Chapter 6 explains Beta-AHPC protocol that utilizes Beta probabilistic model to reduce the number of clusters in the network.

The Chapter 7 provides the design of novel AHPCM protocol and experimental results have been provided that shows the performance of AHPCM protocol. The Chapter 8 provides the analysis of AHPCM protocol. It includes control overhead analysis, time and message complexity analysis of AHPCM protocol. The Chapter 9 explains the optimization of cluster head selection process of AHPC protocol using genetic algorithmic approach to obtain optimum number of clusters in the network. The optimized AHPC protocol has been implemented and experimental results have also been provided and a comparative study has been made with AHPC protocol. The Chapter 10 provides the summary of the research work and the future research directions in the field of clustering of the mobile ad hoc networks.