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A Review of Cluster Head Selection in MANET

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Abstract— **A mobile ad-hoc network is a wireless network composed of mobile nodes that are dynamically and randomly located in such a manner that the contact between each other. These nodes do not make a fixed structure because the nodes can move in any direction. These nodes can communicate with other nodes in the radio range. Such networks are often referred to as multi-hope network. These nodes run batteries and have limited stock of energy in nodes can affects the communication activities in wireless network. So, the efficiency of MANET depends not only on its control protocol, but also on its topology and energy management. Clustering is a key routing technique used to reduce energy consumption. The feasibility of a clustering method can be primarily determined by the complexity of the cluster head selection. This is elected as cluster head according to the specific metric or combination of metrics such as mobility, energy, degree, density, weight etc. In this survey paper we study some clustering schemes such as Mobility based clustering, Energy efficient clustering, Load balancing clustering, and Combined-metrics based clustering.**

***Keywords*— MANET, Clusters, Cluster Head, Mobility**

I. INTRODUCTION

The mobile ad hoc network is a collection of independent mobile nodes formed by means of multi-hop wireless communication without the use of any existent network infrastructure. In an ad hoc network, each mobile node attends as a router. The mobile ad hoc network is infrastructure less wireless network. The communication in MANET is take place by using multi hop paths [5]. The mobile nodes have freedom to move at any direction and have the ability of self-configuring, self-maintaining and self-organizing themselves within the network by means of radio links. Figure 1.1, as in the network there is no base station or central coordinator exists. They are highly suitable for applications involving special outside events, communications in area with no Wireless infrastructure, emergencies and natural disasters and military operations etc.

Figure 1.1 Mobile Ad hoc Network

Routing in a network is the process of selecting paths to send network traffic. Routing can take place either in a flat structure or in a hierarchical structure [3]. In a flat structure [4, 5], all nodes in the network are in the same hierarchy level and thus have the same role. Although this approach is efficient for small networks, it does not allow the scalability when the number of nodes in the network increases. In large networks, the flat routing structure produces broad information flow which can soak the network [6,7]. Hierarchical routing protocols [8] have been proposed to solve this problem among others. This approach consists of dividing the network into groups called clusters. This results in a network with hierarchical structure. Different routing schemes are used between clusters and within clusters. Each node maintains complete knowledge of area information but only partial knowledge about the other clusters. Hierarchical routing is a solution for handling scalability in a network

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where only selected nodes take the responsibility of data routing [9, 10]. However, hierarchical approaches undertake continual topology changes. Thus, topology management plays a vital role prior to the actual routing in MANET. Cluster based structure (hierarchical structure) in net-work topology has been used to improve the routing efficiency in a dynamic network [11].

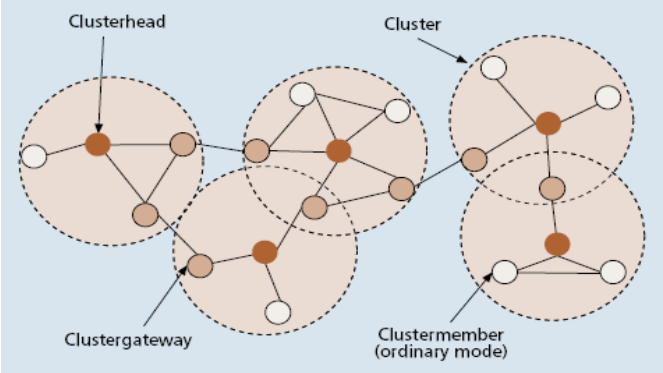

Figure 1.2 Clustered Networks

This review paper is organized as follow: we start by introducing different clustering approaches. Then, we present their advantages and disadvantages. In section 3 we present some existing works on review of clustering in MANETs. In section 4, we review some clustering schemes for MANETs. Finally, in section 5, we conclude the paper.

II. CLUSTERING IN MOBILE AD HOC NETWORK

The process that divides the network into interconnected substructures, called clusters. Each cluster has a particular node elected as cluster head (CH) based on a specific metric or a combination of metrics such as identity, degree, mobility, weight, density, etc. The cluster head plays the role of coordinator within its substructure. Each CH acts as a temporary base station within its cluster and communicates with other CHs [7,8]. A cluster is there-fore composed of a cluster head, gateways and members node.

Cluster Head (CH): it is the coordinator of the cluster.

Gateway: is a common node between two or more clusters.

Member Node (Ordinary nodes): is a node that is neither a CH nor gateway node. Each node belongs exclusively to a cluster independently of its neighbors that might reside in a different cluster.

III. ALGORITHMS FOR CLUSTER HEADS ELECTION IN MANETS

There are several algorithms in the literature for cluster heads election in mobile ad hoc networks: Lowest-ID [7], Highest-Degree [8], Distributed Clustering Algorithm [9], Weighted Clustering Algorithm (WCA) [9] and Distributed Weighted Clustering Algorithm (DWCA) [10].

IV. RELATED WORK

All Jane Y.Yu and Peter H.J.Chong [11], have presented a comprehensive survey of clustering schemes for MANETs. The authors first provided fundamental concepts about clustering. Then they classified proposed clustering schemes into six categories based on their main objectives, which are listed as follows: Dominating-Set-based (DS-based) clustering, low maintenance clustering, mobility-aware clustering, energy efficient clustering, load-balancing clustering, and combined metrics-based clustering. They also grouped the clustering cost terms into five categories: the required explicit control message exchange, the ripple effect of re-clustering, the stationary assumption, constant computation round, and communication complexity.

A. Abbasi and M. F. Younis [12] grouped taxonomy of relevant attributes into three types: cluster properties, cluster head capabilities, clustering process. They categorized the different schemes based on the objectives, the desired cluster properties and clustering process. They highlighted their objectives, features, complexity and the effect of the network model

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on the presented schemes and summarized a number of schemes, stating their strength and limitations. Finally they compared these clustering algorithms based on metrics such as convergence rate, cluster stability, cluster overlapping, location awareness and support for node mobility.

B.A.Correa et al [3], discussed the concepts related to network topology, routing schemes, graphs partitioning and mobility algorithms. The authors described lowest-ID heuristic, highest degree heuristic, DMAC (dis-tributed mobility-adaptive clustering), WCA (weighted clustering algorithm).

R. Agarwal and M. Motwani [10] examined the im-portant issues related to cluster-based MANETs, such as the cluster structure stability, the control overhead of cluster construction and maintenance, the energy consumption of mobile nodes with different cluster-related status, the traffic load distribution in clusters, and the fairness of serving as cluster head for a mobile node.

M. Anupama and B. Sathyanarayana [28], analyzed, compared and classified some clustering algorithms into: location based, neighbour based, power based, artificial intelligence based, mobility based and weight based. They also presented the advantages and disadvantages of these techniques and suggest a best clustering approach based on the observation and the comparison.

V. Clustering Schemes in Mobile Ad hoc Network

We classify the clustering algorithms based on their objectives, the cluster heads election criteria and based on literature review [10, 12 , 13] as:

A. *Identifier Neighbour Based Clustering:*

In identifier neighbour based clustering, a unique ID is assigned to each node. Each node in the network knows the ID of its neighbours. The cluster head is selected based on criteria involving these IDs such as the lowest ID, highest ID...etc. Ephremides et al [17] proposed a clustering algorithm called Linked Cluster Algorithm (LCA) where each node is either, a cluster head, an ordinary node or a gateway node. Initially, all nodes have status of ordinary node; periodically each node in the network broadcasts its ID and its neighbours IDs. Subsequently, the node with the smallest ID is selected as cluster head. A node which can hear two or more cluster heads is a gateway. The process repeats until every node belongs to at least one cluster. Nodes with a small ID are more likely to be selected as cluster heads so they quickly consume their energy.

Chiang et al [14] proposed Least Cluster Change (LCC), an improved versions of LCA algorithm which adds a maintenance step to minimize the cost of re-clustering. The reconstruction of clusters is invoked in only the following two cases: first case If two cluster heads are neighbours, then the one with the highest ID gives up the role of cluster head and another case If a non CH node moves outside its cluster and does not join an existing cluster then it will become cluster head forming a new cluster. LCC improves the stability of clusters but it has some disadvantages e.g. the cost of re-clustering is a bit expensive.

Lin and Gerla [15] proposed another protocol called Adaptive Clustering Algorithm (ACA). In this algorithm, once the clusters are formed, the concept of cluster head disappears and all nodes play the same role in the net-work. The authors' motivation is that cluster heads can become bottlenecks and consume their resources faster than other nodes. The same metric as the LCA (the lowest ID) is used for the CH selection. In cluster maintenance, each node must know its two-hop neighbours. If the distance between two nodes in the same cluster becomes three hops, than cluster maintenance is invoked.

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B. *Topology Based Clustering:*

In the topology based clustering, the cluster head is chosen based on a metric computed from the network topology like node connectivity. We present below some of the existing topology based clustering algorithms.

Gerla and Tsai proposed a protocol called High-Connectivity Clustering (HCC) [16] based on the degree of connectivity to construct clusters. In this protocol the node with the highest number of neighbours is selected as the cluster head. If two nodes or more have the same degree of connectivity, the node with the lowest ID is elected as a cluster head. HCC generates a limited number of clusters. In mobile environment, this algorithm increases the number of re-affiliations of CHs because their degree changes very frequently. This algorithm reduces the number of CHs in the network. CHs and member nodes keep their status for a long period. However, this algorithm requires that each node maintains two tables: a neighbour table and member table that contain all member nodes of the network.

C. *Mobility Based Clustering:*

Lowest Relative Mobility Clustering Algorithm (MOBIC) [8] is based on the LCA algorithm but involves the relative mobility of nodes as a criterion in the cluster head selection. The idea is to choose nodes with low mobility as cluster heads because they provide more stability. MOBIC uses a similar clusters maintenance procedure as LCC [9] with an additional rule to minimize the cost of clusters maintenance. MOBIC uses Cluster Contention Interval (CCI) to avoid unnecessary cluster head relinquishing. If two CHs are neighbours after the CCI time period has expired, then the one with the highest ID gives up the role of CH. This mechanism reduces the CHs maintenance. Involves the relative mobility of nodes as a criterion in the cluster head selection. The idea is to choose nodes with low mobility as cluster heads because they provide more stability. MOBIC uses a similar clusters maintenance procedure as LCC [14] with an additional rule to minimize the cost of clusters maintenance. MOBIC uses Cluster Contention Interval (CCI) to avoid unnecessary cluster head relinquishing. If two CHs are neighbors after the CCI time period has expired, then the one with the highest ID gives up the role of CH. This mechanism reduces the CHs maintenance. However, the limitations of LCC algorithm are not completely eliminated.

D. *Energy based Clustering:*

The battery power of node is a constraint that affects directly the lifetime of the network, hence the energy limitation poses a severe challenge for network performance. CH performs special tasks such as routing causing excessive energy consumption. Next, we discuss some existing energy based clustering algorithms.

A multicast power greedy clustering (MPGC) is based on heuristic to reduce the energy consumption. This algorithm runs in three consecutive phases: beacon phase, greedy phase and recruiting phase. During beacon phase, each node sends a beacon signal with the highest power in order to inform its neighbours of its presence and collects information about its neighbours of the beacons received. During the greedy phase, each node sends a cluster head declaration with necessary level of power required to reach its nearest neighbour, and then it in-creases its power level step by step until it reaches all its neighbours. During last phase, each node has the value of the residual power of its neighbours. If a node u has the highest residual power among all its neighbours, then u is elected as cluster head. MPCG prolongs network lifetime, but it requires several steps to construct the clusters structure which increases network traffic and bandwidth consumption.

E. *Weight based Clustering:*

Weight based clustering techniques use a combination of weighted metrics such as:

transmission power, node degree, distance difference, mobility and battery power of mobile nodes… etc. The weighting factors for each metric may be adjusted for different scenarios. Some of these algorithms are presented next.

A Flexible Weight Based Clustering Algorithm (FWCA) uses a combination of metrics (with different weights) to build clusters. Node degree, remaining battery power, transmission power, and node mobility are used in CHs election process. The cluster size does not exceed a pre-defined threshold value. During cluster maintenance phase, FWCA uses the clusters capacity and the link life-time instead of the node mobility because the link stability metric affects the election of a CH with the same weight as the node mobility metric.

VI. Comparison of Clustering Schemes

They are many clustering schemes for MANETs avail-able in the literature. To evaluate these schemes, we have to decide about the metrics to use for the evaluation. Based on our review and the work presented in [11], the total overheads increase when clusters number is high and CHs change frequently. The weight based clustering scheme performs better than ID-Neighbour based, topology based, mobility based and energy based clustering. The weight based clustering scheme is the most used technique for CH election that uses combined weight metrics such the node degree, remaining battery power, transmission power, and node mobility etc. It achieves several goals of clustering: minimizing the number of clusters, maximizing lifespan of mobile nodes in the network, decreasing the total overhead, minimizing the CHs change, decreasing the number of re-affiliation, improving the stability of the cluster structure and ensuring a good resources management (minimize the band-width consumption).

VII. Conclusion

In this survey, we first presented fundamental concepts about clustering, including the definition of clustering, design goals and objectives of clustering schemes, advantages and disadvantages of clustering, and cost of network clustering. Then we classified clustering schemes into five categories based on their distinguishing features and their objectives as: Identifier Neighbour based clustering, Topology based clustering, Mobility based clustering, Energy based clustering, and Weight based clustering. We reviewed several clustering schemes which help organize MANETs in a hierarchical manner and presented some of their main characteristics, objective, mechanism, and performance. We also identified the most relevant metrics for evaluating the performance of existing clustering schemes. Most of the presented clustering schemes focus on important issues such as cluster structure stability, the total control overhead of cluster formation and maintenance, etc. In addition, the different categories of clustering schemes have different characteristics and objectives.

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