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A Review of Cluster Formation Schemes in MANET

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Abstract

Mobile ad-hoc networks (MANETs) are a form of wireless networks which do not require a base station for providing network connectivity. As MANETS have some limitation. Cluster based routing is one of the routing schemes for MANETs in which various clusters of mobile nodes are formed with each cluster having its own Cluster head which is responsible for routing among clusters. Clustering in Mobile Ad Hoc Networks (MANETs) has many advantages compared to the traditional networks. But the highly dynamic and unstable nature of MANETs makes it difficult for the cluster based routing protocols to divide a mobile network into clusters and determination of cluster heads for each cluster. Optimizing the cluster head selection allows the network to be more efficient by minimizing the signaling overhead and ensuring that the network connectivity is maintained despite topology changes. A variety of approaches for MANET clustering has been developed. In this survey paper we are presenting some of cluster formation schemes.

Keywords: MANET, Cluster formation, Cluster maintenance, CH, Gateway

1. INTRODUCTION

In the case of MANET, dynamic topology is the most important issue for which a lot of techniques are developed to mitigate the problems. However, it has been proved that a flat structure exclusively based on proactive or reactive routing schemes cannot perform well in a large dynamic MANET. In other words, a flat structure encounters scalability problems with increased network size, especially in the face of node mobility at the same time. This is due to its intrinsic characteristics. The communication overhead of link-state proactive routing protocols is O(n2), where n is the total number of mobile terminals in a network . In reactive routing scheme, the control packets flood over the network and the route setup delay becomes considerably high in the existence of both, a large number of nodes and high mobility.[1,2]

In MANETs, when network's size exceeds a certain threshold decreases the performance, resulting in many routing algorithms performing only when network's size is small. To overcome bandwidth and battery power limitations, and reduce routing overhead, it is mandatory to make network organization smaller and manageable. A clustering architecture provides solution for the Problem in MANET environments: network scalability, fault tolerance and reduction of communication overheads.[1]

2. CLUSTERING OVERVIEW

In a clustering scheme the mobile nodes in a MANET are divided into different virtual groups, and they are allocated geographically adjacent into the same cluster according to some rules with different behaviors for nodes included in a cluster from those excluded from the cluster. A typical cluster structure is shown in Fig. 1. It can be seen that the nodes are divided into a number of virtual groups (with the dotted lines) based on certain rules. Under a cluster structure, mobile nodes may be assigned a different status or function, such as clusterhead, clustergateway, or cluster member. A clusterhead normally serves as a local coordinator for its cluster, performing intra-cluster transmission arrangement, data forwarding, and so on. A clustergateway is a non-clusterhead node with inter-cluster links, so it can access neighboring clusters and forward information between clusters. A cluster member is usually called an ordinary node, which is anon-clusterhead node without any inter-cluster links.[2]

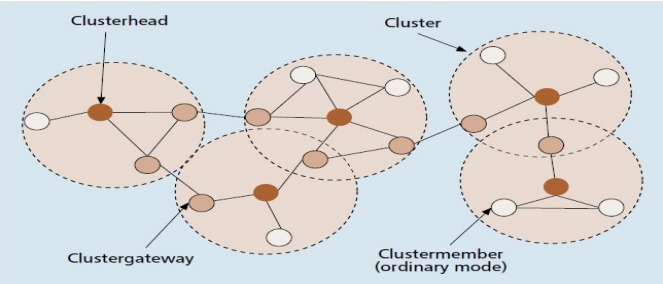

Figure 1 Cluster structure

Clustering presents several advantages for the medium access layer and the network layer in MANET. The implementation of clustering schemes allows a better performance of the protocols for the Medium Access Control (MAC) layer by improving the spatial reuse, throughput, scalability and power consumption. On the other hand, clustering helps improve routing at the network layer by reducing the size of the routing tables and by decreasing transmission overhead due to the update of routing tables after topological changes occur. Clustering helps aggregate topology information since the number of nodes of a cluster is smaller than the number of nodes of the entire network. Therefore, each node only needs to store a fraction of the total network routing information. The purpose of a clustering algorithm is to produce and maintain a connected cluster. In most clustering techniques nodes are selected to play different roles according to a certain criteria.[5]

Advantages and Disadvantages:

• *Advantages*
– Reusability: spatial reuse of resources at nodes
– Simplification: of addressing
– Stability and Localization: smaller and potentially mode stabile sub-network structures

• *Disadvantages*
– Explicit control messaging: clustering related information exchange
– Ripple effect: rebuild of cluster structure in case of network structure changes
– Stationary period: collect and exchange information for cluster formation
– Computation rounds: number of rounds to complete the cluster election
– Communication complexity: amount of control messages exchanged
– No common solution

3. CLUSTERING APPROACHES

3.1 *DS-based clustering*: - Finding a (weakly) connected dominating set to reduce the number of nodes participating in route search or routing table maintenance. Ex - Connected DS , Weak CDS

3.2 *Low-maintenance clustering:* - Providing a cluster infrastructure for upper layer applications with minimized clustering-related maintenance cost. Ex- LCC (Least Cluster Change), 3hBAC (3-hop Between Adjacent Clusterheads), PC (Passive Clustering)

3.3 *Mobility-aware clustering*: - Utilizing mobile nodes' mobility behavior for cluster construction and maintenance and assigning mobile nodes with low relative speed to the same cluster to tighten the connection in such a cluster. Ex - MOBIC, DDCA (Distributed Dynamic Clustering Algorithm)

3.4 *Energy-efficient clustering*:- Avoiding unnecessary energy consumption or balancing energy consumption for mobile nodes in order to prolong the lifetime of mobile terminals and a network. Ex - IDLBC , Energy based DS

3.5 *Load-balancing clustering*: - Distributing the workload of a network more evenly into clusters by limiting the number of mobile nodes in each cluster in a defined range. Ex - DLBC (Degree-Load-Balancing Clustering)

3.6 *Combined-metrics-based clustering:* - Considering multiple metrics in cluster configuration, including node degree, mobility, battery energy, cluster size, etc., and adjusting their weighting factors for different application scenarios. Ex - WCA, On-Demand WCA (Weighted Clustering Algorithm

4. CLUSTER FORMATION ALGORITHM IN MANET

4.1 *Weighted Clustering Algorithm (WCA)*[3]:

A distributed clustering algorithm based on weight values. The weighted clustering algorithm (WCA) selects clusterheads by considering important aspects related to the efficient functioning of the system components. Therefore, in order to optimize battery usage, load balancing and MAC functionality a node is chosen to be a clusterhead according to the number of nodes it can handle, mobility, transmission power and battery power. WCA selects the clusterheads according to the weight value of each node. The weight associated to anode v is defined as-

$$Wv = w1\_v + w2Dv + w3Mv + w4Pv$$

The node with the minimum weight is selected as a clusterhead.The weighting factors are chosen so that,

$$w1+ w2 + w3 + w4 = 1$$

The clusterhead selection algorithm finishes once all the nodes become either a clusterhead or a member of a clusterhead. The distance between members of a clusterhead, must be less or equal to the transmission range between them. No two clusterheads can be immediate neighbors.

4.2 *WCA with Mobility Prediction [4]* :

A modified version of the Weighted Clustering Algorithm(WCA) is proposed for the cluster formation and mobility prediction for cluster maintenance. The cluster formation is done as in WCA. Mobility Prediction, a quantity is applied to predict whether a node moves along with all its 1-hop neighbors has been done for the cluster maintenance. The main aim is to reduce the overhead in communication by predicting mobility of node using linear auto regression and cluster formation.

4.1.1 *Cluster Formation*: Initially, each node broadcasts a beacon message to notify its presence to the neighbors. A beacon message contains the state of the node. Each node builds its neighbor list based on the beacon messages received. The cluster-heads Election is based on the weight values of the nodes and the node having the lowest weight is chosen as CH.

4.1.2 *Cluster Maintenance*: The second phase is the clustering maintenance. There are defined two distinct types of operations for cluster maintenance: the battery power threshold property and the node movement to the outside of its cluster boundary.

4.3 *Improved WCA (iWCA)[5] :*

An improved version of the WCA called improved weighted clustering algorithm (iWCA), by keeping a node with weak battery power from being elected as a CHs, minimizing the number of clusters, and minimizing the overhead for the clustering formation and maintenance. The base for this approach is derived from the WCA algorithm. This has the improved performance on the number of clusters and the re-affiliation frequency.

4.4 *Enhancement on Weighted Clustering Algorithm [EWCA] [6] :*

In the authors introduced a new type of algorithm called Enhancement on Weighted Clustering Algorithm [EWCA] to improve the load balancing and the stability in the MANET. The cluster head that is selected efficiently based on these factors like, high transmission power, transmission range, distance mobility, battery power and energy. Since the cluster head will not be changed dynamically, the average number of cluster formation will be reduced. By applying the load balancing factor, the overhead in the cluster is reduced.

4.5 *Scalable and Adaptive Clustering Scheme [7]:*

In this scheme, the author presents a clustering scheme that minimizes message overhead for cluster formation and maintenance. As we know most existing schemes have large overhead associated with cluster formation and cluster maintenance. They also trigger reclustering periodically. This renders these schemes non-scalable. We do not require reclustering as clusters in our scheme do not degenerate into single node clusters over time. The author proposes a multi-hop clustering scheme that has minimal communication overheads to form and maintain clusters. In this scheme, each node in the cluster can be, at most a distance of K hops from its cluster head. At any point of time, as long as the node is reachable from that cluster's members, it can maintain its membership in that cluster instead of triggering re-affiliation to a new cluster.

This scheme select a CH as when a node boots up, it broadcasts a cluster solicitation message to its immediate neighbors. If it does not get any reply within the specified time interval t, it declares itself as a cluster head. If it receives cluster advertisements in response to its solicitation message, the node examines the hop distance value field in the advertisements. If this is less than or equal to K, then, the node joins the cluster with the minimum hop count by sending a cluster acceptance message to the node(s) from which advertisements were received. However, if the hop count advertised is greater than K for all advertisements received, then, the node declares itself as a cluster head. Reception of multiple cluster advertisements by the new node indicates that it is within reachable distance of multiple clusters. Therefore, the node declares itself a cluster gateway and informs all the nodes which responded to its cluster solicitation.

The cluster formation phase involves very little control message overhead. Cluster maintenance is done by extending DSDV messages and The clusters formed do not vary much with mobility.

4.6 *Signal and Energy Efficient Clustering (SEEC)[8]:*

In this scheme, author proposes a "Signal and Energy Efficient Clustering (SEEC)" algorithm based on signal strength and energy level of nodes in MANET to improve system performance. The algorithm focuses on cluster head formation and maintenance, and prevents death of cluster head by making another cluster node as the cluster head when power level falls below certain threshold value.

The main drawback of routing protocol that the Cluster head dies of due to extra power dissipation. The main focus of the proposed SEEC algorithm is preventing the death of the cluster head by making another node as the cluster head when power level falls below certain threshold value. The proposed algorithm takes care of cluster head formation and keeps it alive after initial cluster formation and avoids re-election of cluster head when signal strength or power level reaches certain minimum threshold value. There is no need for explicit message passing during cluster maintenance. SEEC

maintains two tables for each cluster head they are 'Cluster Head Table' and 'Routing Table' and one 'Neighbor table' by each nodes in cluster.

The basic idea behind this algorithm is that it keeps head always alive & avoids re-election of cluster head thus takes care of cluster head by maintaining both battery power level and signal strength.

4.7 *Mobility Prediction Based Clustering Algorithm (MPBCA) [9]:*

In this paper author proposed mobility prediction based clustering algorithm in which the mobility pattern of the nodes is observed and given importance in electing cluster head. As we know mobility causes the network instable, which leads to link failure. Stability of any network is achieved when there is no mobility. But MANET is a dynamic wireless network in which the mobility is unavoidable. Node mobility denotes the movement of hosts inside the network. Mobility can't be avoided but can be predicted. When the node movement is predicted earlier, the cluster head node could be selected depending upon the mobility prediction method. Hence, the node which is comparatively stable could be selected as a cluster head. This will ensure the network stability.

In this work we introduce a new method called mobility prediction method, which observe the speed of a node and find the mobility pattern. The proposed work has 3 procedures. The first procedure is "PREPROCESSING STAGE" to initially set the network area followed by second procedure which illustrate "MOBILITY MODEL" and finally third procedure is "CLUSTER HEAD ELECTION". To elect a proper cluster head MPBCA, has taken the Distance (D), Mobility (M), Remaining Battery Power (R) and Transmission Range (T). By considering the above parameters a Quality Factor (QF) is calculated. When a node broadcast the hello message it sends the QF of its own which is compared by the neighbor nodes and finally a node with smallest weight is elected as a CH.

4.8 *Improved Distributed Weighted Clustering Algorithm (DWCAIMP)[10] :*

This is again combined weight metric based approach, where author presents an improved distributed weighted clustering algorithm (DWCAIMP). This algorithm can be divided into three phases - Clusters Formation, Running Mobility, and Cluster Maintenance. In DWCAIMP algorithm implemented in two algorithms, first is Weight Calculation Algorithm is applied which calculate the combine weight W for each node. and second is Clusterhead Selection Algorithm. First node finds its neighbors and builds its neighborhood table. Then each node calculates its weight by calling the weight calculation algorithm. All node broadcasts its weight to its neighbors. If it has maximum weight among its neighbors, it sets the clhead variable to 1, otherwise, the clhead variable is set to 0. In case a new node is added, it calculates its weight by calling weight calculation algorithm. In case CH fails, the algorithm is repeated.

This algorithm reduces the CH formation and control messages overhead thus improving overall performance and reducing energy utilization. Since energy utilization is the most important criteria in cluster based routing schemes, this protocol provides better results than existing distributed clustering algorithm. The drawback of this algorithm is that when CH get failed because of any reason then CH has to Re-elect by applying the same computation for CH selection.

Summary of The Above Cluster Formation Schemes

Clustering Scheme	*Advantages*	Clusterhead (CH) Selection
EWCA	1. CH will not be changed dynamically 2. The average number of cluster formation will be reduced. 3. By load balancing factor, the overhead in the cluster is reduced.	The CH is selected based on these factors like, high transmission power, distance mobility, battery power &energy.
Scalable and Adaptive Clustering	1. Minimizes message overhead for cluster formation and maintenance. 2. Do not require re-clustering	After broadcasting a solicitation message if node doesn't get any advertisement message from any other CH within certain amount of time , then it will announce itself as a CH.
SEEC	1. It keeps head always alive. 2. Re-election of cluster head. 3. Enhance system performance	Hello message broadcast to all the nodes which consist ID,SS,PL, after the comparison b/w nodes , node with highest SS and PL select as a CH
MPBCA	1. Node movement is predicted earlier, the CH node could be selected depending upon the mobility 2. It will ensure the network stability.	To elect a CH in MPBCA, has taken the Distance (D), Mobility (M), Remaining Battery Power (R) and Transmission Range (T). By these parameters a Quality Factor (QF) is calculated. When a node broadcast the hello message it sends the QF of its own which is compared by the neighbor nodes and finally a node with smallest weight is elected as a CH.
DWCAIMP	1. Control messages overhead. 2. Reducing energy utilization.	In DWCAIMP algorithm combine weight W in calculate by calling Weight Calculation Algorithm for each node. Then in cluster selection phase all nodes broadcast there calculated weight W to all the neighbor and the node with the minimum W will be selected as a CH.
WCA	1. Algorithm is not periodic and therefore avoids communication overhead. 2. Considers many factors at once.	Minimum weight value among Neighbors Chosen as a CH

WCA with mobility prediction	1. Advantage is, it reduce the overhead in communication by predicting mobility of node using linear auto regression and cluster formation.	Election is based on the weight values of the nodes &the node havingthe lowest weight is chosen as CH.
iWCA	1. A node with weak battery power could not elected as a CH, it minimizing the number of clusters, which help in minimize overhead.	Minimum weight value among Neighbors Chosen as a CH

5. CONCLUSION

In this paper the review of several clustering schemes which help organize mobile ad hoc networks in a hierarchical manner to enable hybrid routing has been done. Clustering methods improve network scalability, routing and topology management of MANET. Even though there are advantages in cluster-based MANET, issues such as the cluster structure stability, the energy consumption of mobile nodes with different cluster related status, the control overhead of cluster construction and traffic load distribution in clusters have to be addressed.

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