Weighted Clustering Algorithms in MANET: A Survey

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Abstract- A mobile adhoc network (MANET) is a collection of independent mobile nodes that communicate over relative bandwidth and power constrained wireless links. The network topology may transform quickly and randomly due to mobility of nodes. Also, in MANET the decentralized network leads to perform the routing functionalities by nodes themselves such as route discovery, topology discovery and delivering messages from source to destination. Clustering provides the finest answer for huge and dense mobile adhoc networks with high mobility. It also lifts the capacity of network and diminishes the routing overhead in order to bring more efficient and effective routing in MANET. There are two mechanisms in every clustering algorithm, (i) cluster formation and (ii) cluster maintenance. In cluster formation, cluster heads are selected among the nodes to form the hierarchical network. Selecting appropriate cluster head is one of the main research issues. In cluster maintenance, a unique mechanism is needed so that the cluster head can maintain the topological information of the cluster in spite of the cluster structure changes every time due to mobility of nodes. This paper mainly focuses on the weight based clustering approaches in MANET.

Keywords – Clustering, Energy, Mobile adhoc network, Mobility.

I. INTRODUCTION

Many WLANs need an infrastructure network. In these infrastructure based wireless networks, communication usually takes place only between the wireless nodes and the access point. The high demand of the long run networks is the speedy deployment of independent mobile nodes that can communicate with each other without the need of a centralized and organized network infrastructure. This type of networks is categorized under the classification of Mobile Ad-hoc Networks (MANETs). A MANET is the collection of mobile devices that comes together to form a network as needed, not necessarily with any support from the existing Internet infrastructure or any other kind of fixed stations. This is in contrast to the well known single-hop cellular network model that supports the needs of wireless communications by installing BSs as access points. In these cellular networks, communication between two mobile nodes relies on the wired backbone and the mounted base stations.

Routing is the most important issue in MANETs. Routing is the process of selecting paths to forward the packets over the network. The primary goal of ad-hoc network routing protocols is to supply correct and economical route establishment between pair of nodes, so the messages are also delivered on time. Route construction should be done with a minimum of overhead and bandwidth consumption. Due to the constraints of power, transmission range and node mobility, path failures are very frequent in this type of networks. To accommodate frequent path failures, special routing protocols are necessary. Basically, routing protocols in MANET can be broadly classified as proactive, reactive, and hybrid routing. In proactive or table-driven protocols, each node maintains a routing table which contains routing information for every reaching node in the network. All the nodes update these tables so as to maintain a consistent and up-to- date view of the network. Some examples of proactive routing protocols are Dynamic Destination Sequenced Distance-Vector (DSDV), Cluster Head and Gateway Switching Routing (CGSR), Wireless Routing Protocol (WRP). These protocols differ in the number of routing related tables and how changes are broadcasted in the network structure. In reactive or on-demand routing, all updated routes are not kept at each node. Routes are generated when needed. When source wants to send data to destination, it invokes a route discovery mechanism to find the path to destination. Some examples of reactive routing protocols are Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector (AODV), Temporally-Ordered Routing Algorithm (TORA). Hybrid protocols combine the benefits of both proactive and reactive routing protocols and overcome their shortcomings. Here, the routing is initially established with some proactively explored routes and then serves the demand from additionally activated nodes through reactive flooding. Zone Routing Protocol (ZRP) is the popular example of hybrid routing protocol.

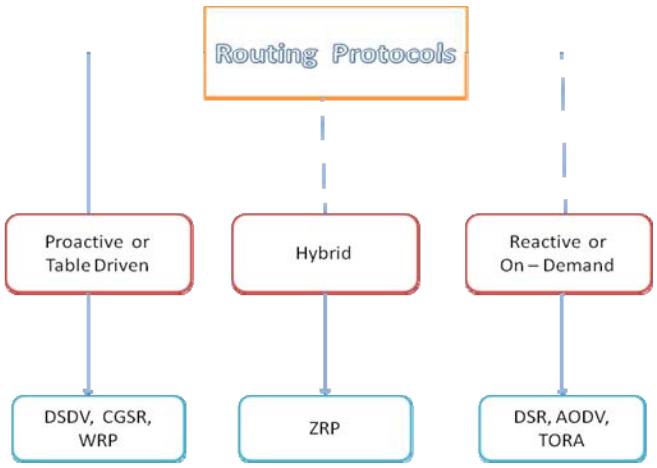

Figure 1. Routing Protocols in MANET

II. CLUSTERING: TYPES & ADVANTAGES

A. Clustering –

Clustering is the virtual partitioning of nodes into sub networks according to geographical area in MANET. A cluster structure makes ad-hoc networks seems to smaller and more stable. Each mobile node in the cluster broadcast the messages to establish connection. If a node changes its cluster then only the nodes which are residing in corresponding clusters are required to update the data, there is no need the changes to be done by the entire network.

The cluster head, cluster members and gateway plays important role in clustering where cluster head and gateway are the backbone nodes in hierarchical ad-hoc network. Cluster-Head (CH) is native organizer of a cluster and Cluster-Member is a standard node. It is a node that is neither a CH nor gateway. Cluster-Gateway is common node between two or more cluster which provides inter cluster links with node to forward information between clusters.

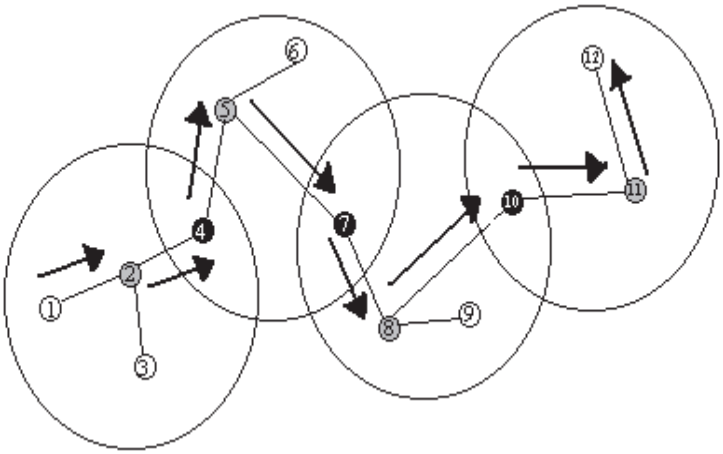

Figure 2. Cluster Structure in MANET

In a cluster, two varieties of communications take place:

Intra-cluster Communication: In this cluster, the cluster head has 1-hop connectivity with each cluster member. Therefore, cluster head will directly communicate with member nodes. However, member nodes cannot directly communicate with other members of cluster.

Inter-cluster Communication: In this cluster communication Multi point relay concept selects the cluster head through which the data packets would be forwarded. This mechanism, minimize the congestion by reducing the number of forwarding nodes and saves the battery power of cluster head.

B. Types of Clustering –

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.

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).

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).

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.

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).

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 (Weighted Clustering Algorithm),On-Demand WCA.

C. Advantages of Clustering –

Aggregation of Topology Information: Due to the fact that the number of nodes of a cluster is lower than the number of nodes in the whole network. The clustering process assists in aggregating topology information.

Efficiency and Stability: The significant feature of cluster structure is that it causes MANET to seem smaller and more stable. That is, once a mobile node changes its attaching cluster, then the nodes lying within the corresponding clusters unit area needed to alter their routing tables.

Bandwidth Efficiency: Only the cluster heads participates in routing process, and the cluster members deal only with its cluster heads, therefore avoids unneeded exchange of messages among the mobile nodes, thus the use of bandwidth is often improved.

Routing Efficiency: In flat topology, every node bears equal responsibility to act as router for routing the packets to every other node so a great amount of flooding messages takes place in order to obtain better routing efficiency. But, such control packets reduces MAC layer strength. Therefore, cluster structure is often the substitute to boost MAC layer strength and to make the routing process easier.

Spatial Reuse of Resources: In cluster structure, each node is assigned with different role and functionality. That is, each cluster is assigned a leader called cluster head and if a node comes within the transmission range of more than

one cluster will be acting as a gateway node. Hence, by this manner, the cluster topology facilitates resource management.

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III. WEIGHT BASED CLUSTERING ALGORITHMS

Weighted Clustering Algorithm (WCA) [1]:
This algorithm was originally proposed by M. Chatterjee et al. It considers four parameters for clusterhead selection. They are:

(1) Degree Difference (Δv): It is calculated as $|dv - \delta|$ for every node v. Here, dv denotes degree of a node and δ is a pre-defined threshold.
(2) Distance Summation (Dv): It is defined as the sum of distances from a given node to all its neighbors.
(3) Mobility (Mv): It is taken by computing the running average speed of every node during a specified time T.
(4) Remaining Battery Power (Pv): It is a measure of how much battery power has been consumed.

WCA selects the clusterheads according to the weight value of each node. The weight associated to a node v is defined as: $Wv = w1\ \Delta v + w2\ Dv + w3\ Mv + w4\ Pv$ ---------- (Eq. 1)
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.

Adaptive Weighted Cluster Based Routing Protocol (AWCBRP) [2]:
Due to the mobility of nodes Topology changes and breakage of exiting paths occurs repeatedly. A routing protocol should quickly adapt to the topology changes and efficiently search for new paths with minimal power consumption. An adaptive weighted cluster based routing protocol for mobile ad-hoc networks improves speedily to the topological changes and efficiently sets up the routing process.

In this approach, the cluster head selection is performed by assigning a weight value based on the factors Energy Level, Connectivity and Stability.
Cluster heads are selected based on the following weighted sum $W = w1\ D1 + w2\ D2 + w3\ D3$ ---------- (Eq. 2)
Where D1 is the power level of the node, D2 is the connectivity factor and D3 is the stability index and w1, w2 and w3 are the weighting factors. Cluster head has the least W value.

After the determination of cluster head and its cluster member, they will be recognized as “considered". Every unconsidered node goes through the election process. After the selection of “considered nodes” the election algorithm will be finished.

Flexible Weight Based Clustering Algorithm (FWCA) [3]:
FWCA is proposed by Zouhair El-Bazzal et al. It has the flexibility of assigning different weights to the nodes and takes into account a combined metrics to form clusters automatically. Limiting the number of nodes inside a cluster allows restricting the number of nodes provided by a clusterhead so that it does not degrade the MAC functioning.

In this algorithm, firstly the IDs of nodes (node ID) and clusterheads (CH ID) are allocated. These IDs are the MAC addresses. The CH ID appended with the node ID forms a unique identifier for every node. Also, a ‘Counter’ is maintained by each node in order to count the number of nodes inside a cluster and to guarantee that the cluster size does not exceed a predefined ‘N’ in terms of number of nodes by cluster.

Each node Ni (member or CH) is identified by a state such as:
Ni (idnode, idCH, Weight, Counter, N)

It also has to maintain a ‘node_table’ wherein the information of the local members is stored. The CHs maintain another clusterhead information table ‘CH_table’ wherein the information about the other CHs is stored.

Every cluster has a limited number of nodes which defines its size. It also has a CH for communication across the cluster. The nodes collaborate to select the best CH. A CH must be able to manage its members, to accept or to refuse the attachment of new arrivals based on its capacity without concerning the functionality of the other members.

Finally, the weight parameter is periodically calculated by each node in order to indicate the suitability of a node for playing clusterhead's role.

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.

Clusterhead (CH) Selection: Election is based on the weight values of the nodes & the node having the lowest weight is chosen as CH.

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.

Cluster Maintenance: In this phase, the two distinct types of operations are defined as: the battery power threshold property and the node movement to the outside of its cluster boundary.

Entropy-based Weighted clustering algorithm (EWCA) and its Optimization (EWCA-TS) [5]:
Entropy poses uncertainty and is a measure of the disorder in a system. So it is a better indicator of the stability and mobility of the ad hoc network. This algorithm uses an entropy- based model for evaluating the route stability in ad hoc networks and electing clusterhead, thus forming a more stable network than WCA.

The two improvements propose in the EWCA over WCA are:
(1) Replacing only the mobility parameter of equation (A) of WCA by the entropy of local networks in order to reduce the frequency of reaffiliation.

We replace one term of (Eq. 1), the average speed of nodes (Mv), by the entropy defined in (Eq. 3). Hence, the new formula to calculate Wv becomes: $Wv = c1\ \Delta v + c2\ Dv + c3\ (-Hv) + c4\ Pv$ …….. (Eq. 3)
where c1, c2, c3 and c4 are weighing factors.

(2) The Tabu Search Optimized EWCA (EWCA-TS)
Tabu Search is used to optimize the election routine which forms the near optimal dominant set. TS have achieved great success in solving complex combinatorial optimization problems.

Connectivity, Energy & Mobility driven Weighted Clustering Algorithm (CEMCA) [6]:
The idea of CEMCA is to find a number of cluster heads that ensures the stability of the network topology. The election of the cluster head is based on the combination of several significant metrics such as: the lowest node mobility, the highest node degree, the highest battery energy and the best transmission range. This algorithm is completely distributed and all nodes have the same chance to act as a cluster head.

CEMCA is composed of two main stages. The first stage consists in the election of the cluster head and the second stage consists in the grouping of members in a cluster. Normalized value of mobility, degree and energy level is calculated and is used to find the quality (normalized to 1) for each node. The quality of the node is a measure of its

suitability as a cluster head. The node broadcasts its quality to their neighbors in order to compare the better among them. After this, a node that has the best quality is chosen as a clusterhead.

In the second stage the construction of the cluster members set is done. Each clusterhead determines its neighbors at two hops maximum. These nodes form the members of the cluster. Next, each cluster head stores all information about its members and all nodes record the clusterhead identifier. This exchange of information allows the routing protocol to function in the cluster and between the clusters.

Improved Weight Clustering Algorithm (iWCA) [7]:
In this paper, the modification in the weighted clustering algorithm is done such that it can be used in sensor networks with the specific constraints in sensor networks being considered. The addition of one more factor about the characteristic of a sensor node into the evaluation formula is considered, such that the nodes chosen as cluster heads may have a better behavior in heterogeneous sensor networks than those without the additional factor.
Calculate the combined weight for every node v: $Wv = w1\Delta v + w2\,Dv + w3\,Mv + w4\,Tv + w5\,Cv$……(Eq. 4)
Choose the node with a minimum Wv as the cluster head

The cluster heads chosen will act as the application nodes in a two-tired wireless sensor network and may change in different time intervals. After a fixed interval of time, this algorithm is re-run again to add new applications nodes such that the system lifetime can be expected to last longer.

Distributed Weighted Clustering Algorithm (DWCA) [8]:
This approach is based on combined weight metric that takes into account several system parameters like the ideal node degree, transmission range, energy and mobility of the nodes. Depending on specific applications some of these parameters can be used in the metric to determine the clusterhead. However more clusterheads lead to extra number of hops for a packet when it is to be routed from source to destination.

The goals of the algorithm are maintaining stable clustering structure, minimizing the overhead for the clustering set up and maintenance, maximizing lifespan of mobile nodes in the system and achieving good end-to-end performance. DWCA chooses locally optimal clusterheads and incorporates power management at the clusterheads.

Distributed Score Based Clustering Algorithm (DSBCA) [9]:
This algorithm considers the Battery Remaining, Number of Neighbors, Number of Members, and Stability in order to calculate the node's score with a linear algorithm. After each node calculates its score independently, the neighbors of the node must be notified about it. Also each node selects one of its neighbors with the highest score to be its cluster head and, therefore the selection of cluster heads is performed in a distributed manner with most recent information about current status of neighbor nodes.

Each node calculates its score by using a formula that considers all the above parameters. The score of node N is defined as Eq. 5. Score= ((Br×C1) + (Nn×C2) +(S×C3) + (Nm×C4)) …….. (Eq. 5)
Where C1, C2, C3, C4 are the score factors for the corresponding system parameters listed below:

Battery Remaining (Br): The residual node's energy. The energy is consumed through transmitting / receiving data packets and messages.
Number of Neighbors (Nn): The number of existing nodes which are located in the transmission range.
Stability(S): The total time in which the neighbors of a specific node have spent their time beside the node. A Higher stability simply means that the neighbors of a certain node has spent a longer time in its transmission range.
Number of Members (Nm): Set of nodes that is handled by each cluster head.

DSBCA was compared through simulation with WCA and DWCA in terms of number of clusters, number of re-affiliations, lifespan of nodes in the system, end-to-end throughput, overhead and gives better results.

Improved Distributed Weighted Clustering Algorithm (DWCAIMP) [10]:
This approach is based on combined weight metric that takes into account several system parameters like the node degree, transmission range, energy and mobility of the nodes. This algorithm can be divided into three phases - Clusters Formation, Running Mobility and Cluster Maintenance.

Cluster Formation: Initially each node is assigned a random ID value. It broadcasts its ID value to its neighbours and builds its neighbourhood table. Each node calculates its own weight based on the following factors:

- *Node connectivity*: The number of nodes that can communicate directly with the given node i.e. that are in its transmission range.
- *Battery Power*: The power currently left in each node. The energy is consumed by sending and receiving of messages.
- *Mobility*: Running average of speed of each node. If mobility is less, the node is more suitable to become clusterhead.
- *Distance*: Sum of distance of the node from all its neighbours.

$$W = w_1 * c + w_2 * e + w_3 * M + w_4 * d \quad \text{..... (Eq. 6)}$$

Each node calculates its weight by (Eq. 6). Then each node broadcasts its weight to its neighbours. If it has maximum weight among its neighbours, it sets the clhead variable to 1, otherwise, the clhead variable is set to 0. Otherwise, the clhead variable is set to 0. The node with maximum weight broadcasts clhead message to other nodes.

Mobility: A random value is assigned between 0 and 1 to each node and a threshold value is taken. If this random value is greater than threshold value, the node becomes mobile and its *x* and *y* parameters changes, otherwise it remains stationary. A node on reaching new destination joins the nearest clusterhead.

Cluster Maintenance: Cluster maintenance is needed in two cases:

(1) When a node is added in the cluster, then even if the weight is more than the clusterhead it does not immediately become the clusterhead and thus reduces the unnecessary overhead in selection of the clusterhead each time a new node is added.
(2) When a clusterhead fails, then the nodes attached to that clusterhead recalculate their weights and select new clusterhead with the maximum weight.

IV.CONCLUSION

In this paper the survey of various weight based clustering schemes have been done. The methods adopted in finding the clusterhead are different in these algorithms. This paper presents a survey of clustering algorithms in which multiple metrics have been used to find clusterhead based on the weight values of the node with other important matrices or parameters are taken into consideration. I hope that the survey presented in this paper will be helpful and provide researchers a platform for choosing the right weight based clustering algorithm for their work in future.

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