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REVIEW OF WEIGHTED CLUSTERING ALGORITHMS FOR MOBILE AD HOC NETWORKS

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Abstract

A research issue in design of ad hoc networks is deployment of dynamic routing protocols that can find routes effectively between communicating nodes. Clustering is a solution to limit the amount of information that propagates inside the network. The idea behind clustering to group the network nodes in to number of overlapping clusters and routes are recorded between clusters instead of nodes. Several algorithms have been proposed by researchers for formation of cluster and election of clusterhead. Most of these algorithms consider a performance factor for election of clusterhead; these performance factors may be identification number, connectivity, mobility, battery power etc. But considering only one performance factor for calculating quality of nodes as a clusterhead may results in degradation of performance of the network. Some work has been done in the area where a number of performance factors are used to find qualification of nodes as clusterheads. This paper presents a review of the clustering algorithms, in which different weights are given to different performance factors and clustering decisions are taken after calculating the combined weights of nodes.

Keywords: *Mobile ad hoc network, clustering, clusterhead, gateway, mobility, connectivity.*

I. INTRODUCTION

Ad hoc networks are wireless, infrastructure less, multi-hop, dynamic networks established by a collection of mobile nodes. This type of network is highly demanding due to the lack of infrastructure, cost effectiveness and easiness in installation. Mobile ad hoc network (MANET) has many emerging applications, which include commercial and industrial, war front applications, search and rescue operations, sensor networks and vehicular communications. The major issues in cluster based MANETs are (i) mobility management (ii) topology assignment (iii) clustering overhead (iv) frequent leader reelection (v) overhead of clusterhead.

There is no stationary infrastructure; for instance, there are no base stations. Each node in the network also acts as a router, forwarding data packets for other nodes. A research issue in the design of ad hoc networks is the development of dynamic routing protocols that can efficiently find routes between two communicating nodes. The routing protocol must be able to keep up with the high degree of node mobility that often changes the network topology. In a large network, flat routing schemes produce an excessive amount of information that can saturate the network. In addition, given the nodes heterogeneity, nodes may have highly variable amount of resources, and this produces a hierarchy in their roles inside the network. Nodes with large computational and communication power, and powerful batteries are more suitable for supporting the ad hoc network functions (e.g., routing) than other nodes.

Cluster-based routing is a solution to address nodes heterogeneity, and to limit the amount of routing information that propagates inside the network. The idea behind clustering is to group the network nodes into a number of overlapping clusters. Clustering makes possible a hierarchical routing in which paths are recorded between clusters instead of between nodes. This increases the routes lifetime, thus decreasing the amount of routing control overhead. Inside the cluster one node that coordinates the cluster activities is clusterhead (CH). Inside the cluster, there are ordinary nodes also that have direct access only to this one clusterhead, and gateways.

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Gateways are nodes that can hear two or more clusterheads.

Ordinary nodes send the packets to their clusterhead that either distributes the packets inside the cluster, or (if the destination is outside the cluster) forwards them to a gateway node to be delivered to the other clusters. By replacing the nodes with clusters, existing routing protocols can be directly applied to the network. Only gateways and clusterheads participate in the propagation of routing control/update messages. In dense networks this significantly reduces the routing overhead, thus solving scalability problems for routing algorithms in large ad hoc networks.

II. CLASSIFYING CLUSTERING SCHEMES

Clustering schemes for MANET can be classify in two categories

1. Single metric based clustering
2. Multiple metrics based clustering

1.Single Metric Based Clustering

These schemes consider only one performance factor for clustering decisions. A number of clustering algorithms for this class have been proposed in the literature[1]. In Lowest ID cluster algorithm (LIC) [2] algorithm a node with the minimum id is chosen as a clusterhead. Thus, the ids of the neighbors of the clusterhead will be higher than that of the clusterhead. Each node is assigned a distinct id. Periodically, the node broadcasts the list of nodes that it can hear A node which only hears nodes with id higher than itself is a clusterhead. Otherwise, a node is an ordinary node. Drawback of lowest ID algorithm is that certain nodes are prone to power drainage [3] due to serving as clusterheads for longer periods of time.

In Highest connectivity clustering algorithm (HCC) [2] the degree of a node is computed based on its distance from others. Each node broadcasts its id to the nodes that are within its transmission range. The node with maximum number of neighbors (i.e., maximum degree) is chosen as a clusterhead. This system has a low rate of clusterhead change but the throughput is low. Typically, each cluster is assigned some resources which is shared among the members of that cluster. As the number of nodes in a cluster is increased, the throughput drops. The reaffiliation count of nodes is high due to node movements and as a result, the highest-degree node (the current clusterhead) may not be re-elected to be a clusterhead even if it looses one neighbor. All these drawbacks occur because this approach does not have any restriction on the upper bound on the number of nodes in a cluster.

K-CONID [4] combines two clustering algorithms: the Lowest-ID and the Highest-degree heuristics. In order to select clusterheads connectivity is considered as a first criterion and lower ID as a secondary criterion. In HCC clustering scheme, one cluster head can be exhausted when it serves too many mobile hosts. It is not desirable and the CH becomes a bottleneck. So a new approach [5] is given in which when a CH's Hello message shows its dominated nodes' number exceeds a threshold (the maximum number one CH can manage), no new node will participate in this cluster. Adaptive multihop clustering [6] sets upper and lower bounds (U and L) on the number of clustermembers within a cluster that a clusterhead can handle. When the number of clustermembers in a cluster is less than the lower bound, the cluster needs to merge with one of the neighboring clusters. On the contrary, if the number of clustermembers in a cluster is greater than the upper bound, the cluster is divided into two clusters.

Mobility-based d-hop clustering algorithm [7] partitions an ad hoc network into d-hop clusters based on mobility metric. The objective of forming d-hop clusters is to make the cluster diameter more flexible. Local stability is computed in order to select some nodes as clusterheads. A node may become a clusterhead if it is found to be the most stable node among its neighborhood. Thus, the clusterhead will be the node with the lowest value of local stability among its neighbors. In Mobility Based Metric for Clustering [8] a timer is used to reduce the clusterhead change rate by avoiding re-clustering for incidental contacts of two passing

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clusterheads. Mobility-based Frame Work for Adaptive Clustering [9] partition a number of mobile nodes into multi-hop clusters based on (a, t) criteria. The (a, t) criteria indicate that every mobile node in a cluster has a path to every other node that will be available over some time period ‘t’ with a probability ‘a’ regardless of the hop distance between them. This is achieved using prediction of the future state of the network links in order to provide a quantitative bound on the availability of paths to cluster destinations. A metric which captures the dynamics of node mobility, makes the scheme adaptive with respect to node mobility.

Most of protocols executes the clustering procedure periodically, and re-cluster the nodes from time to time in order to satisfy some specific characteristic of clusterheads. In HCC, the clustering scheme is performed periodically to check the “local highest node degree” aspect of a clusterhead. When a clusterhead finds a member node with a higher degree, it is forced to hand over its clusterhead role. This mechanism, involves frequent re-clustering. In LCC [10] the clustering algorithm is divided into two steps: cluster formation and cluster maintenance. The cluster formation simply follows LIC, i.e. initially mobile nodes with the lowest ID in their neighborhoods are chosen as clusterheads. Re-clustering is event-driven and invoked if two clusterheads move into the reach range of each other and When a mobile node cannot access any clusterhead. Adaptive clustering for mobile wireless network [11] ensures small communication overhead for building clusters because each mobile node broadcasts only one message for the cluster construction.

3-hop between adjacent clusterheads (3-hBAC) [12] algorithm introduce a new node status, “clusterguest”, which means this node is not within the transmission range of any clusterheads, but within the transmission range of some clustermembers. When a mobile node finds out that it cannot serve as a clusterhead or join a cluster as a clustermember, but some neighbor is a clustermember of some cluster, it joins the corresponding cluster as a clusterguest.

Most of the clustering algorithms require all the mobile nodes to announce cluster-dependent information repeatedly to build and maintain the cluster structure, and thus clustering is one of the main sources of control overhead. A clustering protocol that does not use dedicated control packets or signals for clustering specific decision is called Passive Clustering [13]. In this scheme, when a potential clusterhead with “initial” state has something to send, such as a flood search, it declares itself as a clusterhead by piggybacking its state in the packet. Neighbors can gain knowledge of the clusterhead claim by monitoring the “cluster state” in the packet, and then record the Cluster head ID and the packet receiving time. A mobile node that receives a claim from just one clusterhead becomes an ordinary node, and a mobile node that hears more claims becomes a gateway. Since passive clustering does not send any explicit clustering-related message to maintain the cluster structure, each node is responsible for updating its own cluster status by keeping a timer. When an ordinary node does not receive any packet from its clusterhead for a given period, its status reverts to “initial”.

Load balancing clustering (LBC) [14] provide a nearby balance of load on the elected clusterheads. Once a node is elected a clusterhead it is desirable for it to stay as a clusterhead up to some maximum specified amount of time, or budget. Initially, mobile nodes with the highest IDs in their local area win the clusterhead role. LBC limits the maximum time units that a node can serve as a clusterhead continuously, so when a clusterhead exhausts its duration budget, it resets its VID to 0 and becomes a non-clusterhead node. However, the drawback is that the clusterhead serving time alone may not be a good indicator of energy consumption of a mobile node. Power-aware connected dominant set [15] is an energy-efficient clustering scheme which decreases the size of a dominating set (DS) without impairing its function. The unnecessary mobile nodes are excluded from the dominating set saving their energy consumed for serving as clusterheads. Mobile nodes inside a DS consume more battery energy than those outside a DS because mobile nodes inside the DS bear extra tasks, including routing information update and data packet relay. Hence, it is necessary to minimize the energy consumption of a DS. Clustering for energy conservation [16] assumes two node types: master and slave. The purpose of of this

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scheme is to minimize the transmission energy consumption summed by all master-slave pairs and to serve as many slaves as possible in order to operate the network with longer lifetime and better performance.

2. Multiple metrics based clustering

Combined metrics based clustering or weight based clustering takes a number of metrics into account for cluster configuration, including node degree, residual energy capacity, moving speed, and so on. This category aims at electing the most suitable clusterhead in a local area, and does not give preference to mobile nodes with certain attributes, such as lowest ID or highest node degree. One advantage of this clustering scheme is that it can flexibly adjust the weighting factors for each metric to adjust to different scenarios. For example, in a system where battery energy is more important, the weighting factor associated with energy capacity can be set higher.

2.1 Distributed Clustering for Mobile Ad Hoc Networks

Two algorithms are proposed in this paper DCA and DMAC that partition the nodes of a fully mobile network in to clusters. And the choice of the clusterhead is based on a generic weight (a real number ≥ 0) associated with each node [17]. The bigger the weight of a node, better that node for the role of clusterhead. The main advantage of this approach is that, by representing with the weights mobility related parameters of the nodes, we can choose foe the role of clusterhead those nodes that are better suited for that role. For instance, when the weight of a node is inversely proportional to its speed, the less mobile nodes are selected to be clusterheads. Since these nodes either do not move or move slower than the other nodes, their cluster is guaranteed to have a longer life, and consequently the overhead associated with the cluster maintenance in the mobile environment is minimized.

Although these algorithms can be used in the presence of nodes' mobility, distributed clustering algorithm (DCA) is mainly suitable for ad hoc networks whose nodes do not move or move slowly ("quasi-static" networks). But distributed and mobility adaptive clustering (DMAC) adapts to the changes in the network topology due to mobility of nodes, and it is thus suitable for any mobile environment.

These algorithms do not specify how to find mobility of nodes to assign weights. The algorithms are weight based and weights are depending up on the mobility related parameters. This use only single performance (mobility) for clustering decisions and is not a multiple metrics based algorithm

2.2 WCA: A Weighted Clustering Algorithm for Mobile Ad Hoc Networks

In a mobile ad hoc network the association and dissociation of nodes to and from clusters perturb the stability of the network topology, and hence a reconfiguration of the system is often unavoidable. However, it is vital to keep the topology stable as long as possible. The clusterheads, form a dominant set in the network, determine the topology and its stability. The weight-based distributed clustering algorithm [18] takes into consideration the ideal degree, transmission power, mobility, and battery power of mobile nodes. Depending on specific applications, any or all of these parameters can be used in the metric to elect the clusterheads. This method could have a fully distributed system where all the nodes in the mobile network share the same responsibility and act as clusterheads. The time required to identify the clusterheads depends on the diameter of the underlying graph. This method try to keep the number of nodes in a cluster around a predefined threshold to facilitate the optimal operation of the medium access control (MAC) protocol. The non-periodic procedure for clusterhead election is invoked on-demand, and is aimed to reduce the computation and communication costs.

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2.3 Advanced Efficiency and Stability Combined Weight based Distributed Clustering Algorithm in MANET

This paper proposes a combined weight-based distributed clustering algorithm with hierarchical structure [19] that can maintain topology of MANET as stable as possible, thereby optimizing network performance and making efficient resource allocation for mobile nodes. This algorithm can optimize network performances in dynamic MANET environment and minimize energy consumption by improving the problems of efficiency and stability the existing clustering algorithms are facing with.

In order to decrease initially set overhead generated during clustering setup phase, this algorithm uses "local minima," instead of "global minima" in which the minimum weight is calculated for all nodes in network, to select and manage the cluster head.

When a cluster is setup for all nodes, the cluster head in each cluster selects as pre-cluster head the node with the smallest weight among its neighbor nodes within its single hop. The cluster head, selected after comparison of weight with its neighbors in initial topology configuration, plays a role of cluster head within the range of predefined threshold.

In the algorithm, if there is a node disconnected directly from the cluster head due to move of nodes composing a cluster, if it is connected with the distribute gateway affiliated to the same cluster, it can continue to connect with its cluster head through the distribute gateway. When a distribute gateway is not used in clustering management, a cluster member, moves to perform re-clustering process. Therefore, move of a node can give an influence on other cluster configuration as well as on its own cluster configuration, lowering overall stability of cluster. Therefore, move of node only causes role sharing in its own cluster, not giving an influence on other cluster, thereby heightening stability of the entire network.

2.4 An Adaptive Weighted Cluster Based Routing (AWCBRP) Protocol for Mobile Ad-hoc Networks

In this approach, the cluster head selection is performed by assigning a weight value [20] based on the factors Energy Level, Connectivity and Stability.

Cluster heads are selected based on the following weighted sum

$W = w1D1 + w2D2 + w3D3$

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 node is formed as a cluster head, the node or the members of the node will be discerned as “considered". Every unconsidered” node undergoes the election process. After the selection of “considered nodes” the election algorithm will be terminated.

2.5 Weight Based Adaptive Clustering in Wireless Ad Hoc Networks

One of the drawbacks of WCA algorithm is that it uses the concept of global minima. All the nodes in the network have to know the weights of all the other nodes before starting the clustering process. This process can take a lot of time. Also, two clusterheads can be one-hop neighbors, which results in the clusters not necessarily being spread out in the network. WBACA [21] finds the local minima of weights for the clustering process.

The clustering approach presented in this paper is based on the availability of position information via a reliable position locating system, that is, the Global Positioning System (GPS).

The WBACA considers various important parameters of a node for clusterhead selection. These parameters include: transmission power, transmission rate, mobility, battery power and degree. Each node is assigned a weight that indicates its suitability for the clusterhead role. This weight is decided by a generalized formula that will take into account all the above parameters. The node with the smallest weight is chosen as the clusterhead.

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2.6 An Entropy-based Weighted Clustering Algorithm and Its Optimization for Ad Hoc Networks

WCA has improved performance compared with other previous clustering algorithms. But the high mobility of nodes will lead to high frequency of reaffiliation which will increase the network overhead. To solve this problem, an entropy based WCA(EWCA) was proposed [22] which can prompt the stability of the network.

This paper propose two improvements of the WCA. First is to replace one indices, the average moving speed of nodes, by the entropy of local networks. This approach can reduce the frequency of reaffiliation. Secondly, Tabu Search is used to optimize the election routine which forms the near optimal dominant set. Entropy presents uncertainty and a measure of the disorder in a system. So we consider it a better methodology to measure the stability and mobility of the Ad Hoc network.

2.7 Vote-based clustering algorithm

It is based on two factors, neighbors' number and remaining battery time of every mobile host (MH) Each MH has a unique identifier (ID) number, which is a positive integer. The basic information inside the network is Hello message, which is transmitted in the common channel. Making use of node location information and power information, this algorithm [23] introduce the concept of "vote". The Hello message format is given below. MH_ID item is MH's own ID and CH_ID item is MH's clusterhead ID, Vote item means MH's vote value, i.e. weighted sum of number of valid neighbors and remaining battery time. Option item is used to realize cluster load balance.

MH_ID	CH_ID	Vote	Option

Hello message format

Vote = w1 x (n/N) + w2 x (m/M)

w1; w2: Weighted coefficient of location factors and battery time, respectively,
n: Number of neighbors,
N: Network size or the Maximum of members in a cluster,
m: Remaining battery time,
M: The maximum of battery time remaining battery time.

Each MH sends a Hello message randomly during a Hello cycle. If a MH is a new user to the network, it reset "CH_ID" item. That means the MH does not belong to any cluster and does not know whether it has neighbor hosts. Each MH counts how many Hello messages it can receive during a Hello period, and considers the number of received Hello messages as its own n. Each MH sends another Hello message, in which "vote" item is set to its own vote value and got from Equation. Recording Hello message during second Hello cycles, each MH knows the sender with highest vote and not belongs to any existing cluster is its cluster head. It set its next sending Hello message item "CH_ID" to the cluster head's ID value. When two or more mobile nodes receive the same number of hello packets, the one who owns the lower ID will get priority. Following this approach, every MH knows its cluster head ID after two Hello message periods.

2.8 Connectivity, energy & mobility driven Weighted clustering algorithm (CEMCA)

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 [24]. 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 node broadcasts its quality to their neighbors in order to compare

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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 defines 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.

III. Conclusions

Clustering is the best solution for mobile ad hoc network to adapt itself for its dynamic nature. Selecting Coordinators for clusters is a research issue in the area of wireless ad hoc networks. Clusterhead can be selected by computing quality of nodes, which may depend on connectivity, mobility, battery power etc. Significant performance improvement can be achieved by combining the effect of several performance factors. This paper presents a review of clustering algorithms in which multiple metrics have been taken to find the quality of nodes for selecting them as clusterheads.

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