Comparative Study of Weighted Clustering Algorithms for Mobile Ad Hoc Networks

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Abstract – Routing in MANET is different from routing in wired network. One way to reduce routing overhead is to divide the network into clusters. Clustering of nodes into groups efficiently minimizes routing traffic overhead. Several algorithms have been proposed by researchers for formation of clusters and election of cluster heads. Most of the algorithms consider only one performance factor such as node-id, or mobility or node degree, or energy etc., for the election of cluster head. But considering only one performance factor for electing cluster head may result in performance degradation of the network. But, recently, some works has been done by considering number of performance factors for finding the quality of nodes as cluster heads. This paper presents a review on the comparison of single metric and multiple metric based clustering algorithms.

Keywords – MANET, cluster, cluster head.

I. INTRODUCTION

Mobile wireless networks are gaining its popularity in recent years. It has two variations. They are infra structured mobile network and infrastructure less mobile network, commonly known as ad-hoc network. The types of ad hoc networks are as follows: Mobile ad hoc networks (MANETs), vehicular ad hoc networks (VANETs), Internet based mobile ad hoc networks (iMANETs), Intelligent vehicular ad hoc networks (InVANETs) etc.,

A. MANET

Mobile ad hoc network has no fixed routers; all nodes are capable of movement and can be connected dynamically in an arbitrary manner. Nodes of these networks function not only as an end system but also as a router to discover and maintain routes to other nodes in the network. Example applications of mobile ad-hoc networks are: emergency search-and-rescue operations, Conventional meetings in which persons wish to share information, and data acquisition operations in inhospitable environment. Research issues in MANETs are generally categorized into several topics such as routing, energy management, fault tolerance, security etc.,

B. Routing in MANET

The primary goal of ad hoc network routing protocols is to provide correct and efficient route establishment between pair of nodes, so that the messages may be delivered on time [3]. Route construction should be done with a minimum of overhead and bandwidth consumption [4]. Because of the limitations 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, containing routing information on reaching every other node in the network. All the nodes update these tables so as to maintain a consistent and up-to-date view of the network. DSDV (Destination-Sequenced Distance Vector), is one of the popular proactive routing protocol.

In reactive or on-demand routing, all up-to-date routes are not maintained at every node. Instead, the routes are created as and when needed. When source wants to send data to destination, it invokes a route discovery mechanism to find the path to destination. DSR (Dynamic Source Routing), AODV (Ad hoc On-Demand Distance Vector Routing), are some of the popular reactive routing protocols.

Hybrid protocols combine the benefits of both proactive and reactive routing and overcome their shortcomings. Normally, hybrid routing protocols for MANETs exploit hierarchical network architecture. That is, proactive and reactive routing approaches are exploited in different hierarchical levels, respectively. That is, if the mobile nodes in MANET are assigned different roles and functionalities, the network topology is said to be hierarchical.

C. Structuring and Allocating the Routing Task

Another classification method is based on the roles which nodes may have in a routing scheme.
Therefore, if all mobile nodes in MANET have the same role, functionality and importance, the network topology is said to be flat topology. The routing protocols that fall under flat topology are otherwise called as uniform routing protocols. Examples: DSDV, DSR, AODV.

If the mobile nodes in MANET are assigned different roles and functionalities, the network topology is said to be hierarchical. The routing protocols that uses hierarchical topology is said to be non-uniform routing protocols. Non-uniform protocols further can be categorized according to the organization of mobile nodes and how management and routing functions are performed. Following these criteria, non-uniform routing protocols for MANET are divided into zone-based hierarchical routing, cluster-based hierarchical routing, and core-node based hierarchical routing.

In zone-based hierarchical routing, the network is divided into sub-networks called zones. Within the zone, routes are immediately available. For destinations outside the zone, it employs a route discovery procedure. Example: ZRP (Zone Routing Protocol)

In cluster-based hierarchical routing, nodes are hierarchically organized into clusters based on their relative proximity to one another. It greatly increases the scalability of routing in ad hoc networks by increasing robustness of routes. Example: CGSR (Cluster Gateway Switch Routing)

In core-node based routing, critical nodes are dynamically selected to compose a backbone for the network. The backbone nodes carry out special functions such as constructing routes and broadcasting data and control packets etc., Example: CEDAR (Core-Extraction Distributed Ad hoc Routing).

The rest of the paper is organized as follows: Section –II discusses about clustering and its issues, Section- III presents a detailed review of various weight based clustering algorithm for MANETs, Section-IV concludes the paper, gives the merits and demerits of existing works, and provides directions for future scope.

II. CLUSTERING IN MANET

Clustering technique is one of the most important techniques that help to provide resource management in MANET. [1]. In this technique, the nodes in the network can be either grouped into a number of overlapping or disjoint clusters. The cluster-based MANET defines three types of nodes as shown below:

1. Cluster head (CH): It acts as a coordinator with in its group or cluster.
2. Cluster member: It is ordinary nodes that communicate only with its CH.
3. Gateway node: it is a node that is within the transmission range of more than one cluster.

A. Advantages of MANET Clustering

The cluster architecture ensures efficient performance with respect to very large dense ad hoc networks. The benefit of cluster structure is as follows:

i. 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.

ii. Efficiency and Stability

The significant feature of cluster structure is that it causes MANET to seem smaller and more stable. That is, when a mobile node switches its attaching cluster, only nodes residing in the corresponding clusters are required to modify their routing tables.

iii. Bandwidth Efficiency

Only the cluster heads participates in routing process, and the cluster members interact only with its cluster heads, thus avoids unnecessary exchange of messages among the mobile nodes, thus the utilization of bandwidth can be improved.

iv. 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 efficiency.
Therefore, cluster structure can be the alternative solution to improve MAC layer efficiency and to make the routing process easier.

v. 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. Therefore, by this way, the cluster topology facilitates resource management.

III. LITERATURE SURVEY

According to the way of grouping nodes within clusters, several techniques have been proposed [1]. Most of the techniques consider a single performance factor for election of CH. These performance factors may be, node ID, connectivity, mobility, battery power etc., But, considering only one performance factor for calculating quality of nodes as a CH may results in degradation of performance of the network. Some research works has been done in the area where a no. of performance factors is combined to find the quality of nodes as CHs. This section gives a review of clustering algorithms.

A. Single metric based clustering

These schemes consider only one performance factor for clustering decisions. A no. of clustering algorithms has been proposed under this scheme. Some of them are listed below:

In lowest-ID cluster algorithm (LIC) [3], a node with the minimum-ID is chosen as a CH. That is, each node is assigned a unique-ID. Periodically, the node broadcasts the list of nodes that it can hear. A node with lowest ID will act as a CH. Drawback of LIC algorithm is that certain nodes are prone to power drainage due to serving as CHs for longer period of time.

In highest connectivity clustering algorithm (HCC) [3], 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 (ie., maximum degree) is chosen as a CH. The drawback of this algorithm is that it does not have any restriction on the upper-bound on the number of nodes in a cluster. And, when no. of nodes in a cluster is increased, the throughput gets decreased. The re-affiliation count of nodes is high due to node movement and the CH may not be re-elected even if it loses one neighbor.

K-CONID [3], combines two clustering algorithms such as LID and HCC. In order to select CHs, connectivity is considered as a first criterion, and lowest ID is considered as a second criterion.

Adaptive multihop clustering algorithm [3] sets upper bound and lower bound on the no. of cluster members with in a cluster that a CH can handle. When the no. of cluster members in a cluster is less than the lower bound, the cluster needs to merge with one of the neighboring clusters. And, if the no. of cluster members in a cluster is greater than the upper bound, the cluster is divided into two clusters.

Mobility-based d-hop clustering [4] 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 CHs. A node may become a CH if it is found to be the most stable node among its neighbors. Thus, the CH will be the node with lowest value of local stability among its neighbors.

3-hop between adjacent cluster heads (3-hBAC) algorithm [3] introduces a new node status, called "cluster guest", which means this node is not within the transmission range of any CHs, but within the transmission range of some cluster members. When a mobile node finds out that it cannot serve as a CH or join a cluster as a cluster member, but some neighbor is a cluster member of some cluster, it joins the corresponding cluster as a cluster guest.

Load balancing clustering (LBC) [3] provide a nearby balance of load on the elected cluster heads. Once a node is elected as a CH, it is desirable for it to stay as a CH up to some maximum specified amount of time, or budget. Initially, mobile nodes with the highest ID in thier local area will win the cluster head role. LBC limits the maximum time units that a node can serve as a CH continuously, so, when a CH exhausts its duration budget, it resets its VID to 0 and becomes a normal member node. But, the drawback is that, the cluster head serving time alone may not be a good indicator of energy consumption of mobile nodes.

B. Multiple metrics based clustering

Combined metrics based clustering or weight based clustering takes a no. of metrics into account for cluster configuration. Main advantage of this 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 power is more important, the weight factor associated with energy capacity can be set higher.
The choice of the CH is based on a generic weight (i.e., a real number \(w\geq0\)), associated with each node. The node with the highest weight in its area will act as a CH. And, when the weight of a node is inversely proportional to its speed, the mobile nodes with lowest weight will be selected as cluster heads. Since, these nodes either do not move or move slower than other nodes, their cluster is guaranteed to have a longer life.

The weight-based distributed clustering algorithm (WCA) [4] 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 CHs. This is based on fully distributed approach, where all the nodes in the mobile network share the same responsibility and act as CHs. The time required to identify the CHs depends on the diameter of the underlying network graph. This method keeps a predefined threshold value for no. of mobile nodes in a cluster. The CH election procedure is invoked only on-demand thus reduces routing control overhead.

Advanced Efficiency & Stability Combined weight based Distributed clustering algorithm [9], proposes combined weight-based distributed clustering approach with hierarchical structure, that can able to maintain MANET topology as stable as possible.

In order to decrease the initial overhead that is generated during clustering setup phase, this algorithm uses "local minima" instead of using "global minima". That is, minimum weight is calculated for all nodes in the network to select and manage CH.

The cluster head in each cluster group is selected with a smallest weight among its one-hop neighbors, and plays the role of CH within the range of predefined threshold. In this algorithm, if a node disconnected directly from the CH due to mobility, & if distribute gateway affiliated to the same cluster, it can continue to connect with its cluster-head through the distributed gateway. Therefore, the cluster member does not needs to perform re-clustering process even though it moves, thus improves stability of the entire network.

Weight Based Adaptive Clustering in Wireless Ad Hoc Networks (WBACA) [1] overcomes the drawback of WCA algorithm. That is, it uses the concept of "local minima". That is, all the nodes in the network must calculate its weight before starting the clustering process. This process may take lot of time. Also, two cluster heads can be one-hop neighbors, which unnecessarily results in forming two different clusters instead of one.

Therefore, WBACA uses the concept of “local minima”. That is, the node with the smallest weight is chosen as the cluster head.

Entropy-based Weighted Clustering Algorithm (EWCA) [3] reduces the frequency of re-affiliation in the network. Because, frequent re-affiliation may degrade the performance of the network.

Connectivity, Energy & Mobility driven Weighted Clustering Algorithm (CEMCA) [4] is based on normalization. The normalized value of mobility, degree and energy level is calculated and is used to find the quality for each node (normalized to 1). The node broadcasts its quality to its neighbors in order to obtain the better node among them. And, the node with the best quality is chosen as cluster head.

IV. CONCLUSION

Clustering is the best solution for large and dense mobile ad hoc networks with high mobility. Selecting appropriate cluster head is one of the main research issues. Therefore, in this paper, we compared the single metric and multiple metric based clustering algorithms and observed that the multiple based algorithms (i.e., weighted clustering algorithms) sounds beneficial than single metric based clustering algorithms.

REFERENCES


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