A Review on Mobility Based Clustering Algorithms in Mobile Ad Hoc Networks

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Abstract
In the last few years, various efforts have been devoted to design efficient clustering algorithms for the wireless mobile ad-hoc networks (MANET) considering the network characteristics and mobility of the node. Clustering allows fast connection and better routing and topology management of MANET. In MANET each node is free to move randomly. There are numerous algorithms to construct clusters in MANET on the basis of different parameters. Because of the nodes mobility, the network topology will change over time. A node may join or leave an existing cluster at a time. Many methods have been developed to form stable clusters. In this paper, some of such methods are studied that have been developed for clustering and helpful for forming stable clusters. This paper could be helpful in relative analysis of different approaches clustering. The objective to this paper is to present the main concepts concerning clustering approaches in mobile ad hoc networks.

Keywords
Mobile Ad hoc Networks, Clustering, Node Mobility.

I. Introduction

A mobile ad hoc network [8] is a collection of mobile nodes that dynamically form a network without any infrastructure or pre-defined topology. Mobile nodes in the network are continuously moving in different direction with different speed. In this network environment, each node acts as an information source as well as a router to widen packets to its neighbors. The network is fully autonomous and can be formed at any time and also can be changed. It is characterized by limited battery power, limited bandwidth, frequent network topology changes, and rapid mobility. MANETs are proposed to function independent of the fixed infrastructure with the exception of a few stub gateways to provide access to the larger network. A MANET node is actually mobile and is itself a router with multiple wireless or wired connections. MANET is a wireless network in which all nodes can freely and arbitrary move in any direction with any velocity. They can be formed and deformed spontaneously at anytime and anywhere. Routing is challenging in Mobile Ad hoc Network due to the dynamic nature of the network topology because of mobility characteristics of nodes. There is a well-known method to reduce the amount of routing data exchanges and accordingly, to save the communication bandwidth and energy that method is clustering. Clustering is the process of dividing the nodes of a network into a few organized partitions called clusters [8]. Clustering creates a backbone network of nodes, providing scalability for large networks, and stability for dynamic networks. In Mobile Ad Hoc Networks (MANETs) clustering 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. Clustering algorithm in MANETs should be able to maintain its cluster structure as stable as possible while the topology changes. Most clustering approaches for mobile ad hoc networks select a subset of nodes in order to form a network backbone that supports control functions. A set of the selected nodes are called cluster heads and each node in the network is associated with one. Cluster heads are connected with one another directly or through gateway nodes. The union of gateway nodes and cluster heads form a connected backbone. This connected backbone helps simplify functions such as channel access, bandwidth allocation, routing power control and virtual-circuit support. The objectives of clustering are to minimize the total transmission power aggregated over the nodes in the selected path, and to balance the load among the nodes for prolonging the network lifetime. Clustering is a sample of layered protocols in which a network is composed of several clusters of mobile nodes. In a cluster-based environment, there are some nodes in the network called cluster heads which have high processing speed and battery power than the other nodes. These cluster heads are responsible for cluster management and maintenance of the network. A cluster head allocates the resources to all the nodes that belong to its cluster. In addition to controlling and managing its own cluster, it also communicates with other clusters. It maintains the information about every node within its cluster. Therefore, choosing the appropriate number of cluster heads that can use the network resources efficiently and adapt to the changing network conditions in MANETs is a challenging task. Due to mobility of the network, the nodes can go outside the transmission range of their cluster head and move into another cluster thus changing their neighborhood. This can change the number of clusters and number of nodes in a cluster but this does not result in a change of the dominant set at all. Clustering of nodes in MANETs is one of the biggest challenges. Finding the optimal number of clusters that cover the entire network becomes essential and an active area of research. Although, several authors have proposed different techniques to find the optimal number of clusters, none of them addresses all the parameters of a mobile ad hoc network. Clustering has several advantages in MANETs. The system performance can be improved by allowing the reuse of resources due to clustering because each group of nodes can communicate with each other without affecting the other groups. Secondly, it optimally manages the network topology by dividing the task among specified nodes called cluster heads, which is very useful for network management and routing. There are some requirements of clustering in MANETs. The clustering algorithm must be distributed, since every node in the network has only local knowledge and communicates outside its group only through its cluster head as in case of cluster-based routing. The algorithm should be robust as the network size increases or decreases; it should be able to adapt to all the changes. The clusters should be

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reasonably efficient i.e. the selected cluster heads should cover a large number of nodes as much as possible. Nodes in a cluster must be one of the following types [8]:

A. Cluster head (CH)

An elected node that acts as the local controller for the cluster. The cluster head's responsibilities may include: routing, relaying of inter cluster traffic from cluster members, scheduling of intra-cluster traffic, and channel assignment for cluster members.

B. Cluster Member

A normal node belonging to a cluster. Cluster members usually do not participate in routing, and they are not involved in inter-cluster communication.

C. Gateway Node (CG)

Cluster Gateway is a boundary node which is used to convey the routing information from one cluster to another. The cluster heads and a cluster head allocates the resources to all the nodes that belong to its cluster. In addition to controlling and managing its own cluster, it also communicates with other clusters. It maintains the information about every node and the gateway nodes form the backbone network. Gateway nodes selected among the border nodes. A border node is a mobile node which has at least one neighbor belonging to a different cluster. Border nodes are at the perimeter of the clusters. Gateway nodes are those nodes in a non-cluster head state located at the periphery of a cluster. These types of nodes are called gateways because they are able to listen to transmissions from another node which belongs to a different cluster. In a dynamic network the mobility of nodes cannot be ignored. It has a vital role in maintaining the stable cluster structure. Thus we choose mobility of a node to be the deciding factor for initial cluster setup so that a better cluster stability can be achieved. A node with lower mobility has a higher chance of being a cluster head. The weights assigned to the nodes are reciprocal to their respective mobility. i.e. a node with lower mobility is assigned a higher weight and the node with higher mobility is assigned a lower weight. In these paper different types of mobility of nodes in mobile ad hoc network is studied. This paper presents different algorithm to make the cluster more stable.

II. Various Clustering Algorithms Based On Mobility

A. Distributed Group Mobility Adaptive Clustering Algorithm (DGMA)

Distributed group mobility adaptive clustering algorithm (DMGA) clustering algorithm [1] is used for group mobility in MANETs. In DGMA the revised SD is used as the mobility metric to avoid capturing the instantaneous changes of direction and speed. This makes DGMA algorithm more adaptive to the highly mobile environment. In DGMA coloring method is introduced in this variety of colors represent nodes with different roles in the network. White color indicates the initial color of each node or implies the node has not belongs to any cluster. Cluster heads are represented by node in red color and cluster members are node in yellow color.

We first introduce the terminology used in DGMA:

1. T: the time duration that two red nodes are directly connected with each other.
2. n1 : It represents the ratio of the number of one-hop white neighbors to the number of all one hop neighbors used by red node. n1_Input is the input threshold value of n1
3. n2 : It represents the ratio of the number of one-hop white neighbors to the number of all one hop neighbors used by white node. n2_Input is the input threshold value of n2.

DGMA clustering algorithm has two main phases: First is the nomination phase and the second is cluster maintenance phase. Each node maintains its own status and no centralized entity is responsible for the maintenance of a whole cluster.

DGMA begins with the nomination process that has five steps:

Step 1: Each node initially in white.

Step 2: If a white node is not connected with any red node, it broadcasts a request message to its directly connected neighbor nodes to nominate a red node.

Step 3: After reciving the feedback of individual's TSD from its neighbor nodes, the applicant (node A) compares its TSD with the received TSD values from each of its white neighbor nodes (node B)

a. If TSD(A, t)< TSD(B, t), nomination process is terminated and it remains as a white node;

b. If TSD(A, t)> TSD(B, t), continue until node A has compares with all its neighbors.

Step 4: If the white node has the largest TSD among all of its white neighbor nodes, it turns to red.

Step 5: It broadcasts an invitation to its neighbor nodes and the receiver nodes in white change their color to yellow.

For the maintenance process at a node, it is triggered upon detecting the updates of mobility information. Different maintenance steps will be executed according to a node's color.

For red nodes (i.e. CHs):

1. If two red nodes are connected over a time T, the one with smaller TSD turns into yellow color;
2. If more than n1-Input of neighbors are white, i.e. n1 ≥ n1- Input, it turns into white color.

For yellow nodes (i.e. member nodes):

1. If a yellow node has a bigger TSD than any of connected red nodes, it turns itself into white; or
2. If it fails to find any neighboring red node, it turns into white.

For white nodes (i.e. free nodes):

1. If there is a red neighbor that has a larger TSD value than this white node's, it turns to yellow;
2. Else, if the component of white nodes in the neighbor set is greater than n2-Input, i.e. n2 ≥ n2-Input, it triggers the cluster.

B. Distributed Mobility–Adaptive Clustering (DMAC)

The Distributed Mobility–Adaptive Clustering (DMAC) algorithm [2] is based on the concept of a clusterhead. This exposed node acts as a local controller or coordinator within the cluster and can perform aggregation of topology information and exchange information to neighboring clusters. When a node is added to the network, to determine its role in the cluster it executes an initialization process, i.e., whether it should become a cluster member or cluster head. This decision is based on weight of the node and the weight of its neighbor nodes. The node which is having larger weight, the better it is suited as a cluster head. It is assumed that each node has a different weight. A node decides to join a cluster if there is already a neighboring cluster head with a higher weight; otherwise it decides to become a cluster head itself. After making this decision, it immediately informs all its neighbor nodes about its role. The algorithm is executed at each node and is message driven. The stable condition is defined by the following three properties; first, every ordinary node has at least one cluster head as neighbor. Second, every ordinary node affiliates with the neighboring cluster head with the largest weight. And, third, cluster heads cannot be neighbors. This clustering algorithm is a continuously running online process. As the mobile stations move around, they must decide to which cluster they currently belong and which role they have. In order to be adaptive to mobility, each node reacts to changes in the surrounding topology and it changes its status and cluster membership accordingly. This decision is based only on the local view of their neighborhood. Whenever a link failure happens, each node checks if its own role is cluster head and if the other node belongs to its cluster. In this case, the cluster head removes the node from its cluster. When the link between an ordinary node to its cluster head fails, the ordinary node must have to determine its new role in the cluster same way as it does during initialization.

C. Mobility-based D-Hop Clustering Algorithm (MOBD-Hop)

A mobility-based d-hop clustering algorithm (Mob D-Hop) [3] forms variable-diameter clusters based on mobility pattern of the node in MANETs. This algorithm introduces a new metric to measure the variation of distance between nodes over time in order to estimate the relative mobility of two nodes. On the basis of relative mobility of cluster members we also estimate the stability of clusters. If a node is found to be the most stable node among its neighborhood then it will become a cluster head. Otherwise, it is an ordinary member of at most one cluster. When all nodes first enter the network, they are in non clustered state. A node that is able to listen to transmissions from more than one cluster is known as a gateway node. We use the received signal strength measured at the arrival of every packet to estimate the distance from one node to its neighbor node. Measured signal strength of successive packets is used to estimate the relative mobility between two nodes. In this paper, proposed distributed clustering algorithm forms variable-diameter clusters that may change its diameter adaptively with respect to the mobility of the nodes. In this paper two mobility metrics based on the relative mobility concept is proposed:

(a) Variation of estimated distance between nodes over time and

(b) Estimated mean distance for cluster, in order to measure the stability of a cluster.

These metrics are used to decide cluster memberships. Therefore, the formation of clusters is determined by the mobility pattern of nodes to ensure maximum cluster stability. To achieve the desired scalability, Mob D-Hop forms variable-diameter clusters, which allows cluster members to be more than two hops away from their cluster head. The diameter of clusters or size of the cluster is dependent on the mobility behavior of nodes present in the same cluster. In order to achieve high scalability it also creates lesser and more stable clusters. The change of the cluster head is relatively low.

D. A Mobility-Based Clustering approach to support mobility management

The clustering approach [4] proposed by Javad Akbari Torkestani and Mohammad Reza Meybodi is based on mobility concepts (individual mobility, group mobility) and the availability of position information via a reliable position locating system (i.e. GPS). Global Position System (GPS) accuracy will be increased and its card cost will be decreased. Thus, GPS cards will be mounted in every mobile node. The main idea of this algorithm is to combine both physical and logical partitions of the network, as well as the concept of relative mobility in order to improve the stability in the clustered topology. The mobility-based hierarchical clustering algorithm may

result in variable-size clusters depending on the mobility characteristics of the nodes. Several groups can be hierarchically merged into one group depending on the mobility of each group.

In the following we outline the main steps of the proposed algorithm in order to construct and maintain the various clusters.

Step 1: Mobility Information Dissemination-Each node n periodically disseminates its velocity information to its neighboring nodes.

Step 2: Calculation of Mobility Metrics-Upon reception of node's n velocity information each node m calculates its relative velocity between itself and node n respectively. Then periodically (with period T) each node m calculates the relative mobility between itself and node n.

Step 3: Initial (Tentative) Cluster Construction-Let's denote by Some the set that includes node m and all the nodes from which node m receives mobility information. The mobility threshold is a design parameter of algorithm and can be used to control the stability of the generated clusters in different networks. Moreover, different mobility threshold parameters that may change dynamically and adaptively during the operation of the network can be used.

Step 4: Cluster Merging-If a tentative cluster head is to be included in another cluster according to step 3, then the child cluster joins into the parent cluster with its current cluster members. There is an upper bound (i.e. L hops) rule for merging. After merging the cluster heads, the highest-parent cluster's head is selected cluster as the cluster head of the new generated cluster.

Step 5: Cluster Maintenance/Reconstruction-When a node m in cluster Ci moves into a cluster Cj, if a node n in the cluster Cj satisfies the condition: relative mobility between a pair of nodes during a time period < mobility threshold, and node n is the cluster head of the cluster Cj then node m requests clustering to node n (no cluster head change). If these conditions are not satisfied, node m repeats step 5 during its motion.

In this paper, proposed cluster architecture consists of variable-size clusters that may change adaptively according to the nodes' mobility. The proposed SBC algorithm uses a combination of both physical and logical partitions of the network, as well as the concept of relative mobility that characterizes the degree of mobility of a node with respect to its peers. This algorithm may control and affect the stability of the generated clusters is the mobility threshold.

E. Mobility-Based Clustering (MBC)

A mobility based distributed clustering algorithm [5] is proposed to reduce the freezing time of motion of mobile nodes during the initial cluster setup in the dynamic network. In this paper, there exists a bidirectional link Bij between the nodes i and j when the distance between the nodes dij < range t (transmission range) of the nodes. In the dynamic network the cardinality of the nodes V remains constant, but the cardinality of links L changes due to the mobility of the nodes.

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The algorithm works with the following assumptions:

- Equal transmission range of nodes in the network
- Every cluster head has the information regarding the weight of its cluster nodes.

Basically, we consider the mobility of a node by taking the average of the distances covered by it in last n time slots.

Thus, average Mobility M = Total distance (Dt)/ n

Here, instead of taking the most recent mobility of a node a statistics of distances covered by it in last n unit of time is taken. The weight for individual node is inversely proportional to its mobility. That is a node with higher running average is given lower weight and a node with lower running average is given a higher weight.

During the initial cluster setup phase every node broadcasts it's ID along with its weight to the neighbors and stores the weights that it hears from other nodes within its transmission range. If it does not receive any weight higher than its own weight then it declares itself as a cluster head and the entire 1-hop uncovered neighbor nodes (i.e. whose role is not yet decided) become the members of the currently formed cluster. A lower ID node is preferred for cluster head in case of a tie in the weights of the nodes. This process is repeated till all the nodes are assigned with their role either as a head or a member of the cluster. This ensures a fast cluster setup with minimum freezing time of motion by the nodes. The steps of initial cluster formation in the network:

Step 1: Detect the neighbors of individual node v (i.e. detect the nodes within its transmission range).

Step 2: For individual v, compute the total distances covered by it in last n unit of time.

Step 3: Compute the average mobility of individual node v.

Step 4: Compute the weights of the nodes.

Step 5: For node v, If Wv 〉 Wi where i ∈ neighbor (v), then Set head= v .And, If dist (v, iuncovered) ≤ vtrange then HEAD (iuncovered) = v.

Step 6: Repeat step 5 till all the nodes are covered with a status of either a cluster head or a member node.

The link between every pair of nodes denotes that they are within the transmission range of each other and establish a bidirectional link among each other. This proposed algorithm reduces the freezing time of motion of mobile nodes during the initial cluster setup. A record of previous n set of movements of every node is used to predict their average mobility. Choosing low mobile nodes to act as cluster heads ensure better cluster stability as head nodes rarely move.

F. Mobility and Energy Aware Clustering Algorithm (MEACA)

Mobility and Energy Aware Clustering Algorithm (MEACA) [6] uses the energy status and node mobility to select and evaluate the most stable nodes to be the cluster heads. Besides, to stabilize the formed clusters it avoids premature cluster head re-selection. The objective of clustering algorithm is to increase the network lifetime by form stable clusters in ad hoc networks, where the stableness is measured by the lifetime of a cluster head and the cluster membership time. MEACA works in a distributed manner as in the lowest-ID algorithm. The mobile nodes in the network have different priorities to become cluster head. They exchange their priority values in the cluster with the cluster members to determine who will become the cluster head and who will become the cluster members. After getting the information about the priority values of all its neighbor nodes every node makes its own decision. Because each node's priority value is globally deterministic, the nodes in the network are able to reach unanimous decisions on their roles, though each node decides independently. Unlike the lowest-ID algorithm which fixes a node's priority level beforehand, MEACA using the node's mobility and energy status sets the priority. For this purpose, each node has an energy attribute and mobility attribute. Both are kept up to date. In order to determine its cluster head, a node selects in its neighborhood the node with the relatively highest energy and lowest mobility using these two attributes. The selected node could be the selecting node itself or one of its neighbor nodes. After the cluster head has been choose, the member node registers itself with its cluster head. Re-clustering takes place only when a cluster member node has lost contact to its cluster head or a cluster head node has lost contact to all its cluster members. In other words, if a node will not change its cluster head and/or role as long as its current cluster remains valid. Here the MEACA clustering algorithm uses the energy information and node mobility to stabilize the clusters. At the cost of slightly smaller cluster size, this clustering algorithm has better algorithm scalability than the lowest-ID algorithm. It achieves longer lifetime of the cluster heads and longer membership time of the cluster members.

G. A Mobility-Based Cluster Formation Algorithm for Wireless Mobile Ad-Hoc Networks

In this paper, proposed algorithm [7] is a mobility based cluster formation algorithm MCFA. In this the mobility parameters of the host nodes are assumed to be random variables with unknown distributions. In this proposed clustering algorithm, the expected relative mobility of each host node with respect to all its neighbor nodes is estimated by sampling its mobility parameters in various epochs. In MCFA each mobile node independently chooses the neighboring host node as its cluster head with the minimum expected relative mobility. This is done based on the local information that each host node receives from its neighbor nodes and the host nodes need not to be synchronized. In this algorithm, the expected relative mobility of each host node with respect to all its neighbor nodes is defined as a mobility criterion to find the most stable clusters against the network dynamics. Therefore, this proposed algorithm is composed of two main phases. The first phase is the initial clustering or cluster formation phase which is performed as the network starts up, and the second phase is the cluster maintenance phase which is performed whenever and wherever it is required. The relative mobility of each host node with respect to all its neighbor nodes is defined as its weight. It is assumed that the mobility characteristics of the host node and so the weight associated with the host are random variables with unknown distribution parameters.

III. Discussion

Every clustering algorithm which is described above have some limitations in terms of various aspects. Mob D-hop algorithm is mainly focuses or based on variation of estimated distance between nodes. This algorithm have the drawback that, if a node runs out of energy it act as a distanced node from its physically nearby neighbor node and will transit packets at low power. DMAC clustering algorithm is a message driven algorithm. In this algorithm as density of the node increases, cluster head may become overloaded and it will become the bottleneck. To solve this problem the existing clusters should be split into several smaller clusters and the number of node in the cluster is limited. The max-min d cluster method does not consider the node mobility pattern. To ensure maximum cluster stability node mobility pattern is considered. In WCA, when nodes have high mobility a high re-affiliation can be shown. To solve this problem and to improve network stability of entropy based clustering algorithms can be proposed.

IV. Conclusions And Future Scope

Clustering algorithms help to organize mobile nodes in a network into subgroups and facilitate routing to send packets to other nodes in the network. Clustering can provide large-scale MANETs with a hierarchical network structure to facilitate routing operations. These clustering schemes are useful to create stable clusters to increase network lifetime and avoid frequent re-clustering. In this survey we have studied several clustering algorithms which help organize MANETs in a hierarchical manner and we have explained their advantages and disadvantages. Cluster structure provides measurability and load leveling in MANETs. Additionally by facilitating the spatial reuse of resources it will increase the system capability. It improves network scalability, routing and topology management of MANET. In case of mobility based clustering approach, energy of mobile nodes is essential to take care because as mobile nodes are performing some special tasks and extra responsibilities so they will be exhaust earlier than other mobile nodes and re-clustering will be required.

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