International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Survey of Clustering Schemes in Mobile Ad hoc Networks

Amit Savyanavar[1], Mohini Borate[2]

[1]Associate Professor, Dept. Of Computer Engg, MITCOE, Pune, INDIA

[2]ME Student, Dept.of Computer Engg, MITCOE, Pune, INDIA

Abstract: ***The mobile ad hoc networks (MANETs) are gaining popularity in recent years due to their flexibility and they can be deployed at any location without pre-existing infrastructure. They are used in various contexts such as collaborative, military application or in emergency services. Now a days clustering is a challenging issue in MANETs for addressing efficient resource utilization and must strike a balance between mobility, battery power, node degree, etc. In this paper, we consider the various approaches for clustering have been presented and different approaches focus on different performance metrics. Each cluster contain a particular node called as cluster head which is elected as cluster head according to the specific metric or combination of metrics such as mobility, energy, degree, density, weight etc. In this survey paper we study some clustering schemes such as Mobility based clustering, Energy efficient clustering, Load balancing clustering, and Combined-metrics based clustering.***

Keywords: Clustering, Mobile ad-hoc network, Routing protocol, Mobility, Energy

1. Introduction

A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure-less, wireless network of mobile devices. Each device in a MANET is free to move independently anywhere in any direction. So that it changes its links to other devices frequently. MANETs can be quickly deployed without pre-existing infrastructures. MANETs raise new challenges when they are used in large scale network that contain a large number of nodes. Mobile nodes can communicate with each other over wireless links. Nodes which are within each other's range can directly communicate and are responsible for dynamically discovering each other.

Routers are used for the communication between nodes which are not in senders range. Intermediate nodes are act as routers that relay packets generated by other nodes to their destination. These nodes are often have energy constrained that is, battery power and devices are free to join or leave the network [1-2].

The specific characteristics and complexities for MANETs are autonomous, infrastructure-less, multi-hop routing, dynamic network topology, energy constrained operation, bandwidth constrained variable capacity links, limited physical security, network scalability, self-creation, self-organization and self-administration. Routing is the most important issue in MANETs. Routing is the process of selecting paths to forward the packets over the network. Routing can be either flat structured or hierarchical structure [1-2].

2. What is Clustering?

Clustering is the virtual partitioning of nodes into sub networks according to geographical area in MANET. Mobile ad hoc network (MANET) is the cooperative arrangement of a collection of wireless mobile nodes without any predefined infrastructure relied on to keep the network connected. A cluster structure makes ad-hoc networks appears to smaller and more stable. Every 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 ought to update the data, there is no need the changes to be done by the entire network.

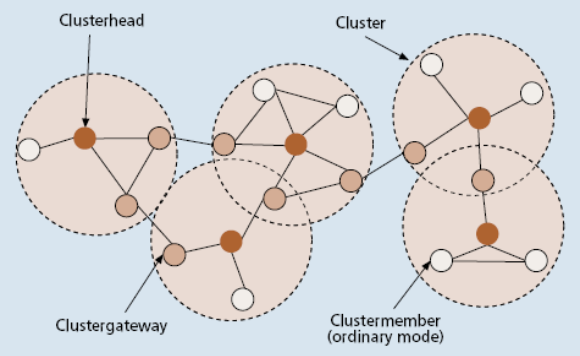

Figure 1: Cluster Structure

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 local coordinator of a cluster and Cluster-Member is an ordinary node. It is 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 forwards information between clusters. Two types of communications are done in cluster.

A. Intra-cluster communication

In the cluster, the cluster head has 1-hop connectivity with every member. So cluster head can directly communicate with member nodes but member nodes cannot directly communicate with other members of cluster.

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B. Inter-cluster communication

In inter-cluster communication routing protocol would be used. 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.

3. Clustering Schemes in Mobile Ad hoc Network

3.1 Mobility Based Clustering

Mobility is a prominent characteristic of MANETs, and is the important factor which affecting topology change and route invalidation. Mobility metric is considered for the stable cluster formation. Mobility based clustering indicates that the cluster structure is determined by the mobility behavior of mobile nodes[2].

Ni et al proposed a mobility prediction based clustering scheme (MPBC) [3] for MANETs with high mobility nodes. MPBC is considered the relative speeds estimation for each node in the whole network. A good clustering scheme provides longer connection lifetime and less re-associations. MPBC clustering scheme mainly include two stages. All nodes broadcast the Hello packets periodically to build their neighbors lists during the clustering stage. Every node estimates its average relative speeds with respect to its neighbors. Nodes are selected as CHs with lowest relative mobility. This guarantees the basic stability performance. During cluster maintenance stage, prediction based method is used to solve the problems caused by relative node movements. By considering some cases when a node moves out of the area of its current CH and when two CHs move within the reach of each other, one CH is required to give up its CH role. This increases the network connection lifetime which results in stable clusters.

MOBIC [4] algorithm is based on LCA algorithm but it involves the relative mobility speed of nodes in CH selection. It means cluster formation and CH selection should take mobility into consideration. Cluster head selection is a local activity so that a CH should be determined by its neighbors and itself. In MOBIC algorithm, for the cluster formation process local mobility metric is considered such that mobile nodes with low speed relative to their neighbors have the chance to become CHs. Also by calculating the variance of a mobile nodes relative speed to each of its neighbors, the aggregate local speed of a mobile node can be estimated [4]. The idea is to choose nodes with low mobility as cluster heads because they provide more stability. MOBIC uses a similar clusters maintenance procedure as LCC [5] with some additional rules to reduce or minimize the cost of clusters maintenance. To avoid unnecessary cluster head relinquishing MOBIC uses Cluster Contention Interval (CCI). CH maintenance is reduces by using this mechanism.

3.2 Energy Efficient Clustering

The battery power of node is a constraint which affects directly to the lifetime of the network hence the energy limitation is big challenge for network performance. CH performs some special tasks such as routing, which causing excessive energy consumption. Now, we discuss some existing energy based clustering algorithms.

A Flexible Weighted Clustering Algorithm based on Battery Power (FWCABP) for MANETs [6] is proposed to maintain the stable clusters. In this algorithm the nodes with low battery power are preventing from being elected as a cluster head, minimizing the number of clusters, and minimizing the clustering overhead. In the cluster formation phase, each node broadcasts a message to inform its neighbors of its status and builds its neighbors list. The CHs election is based on the weight of the degree of nodes, nodes mobility, nodes remaining battery power and sum of distance to its neighboring nodes. The node with the minimum weight is selected as CH. FWCABP performs the cluster maintenance phase when, a node moves outside its cluster region or CH battery power decreases to a predefined threshold value. This algorithm increases network traffic during the cluster head election process which degrades the network performance.

Enhance Cluster based Energy Conservation (ECEC) algorithm [7] is an improvement of Cluster based Energy Conservation algorithm (CEC) [8]. The new topology control protocol that maximizes the lifetime of large ad hoc networks while ensuring minimum connectivity of nodes in the network. The nodes have ability to reach each other and conserve battery power by identifying redundant nodes and turning their radios off. During cluster formation phase, nodes with the highest battery power are elected as CHs. After CHs election procedure, ECEC algorithm then elects gateways to connect clusters. This is shown in [6] that ECEC reduces power consumption which leads to maximize the network lifetime.

Max-Heap tree algorithm [9] is based on energy efficient clustering. In this algorithm small manageable cluster are formed using max-heap tree. This is new improved mechanism for selection of cluster head by choosing the root node of the max-heap as a cluster head. Cluster head is elected based on the energy level of nodes where the highest energy level of node becomes the CH. During the cluster maintenance procedure when an intermediate node departs from the cluster or cluster head departs from the network then tree balancing is needed, because it can violate the property of the max-heap. This algorithm is useful for minimizing the power consumption and maximizing the network lifetime.

3.3 Combined-Metrics Based Clustering

Combined-metrics based clustering technique is combination of number of metrics such as transmission power, node degree, distance between nodes, mobility, battery power of mobile node etc.

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On-Demand WCA (Weighted Clustering Algorithm) [10] considers four parameters for every mobile node in the cluster head election procedure. They are degree-difference, sum of the distance with all neighbors, mobility, and cluster head serving time. According to some predefined values all the parameter values are normalized. On-Demand WCA chooses mobile nodes with minimum weight in the area to be cluster heads. After the election procedure all the mobile nodes covered by elected CHs. And these nodes cannot participate in further CH selection procedure. This procedure is repeated until each mobile node is assigned to any cluster. The cluster head selection algorithm is performed at the beginning of cluster formation or when the current CHs are not able to cover all mobile nodes. If member node changes its attaching cluster then also WCA does not perform re-clustering. This mechanism increases the stability of cluster. If any mobile node goes into a region which is not covered by any cluster head then cluster head election will be performed again. This kind of re-clustering totally destroyed the cluster architecture.

Adabi et al proposed Score Based Clustering Algorithm (SBCA) [11] for MANETs. SBCA aims to maximizing lifetime of mobile nodes and minimizing the number of clusters. It uses a combination of the four metrics to calculate the node score: remaining battery power, node degree, number of members and node stability. In the cluster formation, each node calculates its score and broadcasts the message to all its neighbors. The node with highest score is elected as cluster head. SBCA generates the minimum numbers of cluster than WCA but has the same limitations.

3.4 Load Balancing Clustering

Load Balancing Clustering [13-14], which believe that there is an optimum number of mobile nodes that a cluster can handle. This algorithm is replace the current cluster head with a new cluster head if the current cluster head cannot satisfy the node degree requirement. If the size of the cluster is too small or too large then algorithm merges neighboring clusters together or splits a cluster apart respectively. Load balancing clustering scheme sets the lower limit and upper limit for the mobile nodes. When size exceeds re-clustering is done.

Degree-Load-Balancing Clustering (DLBC) [14] periodically implements the clustering scheme to keep the number of mobile nodes in each cluster around a system parameter *ED*. Where, ED indicates the optimum number of mobile nodes which can be handled by a cluster head. If the difference between *ED* and the number of mobile nodes that it currently exceeds some value then a cluster head becomes an ordinary member node. In this mechanism the clustering scheme tries to make all CHs handles the same and optimal number of member nodes.

4. Comparison of Clustering Schemes

There are many clustering schemes which are available for MANETs in literature. Based on our review and the work which is presented in [3-11], we summarize the comparison in **Table 1**. We can see in **Table 1**, the overheads increase when clusters number is high and CHs change frequently. The combined-metrics based clustering scheme performs better than mobility based and energy efficient clustering. Mostly combined-metrics based clustering scheme is used for CH election that uses combined weight metrics such the node degree, remaining battery power, transmission power, and node mobility etc.

5. Conclusion

In this survey of clustering schemes, we first presented basic concepts about MANET and clustering, including the definition of clustering, objectives of clustering schemes and design goals. Then we classified clustering schemes into four various categories based on their features and objectives such as: Mobility based clustering, Energy efficient clustering, and Combined-metric based clustering and Load balancing clustering. Several clustering schemes which we reviewed are useful to organize MANETs in hierarchical manner. Most of the clustering schemes are focusing on important issues such as stability of cluster, maximizing the network lifetime, controlling the overhead of cluster formation and maintenance. From all the mentioned schemes combined-metrics based clustering scheme is better because it provides high stability in cluster and creates less number of clusters. In collaborative work applications we can use both energy efficient and mobility based scheme which results into optimum utilization of cluster and increases the lifetime of network. Also there are some additional clustering schemes with different objectives and characteristics.

Table 1: Comparison of clustering schemes

Clustering Algorithm	*Based On*	*CHs Election*	*Cluster Radius*	*Overlapping Clusters*	*Clusters Number*	*CH Change*	*Cluster Stability*
MOBIC [4]	Mobility	Lowest mobility	One-Hop	Possible	Relatively High	Low	Relatively High
MPBC [3]	Mobility	Lowest mobility	One-Hop	Yes	Relatively Low	Low	High
FWCABP [6]	Energy	Lowest weight	One-Hop	Possible	Low	Low	High
ECEC [7]	Energy	Highest energy	One-Hop	Yes	Moderate	Low	Relatively High
SBCA [11]	Combined-metrics	Combined weight metric	One-Hop	No	Low	Low	High
On-Demand WCA [10]	Combined-metrics	Combined weight metric	One-Hop	No	Low	Low	Very High

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