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A Survey of Cluster Management Techniques in MANETs

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***Abstract*- Mobile Ad Hoc network (MANET) is infrastructure-less, self-configurable and multi hop wireless network that has dynamic topology. Clustering in MANETs is a hierarchical aspect of dividing the network into various groups of nodes called Clusters. Many clustering schemes have been proposed for adhoc networks. A systematic classification of these clustering schemes enables one to better understand and make improvements. In mobile ad hoc networks, the movement of the network nodes may quickly change the topology of network resulting in the increase of the message overhead in topology maintenance. A variety of approaches for MANET clustering has been developed and proposed by researchers which focus on different performance metrics. This paper includes basic clustering definition, challenges and issues, various existing clustering approaches and their detailed critical analysis based on its advantages-disadvantages, features and their performance metrics. With this survey, researcher can have a more thorough and detailed understanding of ad hoc clustering and the research trends in this area.**

Keywords—Mobile Ad-Hoc Network (MANET), Clustering.

I. INTRODUCTION

Mobile ad-hoc network is infrastructure-less, decentralized and dynamic multi hop wireless Network comprised of mobile nodes that communicate with each other without any pre-existing infrastructure. The network is termed as ad-hoc because each node in environment wants to forward data to other node, so resolution of which node forward data to others is made dynamically depending on the network connectivity [1]. These type of networks functions where fixed infrastructure does not exist to allow the interconnection among work groups moving in urban and rural places. Major applications where these networks find use include Personal Area Networks, Military Environments, and Civilian Environments, Emergency Situations, distributed scientific research or rescue etc.[1][2].

Clustering is a familiar technique of dividing entire network into virtual sub groups called clusters.Particularly, for the large network, flat routing approach results in excessive amount of unnecessary information and message flooding that can saturate the network [3]. Clustering approach enables creation of hierarchy in node's roles within the network. Nodes that has high computational as well as communication power are more preferable for performing the ad hoc network functions than other nodes. Routing on clustered framework address the problem of node heterogeneity. The reason behind clustering technique is to partition the entire network into various groups of nodes called clusters. Clustering enables routing according to hierarchy of nodes in which routes are stored between different clusters instead of storing them between different nodes [3]. This lead to increase in the routes lifetime, which causes reduction in the amount of routing control overhead. Routing in hierarchical manner is a solution to handle scalability in a network where only particular selected nodes will perform data routing.

Structuring the entire network is an important step to simplify the operation of routing in MANETs. Various algorithms based on clustering techniques have been proposed in the literature [4][5][6]. The clustering technique deals with dividing the entire network into a set of nodes that are geographically located nearer to each other. It is an efficient approach to simplify and optimize the network operations. Several clustering techniques have been proposed. These techniques have different characteristics and are designed to meet certain goals depending on the context in which the clusteringapproach is used (routing, security, energy conservation, etc.)[2][7].

The rest of the paper is organized as follow: In section 2, we start by understanding basic concept of clustering. Then, In section 3 we present Challenges and issues of clustering in MANETs, In section 4, we present literature review of clustering in MANETs. In section 5, The comparative analysis of various schemes is presented and at last section 6 describes the conclusion of this survey paper.

II. CLUSTERING IN MANETS

A. Definition

The mechanism that divides the entire network into interconnected substructures, called clusters. Each cluster is associated with particular node selected as cluster head (CH) based on a particular metric or a combination of metrics such as identity, degree, mobility, weight, density, etc. The cluster head plays the role of coordinator within its substructure. Each CH acts as a temporary base station within its cluster and communicates with other clusters viaCHs [8]. A cluster is therefore made up of a cluster head, gateways and members node as per described in below clustered network topology.

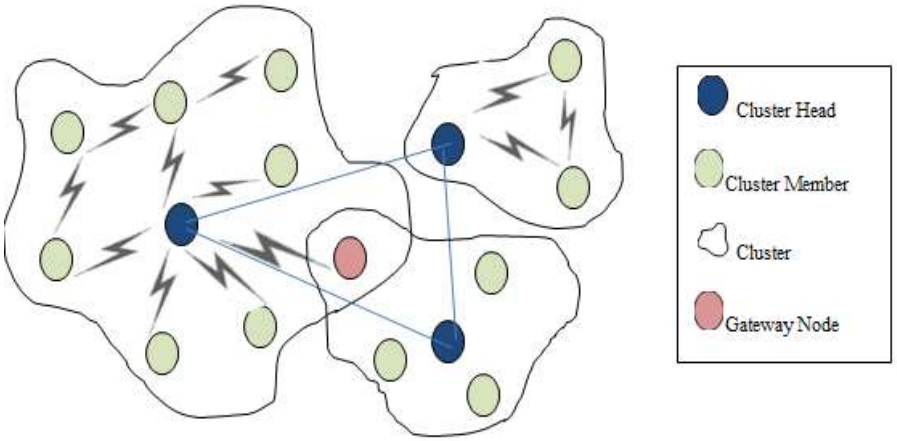

Figure 1. Example of Clustered Network

Different elements of clustered topology is described below.

Cluster Head (CH): it is the coordinator of the cluster.
*Gateway:*It is a common node between two or more clusters.
*Member Node (Ordinary nodes):*Itis a node that is neither a CH nor gateway node. Each node belongs exclusively to a cluster independently of its neighboring nodes that might reside in a different cluster.

III. CHALLENGES AND ISSUES

The highly dynamic and unstable characteristics of MANET's make it difficult for the Cluster based routing protocol to divide the entire mobile network into clusters and determination of cluster heads for each cluster. Clustering reduces communication and control message overheads due to predetermined routes of communication through cluster heads. It is vital for scalability of media access protocols, routing protocols and the security infrastructure [9]. A large number of mobile nodes are managed by a MANET using a cluster topology. The construction and maintenance of a cluster structure requires additional cost compared with a topology control without cluster. Clustering has some side effects and issues [10].

1) The maintenance cost for a large and dynamic mobile network requires explicit message exchange between mobile node pairs. As the network topology changes quickly and concerns many mobile nodes, the number of information message exchange grows to reach a critical point. This information exchange consumes a lot of network bandwidth and energy in mobile nodes.

2) A ripple effect of re-clustering occurs if any local events take place like the movement or the death of a mobilenode, as a result it may lead to the re-election of a new cluster-head. When a new cluster-head is re-elected it may cause re-elections in the whole of the cluster structure. Thus, the performance of upper-layer protocols is affected by the ripple effect of re-clustering.
3) One of the major issues of clustering in MANETs is that some nodes consume more power when compared to others nodes of the same cluster. As special node like a cluster-head or a cluster-gateway manage and forwardall messages of the local cluster their power consumption will be high compared to ordinary nodes. It may cause untimely shutdown of nodes.

IV. LITERATURE SURVEY

A. Identifier Neighbor Based Clustering

In identifier neighbor based clustering, a unique ID is assigned to each node in the network. Each node knows the ID of its neighbor nodes. The cluster head is selected based on criteria involving these IDs such as the lowest ID, highest ID...etc.

Ephremides et al [11] proposed a clustering algorithm called Linked Cluster Algorithm (LCA) in which each node is either, a cluster head, an ordinary node or a gateway node. Initially, all nodes have status of ordinary node; at regular period, each node in the network broadcasts its ID and its neighbor nodes' IDs. Subsequently, the node with the smallest ID is selected as cluster head. A node which is in the transmission range of two or more cluster heads is a gateway node. The process continues until every node belongs to at least one cluster. Nodes with a small ID have more chances to be selected as cluster heads so they quickly consume their energy. The Lowest-ID approach concerns only with the lowest node *ids* which are arbitrarily assigned numbers without considering any other qualifications of a node for selection as a clusterhead node. Since the node *ids* do not change with time, those with smaller *ids* are more likely to become clusterheads than nodes with larger *ids*. Thus, disadvantage of lowest ID scheme is that certain nodes are prone to battery drainage due to serving as clusterheads for longer time periods.

B. Highest Connectivity based clustering

The Highest Degree algorithm also known as connectivity-based clustering was originally proposed by Gerla and parekh[12].The degree of a node is determined based on its distance from others. Each node broadcasts its id to the nodes that arewithin its transmission range. The node with maximum number of neighbors (i.e., maximum degree) is selected as a clusterhead. . In this algorithm every node broadcast their ID in the same network. Based on the number of received IDs, each node calculates its degree value and the one who has the maximum degree value will be selected as cluster-head (CH).If two nodes or more have the same degree value then node with the lowest-ID is selected as the cluster head.In this approach, the number of cluster heads is relatively low in comparisonwith lowest ID approach. In addition, it also reduces value of packet delivery delay. However, the number of re-affiliations of CHs increases when the topology changes.This system has a low rate of clusterhead change but thethroughput is comparatively low. Typically, each cluster is assigned someresources which is shared among the member nodes of that cluster. Major shortcomings of this algorithm include the situation where the degree of a node changes very frequently, and thus the CHs are not likely to play their role as cluster-heads for very long. Moreover, while the numbers of ordinary nodes are increased in a cluster, the throughput drops and system performance degrades. All these shortcomings happen because this scheme does not have any restriction on the upper limit of the number of nodes inside a cluster.

C. Mobility Based Clustering

P. Basu, N. Khan, and T.D.C. Little proposedLowest Relative Mobility Clustering Algorithm (MOBIC) [13] which is based on the LCA(Linked Cluster Algorithm)algorithm but involves the relative mobility of nodes as a criteria in the cluster head selection. The idea is to choose nodes with low mobility as cluster heads because they provide more stability of clusters. MOBIC uses a similar clusters maintenance approach as LCC(Least Cluster head change) with an additional rule to reduce the cost of cluster maintenance procedure. MOBIC algorithm uses concept of Cluster Contention Interval (CCI) to avoid unnecessary cluster head relinquishing. If two CHs are neighbors after the CCI timer timeout, then the one with the highest ID gives up the role of CH. This approach reduces the CHs maintenance overhead. However, the shortcomings of LCC(Least Clusterhead Change) algorithm are not completely removed.This scheme is effective for MANETs with group mobility behavior, in which a group of mobile nodes moves with same speed and direction, as in highway traffic. Thus, a selected clusterhead can normally promise about the low mobility with respect to its member nodes. However, if mobile nodes move randomly the performance may degrade.

D. Energy Based Clustering

The battery power of node can directly affects the lifetime of the network; hence the energy limitation causes several challenges for network performance. The CHnode performs special functions such as routing causing excessive energy consumption. So, we discuss some existing energy based clustering algorithms.

A. Fathi and H. Taheri proposedA Flexible Weighted Clustering Algorithm based on Battery Power (FWCABP) for MANETs [14] to maintain stable clusters by preventing nodes that has low battery power from being selected as cluster head, minimizing the number of clusters, and minimizing the clustering overhead. During cluster formation stage, each node broadcasts a beacon signal message to inform its neighbor nodes of its status and constructs its neighbors list. The CHs selection is based on the weight values which is computed based on the degree of nodes, sum of distance to its neighboring nodes, nodes mobility and remaining battery power. The node with the smallest weightvalue is selected as CH. FWCABA calls the maintenance procedure when: a node moves outside its cluster boundary and/or CH battery power decreases to a predefined threshold value. FWCABP increases network traffic during the cluster head selection phase which leads to network performance degradation.

E. Weight Based Clustering

Weight based clustering approaches uses a combination of predefined weighted metrics such as: transmission power, node degree, distance difference, mobility and battery power of mobile nodes etc. The weighting factors for each metric may be adjusted for different scenarios. Some of these algorithms are presented here.

El-Bazzal, Zouhair, et al. proposedA Flexible Weight Based Clustering Algorithm (FWCA)[15] which uses a combination of different metrics (with different predefined weights) to form clusters. Node degree, remaining battery power, transmission power, and node mobility are used during CHs selection phase. The cluster size does not exceed to predefined threshold value. During cluster maintenance phase, FWCA uses two different parameters as clusters capacity and the link lifetime instead of the node mobility because the link stability metric affects the selection of a CH node with the same weight as the node mobility metric does.

Adabi et al proposed Score based clustering algorithm (Sbca) [16] for MANETs which focuses on minimizing the number of clusters and maximizing the lifespan of mobile nodes. It uses a combination of the following four different metrics to determine the score of node: remainingbattery power of node, node degree, number of members and node stability. During cluster formation phase, each node computes its score value and broadcasts it to its all neighbor nodes. The node with highest score value is selected as cluster head. Sbca produces less no of clusters than WCA but has the same drawbacks.

R. P. Selvam and V. Palanisamy proposed An efficient weight-based clustering algorithm (EW-BCA) for MANETs [17] which focuses on improvement of the usage of scarce resources such as bandwidth and energy by stable cluster formation, minimizing routing overhead, and increasing end to end throughput. Each node has a combined weight value of different parameters such as Number of Neighbors, Battery Residual Power, Stability and Variance of distance with all neighbors that indicates its suitability for selection of CH. Each node is: NULL, CH, member node, getaway node. Initially all nodes are in the NULL state. Each node computes its combined weight value and broadcasts it to its all neighbor nodes. The node with highest combined weight value is selected as CH. Cluster maintenance procedure is invoked when a node goes outside the boundaries of its cluster and/or when cluster head consumes most of its battery power.

M. Chatterjee, S. K. Das, and D. Turgut proposedWeighted clustering algorithm (WCA)[18] which selects a clusterhead based on the number of nodes it can handle,mobility, transmission power and battery power. To avoid communication message overhead, this approach is not periodic and the clusterhead selection process is only called depending on node mobility and when the current dominant set is not capable to cover all the nodes. To verify that clusterhead nodes will not be overloaded a predefined threshold value is used which shows the number of nodes each clusterhead can ideally handle. WCA selects the clusterheads based on the weight value of each node. The weight value of each node v is defined as:

$$W_V = w_1 \Delta V + w_2 D_V + w_3 M_V + w_4 P_V \quad (1)$$

The node with the lowest weight value is selected as a clusterhead. Different weighting factors are selected so that w1 + w2+ w3 + w4 = 1. Mv is the measure of mobility of node. It is taken by calculating the running average speed of every node during a specified period of time T. Δv is the degree difference. Δv is obtained by first calculating the number of neighbors of each node. The result of this calculation is defined as the degree of a node v, dv. To ensure load balancing, the degree difference Δv is calculated as $|dv - \delta|$ for every node v, where δ is a pre-defined threshold. The parameter Dv is defined as the sum of distances from a given node to all its neighbors. This factor is

related to energy consumption since more power is needed for larger distance communications. The parameter Pv is the cumulative time of a node being a clusterhead. Pv is a measure of how much battery power has been consumed. A clusterhead consumes much battery power than an ordinary member node because it has extra functions to perform[19].The clusterhead selection algorithm completes once all the nodes become either a clusterhead or a member node of a clusterhead. The distance between the member nodes of a clusterhead, must be less or equal to the transmission range between them. No two clusterheads can be immediate neighbors of each other.

V. COMPARATIVE ANALYSIS

There are many clustering techniques for MANETs are available in the literature. To evaluate these schemes, we have to choose the metrics to use for the evaluation of these. Based on our review and the work presented in [2], we summarize the comparison in **Table 1**. We can observe in **Table 1**, the total overheads increase when clusters number is high and CHs change frequently. The weight based clustering scheme performs better than ID-Neighbor based, topology based, mobility based and energy based clustering[8]. The weight based clustering scheme is the most used technique for CH election that uses combined weight metrics such the node degree, remaining battery power, transmission power, and node mobility etc. It achieves various goals of clustering approach: minimizing the number of clusters, maximizing lifespan of mobile nodes in the network, decreasing the total overhead, minimizing the CHs change, decreasing the number of re-affiliation, improving the stability of the cluster structure and ensuring a good resources management (by minimizing the bandwidth consumption) .

TABLE 1 COMPARISON OF CLUSTERING SCHEMES

Clustering Schemes	Based on	CHs Selection	Cluster Radius	Overlapping Clusters	Clusters Number	CH change	Cluster Stability	Total Overhead
LCA[11]	ID-Neighbor	Lowest ID	One-Hop	Possible	High	Very High	Very Low	High
HCC[12]	Topology	Highest Degree	One-Hop	No	High	Very High	Very Low	High
MOBIC[13]	Mobility	Lowest Mobility	One-Hop	Possible	Relatively High	Low	Relatively High	High
FWCABP [14]	Energy	Lowest Weight	One-Hop	Possible	Low	Low	High	Relatively Low
FWCA[15]	Weight	A Combined Weight Metric	One-Hop	Possible	Low	Low	High	High
Sbca[16]	Weight	A Combined Weight Metric	One-Hop	No	Low	Low	High	Relatively High
EWBCA[17]	Weight	A Combined Weight Metric	One-Hop	No	Low	Low	Very High	Relatively Low
WCA[18]	Weight	A Combined Weight Metric	One-Hop	No	Low	Very Low	Very High	Low

Clustering approach will offer an outsized scale MANET with hierarchal network structures to overcome the difficulties of crucial quantifiability and message flooding that impair the function of flat network structure of MANETs. It brings attention to important components relating to routing operations, network management, mobility management, quality of service support etc. This Clustering schemes have its own advantages in terms of stability of clusters, minimum no of clusters formed , less reaffiliations of CH etc and disadvantages in terms of high maintenance overhead, low throughput and system performance. These schemes also have scope where they can be enhanced or can be extended and at the result we can improve overall system throughput. Table 2 describes critical analysis of clustering schemes with their advantages, disadvantages and detailed remarks which proves strengthen of weight base clustering approach over other approaches of clustering.

TABLE 2 ANALYSIS OF CLUSTERING SCHEMES

Clustering Schemes	Advantages	Disadvantages	Remarks
LCA[11]	Clustering Procedure with less maintenance overhead	Power Drainage of CH nodes	This scheme concerns only with lowest id value, not about any other quality of nodes.
HCC[12]	This system has a low rate of CH change	When the no of nodes within cluster increases, the throughput drops.	This Approach does not have any restriction on the upper bound on the number of nodes in a cluster.
MOBIC[13]	Stability of cluster is more, as a node with low mobility will be chosen as CH	The cost of Re-clustering is bit-expensive.	This scheme uses similar cluster maintenance procedure as LCC(Least CH change) with CCI (cluster contention interval) facility.so inherits its drawbacks.
FWCABP[14]	Maintain stable cluster, minimizing the number of clusters and clustering overhead.	This scheme increases network traffic during CH Selection process which degrades the network performance	• Re-selection of CH should not only focused on remaining battery power of node • No restrictions and conditions for cluster maintenance procedure
FWCA[15]	It takes combination of different reliable metrics with different weights to select CH.	Before Clustering procedure starts, values of parameters should be known in advance.	It can take several other metrics into consideration while CH selection, likebandwidth requirement of node.
Sbca[16]	It aims to minimize the no of clusters and maximize lifespan of mobile nodes.	It generates more overhead during score calculation by each node in cluster formation phase.	Mobility of node should be consider as one metric while CH selection
EWBCA[17]	It produces stable clusters, minimizing routing overhead and increasing end to end throughput.	It generates more overhead during weight calculation by each node before cluster formation starts.	It can take several other metrics into consideration while CH selection.
WCA[18]	It Produces Clusters with high stability	The Overhead generated during cluster formation is high.	To estimate the mobility of node as a part of cluster formation, the efficient mobility prediction method should be used.

V. CONCLUSION

In this survey, we first presented basic concepts of clustering, including the definition of clustering, design goals and objectives of clustering approaches, advantages and disadvantages of clustering, and cost of clustering a network. Then we classified clustering approaches into five categories based on their distinguishing features and their objectives as: Identifier Neighbor based clustering, Topology based clustering, Mobility based clustering, Energy based clustering, and Weight based clustering. We reviewed several clustering approaches which helps to organize MANETs in a hierarchical manner and presented some of their main characteristics, objective, mechanism, and performance. We also presented the most relevant metrics for evaluating the performance of existing clustering approaches. Most of the presented clustering approaches focuses on various important issues such as cluster stability, the total control message overhead of cluster formation and maintenance phases,the energy consumption of mobile nodes with different cluster related status, the traffic load distribution in clusters, and the fairness of serving as cluster heads for a mobile node, etc.By doing a critical comparative analysis of various clustering approaches, we

can conclude that weight based clustering approach has beneficial over other schemes in terms of cluster stability, bandwidth utilization and overall system throughput.

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REFERENCES

[1] S.Muthuramalingam, R.RajaRam, Kothai Pethaperumal and V.Karthiga Devi ,"A Dynamic ClusteringAlgorithm for MANETs by modifying Weighted Clustering Algorithm with Mobility Prediction."International Journal of Computer and Electrical Engineering, vol. 2, no. 4, August 2010.

[2] J. Y. Yu and P. H. J. Chong. "A Survey of Clustering Schemes for Mobile Ad Hoc Networks," IEEE Commu-nications Surveys and Tutorials, vol. 7. no. 1,pp. 32–48,2005.

[3] R. Agarwal and M. Motwani, "Survey of Clustering Algorithms for MANET", International Journal on Com-puter Science and Engineering ,vol. 1, no. 2, 2009.

[4] S. A. Ade and P.A. Tijare , "Performance Comparison of AODV, DSDV, OLSR and DSR Routing Protocols in Mobile Ad Hoc Networks," I*nternational Journal of In-formation Technology and Knowledge Management*, Vol. 2,pp. 545-548, 2010.

[5] P. Suman, D. Bisen, P. Tomar, V. Sejwar and R. Shukla, "Comparative Study of Routing Protocols for Mobile Ad-Hoc Networks," *International Journal of Information Technology & Knowledge Management*, 2009.

[6] B. Maqbool, M.A.Peer, "Classification of Current Rout-ing Protocols for Ad Hoc Networks," IJCA, 2010.

[7] S. Chinara, S. Rath, "A Survey on One-Hop Clustering Algorithms in Mobile Ad Hoc Networks," *Journal of Network and Systems Management*, Vol. 17, No. 1-2, pp. 183-207, 2009.

[8] Bentaleb, Abdelhak, Abdelhak Boubetra, and Saad Harous. "Survey of clustering schemes in mobile ad hoc networks." *Communications and Network* vol 5, no 2 ,pp. 8-14, 2013.

[9] Naveen Chauhan, L. K. Awasthi, Narottam chand, Vivek Katiyar, and Ankit Chug, "A Distributed Weighted Cluster Based Routing Protocol for Manets," *World Academy of Science, Engineering and Technology* 75,pp.1167-1171, 2011.

[10] M. Anupama and B. Sathyanarayana "Survey of Cluster Based Routing Protocols in Mobile Ad hoc Networks," *International Journal of Computer Theory and Engi-neering*, Vol. 3, No. 6, 2011.

[11] A.Ephremides, J. E. Wieselthier and D.J. Baker. "A Design Concept for Reliable Mobile Radio Networks with Frequency Hopping Signaling,"*IEEE*, pp. 56-73, 1987.

[12] M. Gerla and J. T. Tsai, "Multiuser, Mobile, Multimedia Radio Network," Wireless Networks, vol. 1, pp. 255–65, Oct. 1995.

[13] P. Basu, N. Khan, and T.D.C. Little. "A Mobility Based Metric for Clustering in Mobile Ad Hoc Networks," *ICDCSW*, pp. 413-418,2001.

[14] A. Fathi and H. Taheri. "Enhance Topology Control Pro-tocol(ECEC) to Conserve Energy based clustering in Wireless Ad Hoc Networks," 3rd IEEE ICCSIT, 2010.

[15] El-Bazzal, Zouhair, et al. "A flexible weight based clustering algorithm in mobile ad hoc networks." *Systems and Networks Communications, IEEE ICSNC 2006*.

[16] M.R Monsef, S. Jabbehdari and F. Safaei. "An Efficient Weight-Based Clustering Algorithm for Mobile Ad-hoc Networks," *Journal of Computing*, Vol. 3, 2011.

[17] R. P. Selvam and V. Palanisamy, "Stable and Flexible Weight based Clustering Algorithm in Mobile Ad hoc Networks," *International Journal of Computer Science and Information Technologies*, pp. 824-828,2011.

[18] M. Chatterjee, S. K. Das, and D. Turgut, "An On-Demand Weighted Clustering Algorithm (WCA) for Ad hoc Networks," in proceedings of IEEE Globecom'00, pp. 1697–701, 2000.

[19] A. Bdelhak,S. Harous,A. Boubetra, " A weight based clustering scheme for mobile ad hoc networks", in proceedings of ACM MOMM, 2013.