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A Survey of Clustering Approaches for Mobile Ad Hoc Network

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Abstract: In MANET, Clustering is the most significant research area now days. Clustering offers several advantages like it improves stability of network, enhances routing in network, efficient resource allocation among mobile nodes in network and hierarchical routing structure. This survey paper analyzes number of clustering approaches which are widely used for partitioning mobile nodes into different virtual groups. Each clustering algorithm considers different parameters for selection of Cluster Head in Cluster. Cluster Head election is invoked on demand and it is aimed to decrease the computation and communication cost in MANET. Each approach has its own pros and cons.

Keywords: Mobile Ad Hoc Network, Clustering, Cluster Head, Cluter Gateway, Cluster Member

I. INTRODUCTION

The term 'Ad Hoc' says 'for this purpose only'. Mobile Ad Hoc Networks is a collection of mobile nodes. It forms a temporary network. In MANET mobile nodes communicate with each other without use of a network infrastructure. The nodes communicate with each other using Multi-hop wireless links. Each node within the network behaves as a router. It forwards data packets for other nodes. The growth of laptops and 802.11/Wi-Fi wireless networking has made MANET a popular topic for research in recent time.

In Clustering, the mobile nodes in a network are partitioned into distinct virtual groups. Nodes are assigned geographically adjacent into same cluster according to some rules [1]. Cluster based network introduces three types of nodes in MANET:

1. Cluster Head:

Cluster Head serves as a leader node for its Cluster. It performs communication among various mobile nodes in a cluster. It performs inter cluster transmission; data forwarding and so on.

2. Cluster Gateway:

It is a non Cluster Head node. It is also called as Border node in Cluster. It is responsible for communication among neighboring clusters.

3. Cluster Members:

It is also called as Ordinary nodes in a cluster. It is neither Cluster Head node nor Gateway node. It does not have any inter cluster links.

Clustering offers several benefits when it is used with MANET:

1. It increases system capacity by spatial reusing available resources [2]. If two clusters are not neighboring clusters and they are not overlapped then they can use same set of frequency.
2. Cluster Head and Border nodes form a virtual backbone for routing among neighboring clusters. So generation and spreading of routing information is minimized to this set of nodes.
3. Resource allocation can be done in efficient manner among mobile nodes.
4. MANETs appear stable and smaller in view of each mobile node. When mobile node moves to another cluster, only nodes present at that cluster need to update the information. In this manner local changes need not be seen and updated by entire network. So information stored by each node is reduced.

Disadvantages of Clustering in MANETs:

1. When any mobile node dies or node moves to another Cluster it causes the re-clustering sometimes. It is called as the ripple effect of re-clustering.

2. Clustering is divided into two phases, Cluster Formation and Cluster Maintenance. During Cluster Formation we have to assume that all mobile nodes have static behavior. This assumption is not applicable in an actual scenario [2][4].

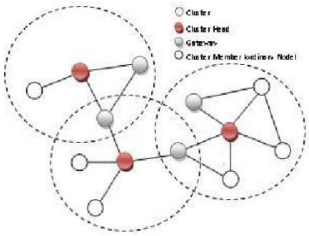

Fig.1 Cluster heads, Gateways and Member nodes [3]

II. SURVEY ON CLUSTERING APPROACHES FOR MANETS

A. *Lowest ID Clustering (LIC)* [5][6]

In this Clustering approach unique identifier is assigned to each mobile node in the network. After assigning ID to each node; nodes recognize its neighbors ID. The node which has smallest ID is selected as Cluster Head node. So; CHs' all neighbors have ID higher than CH.

Advantages:

1. It is simplest approach.
2. It is easy to implement and to understand.

Disadvantages:

1. There is no limit to the number of nodes which can be attached to the same CH.
2. Elected CH serves the network for long duration; so it is prone to power drainage.

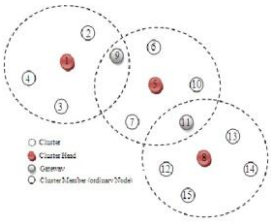

Fig.2 Lowest ID Clustering approach [3]

B. *Highest Degree Clustering (HCC)* [5][6][7]

It is connectivity based Clustering approach. All nodes broadcast their ID to the nodes which are in their transmission range. The node which has highest number of neighbors is selected as CH by this approach. There is a direct link between CH and its neighbors.

Advantages:

1. Number of nodes in the Cluster gets increases while number of Cluster decreases.

Disadvantages:

1. There is no limit on the number of nodes in the Cluster.
2. There is flooding of control messages in the entire network.
3. CH bottleneck problem can also raise in this approach.

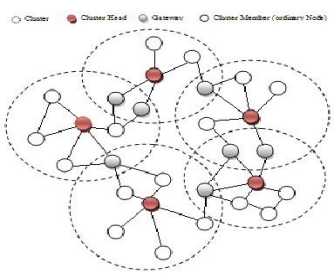

Fig.3 Highest Degree Clustering approach [3]

C. *K- hop connectivity ID Clustering (K-CONID)* [6][8]

This approach combines Lowest ID Clustering approach with highest degree Clustering approach. HCC is considered as first criteria and Lowest Id as second criteria. In this Clustering approach the node connectivity D is paired with node ID which can be written as DID = (D, ID). The node is selected as Cluster Head if and only if it has highest degree and lowest ID.

Advantages:

1. If used only lowest ID approach then it causes more number of Clusters than necessary. So set of CH increases. If only HCC approach is used then there is possibility than number of nodes has same connectivity. So nodes have highest connectivity is selected as Cluster Head. If two or more nodes have same connectivity value than to break ties among them the node which has smallest ID is selected as Cluster Head.

Disadvantage:

1. Every node has to maintain two parameters degree of connectivity and ID.

D. *Adaptive Cluster Load balance approach* [6] [9]

In HCC approach; CH becomes a bottleneck when it serves many numbers of Cluster Members. It is not desirable. So this new approach is given. In Hello message format; there is an "Option" field. If a sender node is a Cluster Head; it will set the number of dominated member nodes as an "Option" value. When a sender node is not a Cluster Head or it is an undecided (CH or non-CH); "Option" item is reset too zero (0). When Hello message of Cluster Head shows that its number of member nodes exceeds a predefined threshold (the maximum numbers of mobile nodes CH can manage); no new node will take part in this Cluster. So, in this manner CH bottleneck can be removed and the load can be balanced among various Clusters.

Advantages:

1. Load balancing can be achieved.
2. CH bottleneck phenomenon can be removed.

Disadvantages:

1. This approach can not eliminate the tie between nodes having same cardinality.

E. *Mobility Based Metric for Clustering: (MOBIC)* [5][9]

In MOBIC approach; mobile nodes with low speed relative to their neighbors have more chances to be selected as Cluster Head node. The only difference between Lowest ID and MOBIC approach is that, Lowest ID approach uses ID parameter of node for election of Cluster Head. While MOBIC approach uses nodes' mobility value as parameter for election of Cluster Head. In Hello message every node broadcasts its own mobility metric to its neighbors and it is stored in the neighbor table of each neighbor with the timeout period. In this manner each node receives aggregate mobility value from all its neighboring nodes. After that each node compares its own mobility values with mobility value of its neighbor nodes. Node which has smallest mobility value is elected as Cluster Head.

Advantages:

1. It reduces the re-clustering to a large extent because we have selected node which has low mobility as

Cluster Head. So, probability of moving out side to the assigned Cluster is very less here.

Disadvantages:

1. Each node has to compute mobility value; its computation requires some amount of time.

F. Least Clustering change approach: (LCC) [6]

LLC has significant improvement over Lowest ID and Highest Degree Clustering. Most of the approaches require performing procedure of Clustering periodically to fulfill specific characteristics of the Cluster Head. In Highest Degree Clustering; each node's cardinality is checked frequently. So there is frequent re-clustering.

LLC Clustering approach is divided into two steps:

1. Cluster Formation step
2. Cluster Maintenance step

Cluster formation simply follows Lowest ID Clustering. So initially mobile node which has smallest ID is selected as CH.

Re-clustering is event driven which is called only under two cases:

1. When two Cluster Heads move into range of each other; one gives up the Cluster Head role.
2. When a mobile node cannot access any Cluster Head; it rebuilds the Cluster structure for the network according to Lowest ID.

Advantages:

1. LCC significantly improves Cluster stability by releasing the requirements that a Cluster Head should always have some specific attributes in its local area.

Disadvantages:

1. If single node moves outside the assigned Cluster; it may be require complete Cluster structure re-computation.

G. Load balancing Clustering:[5][6]

It provides the balance of loads on Cluster Heads. Once a node is elected as a Cluster Head; it is desirable for it to stay as a Cluster Head up to some maximum specified amount of time or budget. Budget is a user defined constraint placed on the heuristic and can be modified to meet some specific characteristics of the system. Two local parameters are maintained Physical ID – unique ID for each node and Virtual ID (VID). Initially VID is set as its ID number at first. Mobile nodes have highest IDs in their local area is elected as Cluster Head first. LBC limits the maximum time unit that a node can serve as a Cluster Head continuously by budget; so; when selected Cluster Heads' budget is over; it is reset to zero. After that it becomes non Cluster Head node. When two Cluster Heads move into the range of each other; the one having higher VID wins as CH.

Advantages:

1. Newly chosen mobile nodes will have good energy level. So, no CH bottleneck problem.
2. Equally load is distributed among various mobile nodes.

Disadvantages:

1. Cluster Head serving time cannot be good indicator for energy consumption of a mobile node.

H. Power-aware connected dominant set:[5][6][10]

It is an energy efficient clustering approach which decreases the size of Dominating set (DS) without affecting its functions. Unnecessary nodes are removed from the DS without. A set is dominating if all the nodes in the system are either in the set or neighbor of the nodes in the set. In this schema energy level instead of ID or node degree is used as Metric for CH selection. Nodes in dominating set consume more energy than nodes outside the set because they handle extra responsibilities like updating routing information, data packet relay etc. So it is required to minimize the energy consumptions of Dominating set. A mobile node can be deleted from the Dominating set when its close neighbor set is covered by one or two dominating neighbors.

Advantages:

1. It reduces the size of Dominating set so energy consumption will be less.

I. Weighted Clustering approach:[5][11][12]

WCA is based on the use of a combined weight metric. For Cluster Head selection; used parameters are number of neighbors, distance with all neighbors, mobility, transmission power and battery power. To decrease communication overhead; this approach is not called periodically. Cluster Head election procedure is invoked based on node mobility and when current Dominating set cannot cover all mobile nodes in the network.

Steps for WCA approach:

Step 1: Find the set of Neighbors of each node v called N(v).

Step 2: Calculate the degree difference for each node;

$\Delta v = | d_v - \varrho |$ where d_v is the number of neighbor of nodes and ϱ is the pre-defined threshold value which shows maximum number of nodes Cluster Head can handle ideally.

Step 3: For every node compute sum of distances D_v with all its neighbors. Then compute running average of the speed for every node until current time T. This gives a measure of mobility M_v where (Xt, Yt) defines the position of node V at instant t.

$M_v = \frac{1}{T} \sum_{t=1}^{t} \sqrt{(Xt - Xt-1)^2 + (Yt - Yt-1)\hat{}2}$

Step 4: Compute the cumulative time P_v during which node V acts as Cluster Head. P_v measures how much battery power has been consumed.

Step 5: Calculate $W_v = w1\ \Delta v + w2\ D_v + w3\ M_v + w4\ P_v$.

The node with the minimum weight is elected as Cluster Head.

Advantages:

1. To avoid communication overhead; it is not invoked periodically and Cluster Head election procedure is called based on node mobility and current DS is incapable to cover all the nodes.

Disadvantages:

1. Knowing the weights of all the nodes before starting the Clustering procedure.
2. Drains Cluster Heads rapidly.

J.Max-Min d-cluster formation Algorithm[5] [13]

In most clustering approaches, all nodes are one hop away from elected cluster head in the cluster. The main drawback of these approaches is they generate large number of cluster heads within the network. Because of it network becomes congested. So, in Max-Min heuristic clusters are formed by nodes that are d-hops away from the cluster head. A d-neighborhood of a node consists of node itself and the set of all nodes located within d-hops away from the node. In this approach d is defined as the maximum number of hops away from nearest cluster head. This value is an input to the clustering approach which allows control over the number of cluster heads to be selected.

Advantages:

1. No. of cluster heads selected in the network can be controlled by value of d. (d= heuristic value to the input of algorithm).
2. Congestion can be avoided in the network.
3. Good Controlled message complexity because the number of message sent from each node is limited to a multiple of d rather than n.

Disadvantages:

1. How to select value of d is not specified.
2. Number of members increased in a cluster So, CH drains rapidly.

K. MobDHop Clustering approach:[5][13][14]

It divides an ad hoc network into d-hop clusters based on mobility metric. This approach makes the cluster diameter more flexible by forming d-hop clusters. The metric used is relative mobility of two nodes. It can be measured by the variation of distance between nodes over times. The cluster formation is done by mobility pattern of nodes to ensure maximum cluster stability. First, MobDHop forms non-overlapping two-hop cluster like other clustering algorithms. Next, merging process is called among clusters if they could listen to one another through border nodes. If the required level of stability is achieved then only the merging process will be successful. This approach assumes that each node can measure its received signal strength. Strong received signal strength implies closeness between two nodes.
This approach requires the calculation of five terms:
(1)The estimated distance between nodes (2) The relative mobility between nodes (3) The variation of estimated distance over time (4) The local stability (5) The estimated mean distance.

Advantages:

1. Minimizes the number of clusters by considering group mobility pattern.
2. Makes cluster more stable

Disadvantages:

1. Only mobility metric is considered for clustering.

L. Passive Clustering: [6][15]

Most of the clustering approaches require all the mobile nodes to announce cluster dependent information repeatedly to construct and maintain the cluster structure. So, clustering is one of the main sources of control overhead. A clustering protocol that does not use dedicated control packets and signals for clustering specific decision is called passive clustering. In this approach, a mobile node can be in one of the following four states: (1) Initial (2) Cluster Head (3) Gateway (4) Ordinary node. All the mobile nodes are with "Initial" state at the beginning. Only mobile nodes with "Initial" state have the potential to be CH. When a potential CH with "Initial" state has something to send, such as a flood search, it declares itself as CH by piggybacking its state in the packet. Neighbours can gain knowledge of the CH claim by monitoring the "cluster state" in the packet, and then record the CH id and the packet receiving time. A mobile node that receives claim from only one CH becomes an Ordinary node, and a mobile node that hears more than one claim becomes a gateway.

Advantages:

1. Passive clustering can form and maintain its cluster structure without explicitly exchanging the clustering control packets. Thus, it can completely eliminate the control overhead caused by active clustering.

III. COMPARITIVE ANALYSIS

Clustering Scheme	Cluster Head Selection Criteria	Benefits	Drawbacks
Lowest ID	Node with minimum id which is distinct	Simple to implement	1.Certain nodes are prone to power drainage due to serving as CH for longer time 2.Generates more CH than necessary
Highest Degree	Node with highest connectivity value among its neighbors.	Less hop to fulfill a request.	1. Due to high mobility frequent change of topology occurs. Hence Congestion in Cluster head and erratic exchange of CH occurs. (2)Numerous ties between nodes. (3)Only one hop connectivity.
Max Min d	(1)Node	(1)Less	(1)How to

cluster	participates in CH selection based on their node id. (2)Once the CH is selected sender node determines the shortest path.	number of CHs and hence less traffic. (2)Operates asynchronously. (3)No. of messages sent from each node is limited to a multiple of d rather than 'n'.	select value of d is not specified. (2) Number of members increased in a cluster So, CH drains rapidly.
K-hop connectivity	Node with higher connectivity is chosen as CH, in case of tie ID is considered to select CH. Each node has 2 tuples (d,ID) d: degree	(1)Obtain minimum no. of clusters and smaller size of dominating set.	(1)Number of nodes will be increased in a cluster so CH will drain rapidly.
Adaptive cluster load balancing	(1)Hello Message format is used which has an item 'options'. a.If sender node is CH it will assign 'options' to no. of dominating members else it will be reset to 0. b. If hello message of CH shows its dominating set is greater than threshold (max. no. one CH can manage) no new node will participate in that cluster.	(1) Cluster head (CH) bottleneck phenomenon is eliminated and cluster structure is optimized. (2) Load balance between various clusters is implemented. (3) Resource consumption and information transmission is distributed uniformly among all clusters.	Can not eliminate the tie between same nodes having same cardinality
MOBIC	Mobility (compute d over a small time period by calculating the variance of relative mobility between a node and all its neighbor)	Re-affiliation count is decreased	In case of particular scenarios where the relative mobility between nodes does not differ drastically, the mobility metric gives better results.
MobDHop	Relative mobility of two nodes (variation of distance between nodes over time)	(1) Minimizes the number of clusters by considering group mobility pattern (2)Makes cluster more stable	Only mobility metric is taken into considerate-on.
LCC	Node ID	LCC significantly improves Cluster stability by releasing the requirements that a Cluster Head should always have some specific attributes in its local area.	If single node moves outside the assigned Cluster; it may be require complete Cluster structure re-computation
LBC	Energy level	(1) The newly chosen mobile node would be having good Energy level. So, no CH bottleneck (2) And its previous total cluster head serving time is the shortest in its neighbour-hood.	Cluster head serving time can not be good indicator for energy consumption of a mobile node.
WCA	Node degree, Distance summation to all its neighbouring nodes, Mobility , Remaining battery power	(1)To avoid Communication overhead, this algorithm is not periodic and the Cluster head Election procedure is only invoked based on node mobility and	(1)Knowing the weights of all the nodes before starting the clustering process (2)Drains the CHs rapidly.

		when the current dominant set is incapable to cover all the nodes. (2) To ensure That cluster heads will not be over-loaded, a pre-defined threshold is used	

CONCLUSION

We have reviewed some of the Clustering approaches which help to organize Mobile Ad Hoc Networks in a hierarchical manner. In this survey paper we have seen the importance of the Clustering approaches, we have also seen that a Cluster based Mobile Ad Hoc Networks have various issues to examine, such as the Cluster stability, the energy consumption of mobile nodes, the load distribution, and the fairness of serving as CHs for a mobile node.

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