Clustering Schemes in Wireless Sensor Networks and Mobile Adhoc Network: Classification and Comparison

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***Abstract*— Number of clustering schemes has been proposed so far for different adhoc networks which play an important role in self organizing them. The two prominent adhoc networks which have gained lot popularity during the last few years are Wireless Sensor Networks (WSN) and Mobile Adhoc Networks (MANETs). This paper surveys clustering schemes used in these two networks and classifies them accordingly. A systematic classification of these schemes enables one to better understand and make improvements. Both of these networks focuses on different criteria for clustering of networks based on the constraints imposed on them and the requirements of the applications using the network. MANETs focuses on reducing overhead, handling node mobility and topology maintenance etc. WSN focuses on maximizing the energy efficiency and network lifetime.**

Keywords- WSN, MANETs, LEACH, TEEN, PEGASIS,HCC.

I. INTRODUCTION

Ad hoc network is a self-organizing multihop system of wireless nodes which can communicate with each other without pre-existing infrastructure. A wireless sensor network is a set of sensors deployed in a sensor field, to monitor specific characteristics of the environment, measure those characteristics and collect the data related to that phenomena. The design of WSN is constrained by various constraints like: battery powered sensor nodes, unreliable sensors, data redundancy, application specific, frequent topology change, sever energy, computation and storage constraints, security [1]. Mobile Ad Hoc Networks (MANETs) can be characterized as having a dynamic, multihop, potentially rapid changing topology. The design of MANETs is also constrained by various constraints like: dynamic topology, reserved energy nodes, large networks, QoS, Limited physical security. Therefore routing is a tough task in both of these networks.

Routing is the main issue in all networks. Routing protocols are the in charge of discovering and maintaining the routes in the network. The architecture greatly affects the routing strategy being used and the pros and cons of that strategy. Due to various constraints on the wireless networks the routing protocols used in these networks are also subject to various constraints. A lot of research has been conducted in this field and two types of topology structure have been proposed mainly: flat topology and hierarchical topology. In a flat structure, all nodes in a network are at the same level and have the same routing functionality. Flat routing is simple and efficient for small networks. The problem is that when a network becomes large, the volume of routing information will be large and it will take a long time for routing information to arrive at remote nodes. For large networks, hierarchical (cluster-based) routing may be used to solve the problems. In hierarchical routing the nodes in the network are dynamically organized into partitions called clusters, and then the clusters are aggregated again into larger partitions called super clusters and so on.

In this paper, I am going to discuss various clustering schemes used by WSN and MANETs. Section II discusses clustering, its advantages and its components. Section III deals with the clustering schemes for WSN and Section IV deals with clustering schemes for MANETs. Section V brings in glance various challenges for clustering algorithms. Section VI compares the clustering schemes for the two networks and tries to point out strength and weakness of different schemes and in the end, Section VII concludes the paper.

II. CLUSTERING

Clustering refers to a scheme of aggregating the nodes in a network into groups, known as clusters. Clustering plays an important role in self organizing the adhoc networks that makes the communication process easy between the nodes. In almost all the clustering schemes the nodes in the clustered networks are categorized into three mains categories : the CH (cluster-head) - a dominating node which handles all the communication in the network, the ordinary nodes- all the other nodes of the network which sends their requests to CH, the gateway nodes. CH is a kind of local controller. The ordinary node sends data to CH node which transfers it further. The gateway node, bridges the CHs in the clusters. There are a number of constraints have been imposed on the clustering techniques like size of the cluster, selecting of cluster head, switching of CHs etc. therefore it has been a tough job for protocol designers to design a “all-in-solution”. In clustering adhoc networks, both proactive and reactive routing protocols are used that’s why clustering algorithm are sometimes known as hybrid routing approach. Intra cluster (between the clusters) and inter cluster (within the single cluster) communication can

make use of proactive and reactive routing protocol depending upon the underlying strategy of routing being used.

A. Advantages of Clustering

A number of advantages of clustering scheme are there as: 1) Clusters helps maintain a relatively stable network topology. 2) The routing overhead is largely reduced due to propagation of high level information across the clusters. 3) Only the CHs or gateway nodes need to maintain the route information. 4) Lowers energy consumption. 5) Increases network scalability.

III. CLUSTERING IN WIRELESS SENSOR NETWORKS

A WSN typically consists of a large number of low-cost, low-power, and multifunctional wireless sensor nodes, with sensing, wireless communications and computation capabilities [2]. There are several issues that designers must carefully consider, while using any clustering scheme in WSNs. These are [3]: cost of clustering, real-time operation since WSN is mostly used for time critical operations like military etc., data aggregation, repair mechanisms, selection of cluster heads and clusters, QoS, synchronization and scheduling of nodes since it plays a important role in energy consumption. Several classifications are given for classifying clustering schemes in WSN.

A. Classification of Clustering in WSN

Clustering can be classified according to different criteria. A few among them are [4]:

1) Based on the parameters for electing CHs as Deterministic and Adaptive: Deterministic schemes, gives consideration to special attributes of sensor nodes like their ID, number of neighbors they have been within a pre-specified transmission (Node degree). In this approach node with lower ID is more suitable for becoming CHs. This scheme is not energy efficient. Whereas Adaptive schemes, focuses on node having higher weights becomes CHs.

2) Based on the importance given to the particular features as Heuristic schemes, weighted schemes, Hierarchical schemes and Grid schemes: Heuristic schemes deals with finding the optimal solution or finding an algorithm with reasonable run-time. Example [14]: LCA, Highest Connectivity, Max-Min D-Cluster. These schemes mainly focus on choosing CHs dealing with a subset of parameters. These schemes are application specific rather than used by any arbitrary wireless mobile network. A Weighted scheme gives importance to election of CH every time a new network topology has been created. It is an important energy saving scheme because the energy consuming re-election process occurs less frequently. Example: WCA [19] (Weighted Clustering Algorithm). Hierarchical schemes are schemes in which different hierarchies of CHs are made and the decision whether a node elevates to CH is made dynamically at each interval. It saves lot energy. Therefore can be said Hierarchical schemes are energy efficient schemes. Example: HEED [15] (Hybrid Energy-Efficient Distributed Clustering), LEACH [16] (Low Energy Adaptive Clustering Hierarchy), EECS (Energy Efficient Clustering Scheme). Grid schemes build grids using the source and destination nodes. Grid seed (GS) is selected on the basis of residual energy, these GS selects the CHs. Energy conservation is done by these schemes. Example: PEGASIS [20] (Power Efficient Gathering in Sensor Information System), GROUP.

3) Based on the clustering process as Static, Dynamic: In Static approach clusters are formed only during the time of network deployment and remain static. This approach is easy to deploy but has limited usability. In Dynamic approach clusters are dynamic and nodes get interchanged between the clusters. This scheme is more feasible in now-a-days applications, where targets are mostly moving.

4) Based on network type Proactive, Reactive: Proactive schemes are those which use the proactive routing approach of wireless network approach in which nodes always have route to send data to any other node in the network. Example: HEED, EECS [17], EEDC. Reactive schemes uses reactive routing approach of wireless networks in which on demand routes & data send between the nodes take place. Example: TEEN [18], APTEEN, CAG.

Except from these classification criteria various other classifications are available for WSNs. In each of the category a number of algorithms are there. The main focus of WSN is energy saving therefore all these schemes must be energy efficient or tries to be energy efficient.

IV. CLUSTERING IN MOBILE ADHOC NETWORKS

A MANET is a decentralized, self organizing network made of number of mobile nodes, where each node can act as a router during the communication process. MANET is characterized by the constraints like: energy consumption, network capacity, mobile nodes, changing topology etc. Clustering in MANETs provide a number of advantages [5]. It helps in the network management, which makes routing easy, avoids flooding which saves energy. In MANETs less storage during routing is required reducing the network overhead. Clustering makes the network robust since communication failure inside one cluster affects only that particular cluster and not the whole network. Clustering also improves throughput, spatial reuse and scalability.

A. Classification of Clustering in MANETs

Clustering in MANETs can be classified according to different criteria. Almost all the clustering algorithm in MANETs is designed keeping in mind the selection of CH and classification is also done on this basis. I am discussing here only a few:

1) Based on ID as Lowest-ID and Highest-ID: In these algorithms every node has assigned a weight according to some parameters. Lowest-ID algorithm selects the node with the lowest id as the CH whereas the Highest-ID selects the node with the highest id as CH. The ids once assigned to the nodes will not change with time. The drawback of these algorithms is that only some nodes having the highest and lowest ID will act as CH leading to power drainage of some nodes acting as CHs. K-CONID algorithm is the algorithm in which the CH is selected on the basis of connectivity and lower ID. This overcomes the drawback of above two algorithms.

2) Based on distance between the nodes as Max-Min d-cluster and MobDhop: In Max-Min d-cluster [6] CH is selected at a d-hop distance between the nodes. Clusters are formed by nodes that are d-hops away from CH. The number of CHs in this case is comparatively less, leading to requirement of fewer resources. But this algorithm does not consider mobility of nodes during cluster formation. To overcome this new algorithm MobDhop algorithm is there, it is similar as above with the node mobility consideration. The diameter of cluster is adaptable to node mobility. The distance of a node from its neighbors is measured using the strength of the received signals. The variation of distance between the two nodes is calculated instead of calculating physical distance between two nodes. The CH is selected on the basis of local stability of the nodes. Most stable node is considered as CH.

3) Based on connectivity as HCC and Adaptive Multihop Clustering: In Highest Connectivity Clustering (HCC) algorithm the node with the highest degree is selected as the CH. The degree of a node is calculated on the basis of its distance from others. HCC provides a low rate of CH change. But has many drawbacks like low throughput, because it does not have any restriction on the upper bound of the nodes in a cluster. Adaptive Multihop Clustering [7] sets upper and lower bounds (U and L) based on the number of nodes within a cluster that a CH can handle. This scheme does not provide any specific criteria to select CH. It is a load balancing scheme.

4) Based on some weight criteria as DMAC, WCA, PMW, CBMD and a few more: Distributed Mobility Adaptive Clustering algorithm (DMAC) [8] is a distributed scheme in which CH is selected using a weight-based criterion that depends on node mobility-related parameters. A node with the highest weight is selected as CH. DMAC takes into consideration the mobility of nodes while cluster formation which makes it more preferred to other algorithms. It is a message driven algorithm. Major drawback of DMAC is that with the increase in node density CH overhead increases. It can also trigger undesirable global rippling effects. Weighted clustering algorithm (WCA) [9] selects CH according to the weight value of need node which depends upon number of nodes it can handle, mobility, transmission power and battery power. It selects the node with the minimum weight is as CH. The CH range is defined by pre-defined threshold value so as to avoid CH overhead. No two CHs can be immediate neighbors. Various other versions of WCA are also available which overcomes the drawbacks of WCA like WCA with mobility prediction, Improved WCA. Power Mobility Workload (PMW) [10] is a robust weighting algorithm in which the weight of each node is calculated by three parameters: remaining power, mobility prediction and workload calculated locally. This algorithm forms stable clusters and provides high scalability. CBMD is a distributed clustering algorithm which chooses local CH based on the four parameters: connectivity (C), residual battery power (B), average mobility (M) and distance (D). This algorithm maintains a lowest number of stable clustering structure providing increase in the lifespan of the mobile nodes and decrease in the cluster formation overhead. Various other weight based clustering algorithms are available for MANETs such as Entropy-based weighted clustering, Weight-based adaptive clustering algorithm, and Vote-based clustering algorithm.

5) Based on cost of maintenance of cluster as LCC, adaptive clustering, 3-hBAC, passive clustering: Least Cluster Change algorithm [11] is divided into following steps: cluster formation, which is similar as LIC the node having the lowest ID being selected as CH and cluster maintenance. This algorithm improves cluster stability but has large communication overhead. Adaptive clustering, allows each mobile node to broadcast only one message for cluster formation. Every node i keep its own ID and the ID of its direct neighbors in a set Gi. Node with the lowest ID is selected as CH and sets its own ID as CID. Cluster formation and cluster maintenance mechanism is there. Size of cluster decreases in this algorithm and the number of clusters increases leading to a single-node cluster structure. 3-hop Between Adjacent CHs (3-hBAC) [12], introduces the concept of cluster guest, which is a node that is not in the transmission range of any CHs but within the transmission range of some cluster members. Cluster formation begins from the neighborhood of the node with the lowest ID. The mobile node with the highest node degree is chosen as CH. All the CHs are at least two-hops away. The cluster maintenance, takes place when two CHs move into the reach range of each other, one is required to give its CH role. This algorithm prevents any ripple effect when re-clustering. The number of clusters in this algorithm is less because it avoids formation of small unnecessary clusters because of the use of cluster guest concept. Passive clustering is a clustering protocol that does not use dedicated control packets or signals for clustering specific decision. In this scheme a mobile node can attain any of the following four states: initial-at the beginning, CH-when it claims to be CH, gateway- when a mobile node hears the CH claims of more than one CHs and ordinary node- when a node hears the CH claims of just one node.

V. CHALLENGES FOR CLUSTERING ALGORITHMS

Clustering in WSNs and MANETs no doubt has provided a number of advantages in deployment of routing protocols over the non clustering routing protocols. But it has to face several deployment challenges, such as

- Computing the optimal size clusters, traffic load distribution in clusters and the cluster stability.
- Ensuring connectivity.
- Selecting the appropriate CHs and the gateway nodes.
- Selecting the optimal frequency of CH rotation.
- Avoiding CH from becoming a bottleneck and single point of failure of the cluster.
- Optimal mode of communication between ordinary node and the CH.
- The control overhead of cluster construction and maintenance.
- Facing the network mobility and changes in the cluster structure frequently.

- Switching of responsibilities from one node to another node in the mobile network.
- The energy consumption of mobile nodes with different cluster-related status.

VI. COMPARISON

The two wireless networks WSNs and the MANETs are different from each other considering a number of issues like communication, types of nodes, architectural differences, capabilities of nodes, power sources for nodes and most important their application areas. Therefore the clustering requirements of these two will be some how different from each other. Here I am going to compare all the clustering schemes on the basis of their characteristics [5] [13] [15] [16] [17].

TABLE I. COMPARISON OF DIFFERENT CLUSTERING SCHEMES

Clustering scheme	**Comparison metric**		
	Characteristics	***Type of network***	***Type of scheme***
LCA	CH decided on the basis of unique ID. Basic algorithm, no specific features. Suited only for small networks.	WSN	Heuristic scheme
Highest Connectivity	Node with the highest connectivity or lowest ID selected as CH. Dynamic CHs. High overhead of rotating CHs	WSN	Heuristic scheme
Lowest-ID	CH selection based on lowest-ID. Preferred in static networks. Energy inefficient. Certain nodes prone to power drainage	MANET	Heuristic scheme
Highest Degree	CH selection based on highest-node degree.	MANET	Heuristic scheme
k-CONID	CH selection on basis of connectivity and lower ID. Reduces the number of clusters formed.	MANET	Heuristic scheme
WCA	CH seleceted on the basis of node degree, mobility,energy. Proper CH distribution. Energy efficient.	MANET/ WSN	Weighted scheme
LEACH	Balanced energy usage. Rotating CHs.Distributed cluster forming appraoch. Reduced data transmission. Homogenous, stationary sensors	WSN	Hierarchical scheme
EECS	Homogenous, stationary sensors. Dynamic clustering process. Extended lifetime. Better energy & resource usage.	WSN	Hierarchical scheme
Max-Min D-hop	Ditributed CH election procedure, provides load balancing among CHs. Flooding used.	MANET/ WSN	Heuristic scheme
HEED	CH selection on basis of residual energy, intra-cluster communication cost.	WSN	Hierarchical scheme
	Homogenous mobile/stationary sensors.Energy efficient.distributed cluster formation		
DMAC	CH selected on weight base critera. Suited for mobile networks. CH may become overhead	MANET	Distributed scheme
PEGASIS	Nodes directly not forming clusters. Less data transmission range required by a node. More energy efficient.	WSN	Grid scheme
PMW	Weight calculated on Power,Mobility and Workload basis. Stable clusters are formed. Low reclustering overhead	MANET	Weighted scheme
CBMD	Stable cluster formation with lowest number of clusters formed. CH chosen on basis of largest local weghts. Increase the lifespan of mobile nodes.	MANET	Weighted scheme
TEEN	Homogenous,stationary / mobile sensors. CH selection based on attribute. Focus on information aggregation. Useful for time critical applications.	WSN	Hierarchical scheme
LCC	CH selection on the basis of local highest node degree. Frequent reclustering. Improved cluster stability. Large communication overhead.	MANET	Weighted scheme
3-hBAC	CH formation on the basis of lowest ID. Re-clustering is easy . Less number of clusters formed.	MANET	Weighted scheme
GROUP	CH selection on the basis of residual energy. Low data transmission distance. Less energy use.	WSN	Grid scheme
EEDC	Homogenous, stationary sensors, dynamic clustering process. CH selection on the basis of some attributes.	WSN	Weighted scheme

VII. CONCLUSION

A number of clustering schemes have been proposed for different adhoc networks so far. No doubt, clustering provides a number of advantages like scalability of adhoc networks but there are still issues such as energy consumption in the mobile nodes which have to be taken under consideration. In this paper I have discussed the classification of a few important schemes since a systematic classification of these schemes enables one to better understand and make improvements. A comparison between these schemes is also shown to give a quick access to the important clustering strategies discussed throughout the paper. I hope the paper will help the readers understand the clustering schemes more clearly.

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