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Improving Performance of Mobile Ad Hoc Network Using Clustering Schemes

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ABSTRACT

Mobile ad hoc network become nowadays more and more used in different domains, due to its flexibility and low cost of deployment. However, this kind of network still suffering from several problems as the lack of resources. Many solutions are proposed to face these problems, among these solutions there is the clustering approach. This approach tries to partition the network into a virtual group. It is considered as a primordial solution that aims to enhance the performance of the total network, and makes it possible to guarantee basic levels of system performance. In this paper, we study some schemes of clustering such as Dominating-Set-based clustering, Energy-efficient clustering, Low-maintenance clustering, Load-balancing clustering, and Combined-metrics based clustering.

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1. INTRODUCTION

Mobile Ad hoc NETwork (MANET) it a group of autonomous nodes that are mobile and able to communicate with each other without the existing of any fixed infrastructure or a centralized administration. Also, it characterized by the flexibility and a low cost of deployment [1]. These characteristics enable MANETs to give us significant benefits in virtually any scenario that includes a cadre of highly mobile users or platforms, a strong need to share IP-based information, and an environment in which fixed network infrastructure is impractical, impaired, or impossible. Key applications include disaster recovery, heavy construction, mining, transportation, defense, and special event management [2].

Each entity in the network cans communicate directly with their neighbors that exist in its range. To communicate with other entities, it is necessary to pass its data packet to others entities that will be responsible for forwarding it. To do this, it is essential that the entities are situated in relation to each other, and are able to construct routes between them: this is the role of the routing protocol. A routing protocol is used to discover routes between the sender and the receiver entities. The main objective of such an ad hoc network routing protocol is the establishment of a correct and efficient route between a pair of entities so that messages may be delivered in a timely manner. The construction of the route should be done with a minimum of overhead and bandwidth consumption [3]. Many protocols have been proposed to the Internet Engineering Task Force Mobile Ad Hoc Networking group, based on different assumptions, such as Ad-hoc On-demand Distance Vector (AODV) [4], Dynamic Source Routing (DSR) [5], Destination Sequenced Distance-Vector (DSDV) [6] and Temporally Ordered Routing Algorithm (TORA) [7]. These protocols during building the route are based on the broadcast of control messages to find the optimum path between the source and destination. However, this method shows it is less relevant. Since most of these protocols take

the shortest path as the main metric, other parameters like the state of nodes are not taken in consideration. Also, the diffusion of control messages in the whole network has a bad effect on the entities as the excessive consumption of resources. Many solutions are proposed to face this problem; in this paper we are interested to clustering solution that aim to reduce these problems especially in a dense network. Clustering approach tries to partition the network into a virtual group with respect of certain rules.

The rest of the paper is organized as follows. Section 2 gives a brief description of routing protocol in mobile ad-hoc network. Section 3 describes the clustering method with the different classes. Finally, Section 4 concludes the paper.

2. ROUTING PROTOCOL IN MANET

In mobile ad hoc network, each node needs to send a data packet toward another node that does not exist in its transmission range; it uses the neighboring nodes to reach the destination node. As well, each mobile node operates as an ordinary node and also as a router by forwarding packets for other mobile nodes in the network. So, each node by forwarding a packet, it based on an ad-hoc routing protocol that allows it to discover multi-hop paths through the network to any other node. Many protocols have been proposed. These protocols in general can be divided into three categories [8-9] Figure 1 shows examples of these categories:

a. **Proactive protocols (Table Driven):** These types of protocols are called table driven protocols in which, each node has the route to any destination in his routing table. Packets are transferred to the predetermined route specified in the routing table. In this class of protocol, the packet transmission is done faster, but the routing overhead is higher because all the routes must be defined before transferring the packets. On the other hand, proactive protocols have lower latency because all the routes are maintained at all the times. Examples of proactive are Destination Sequenced Distance Vector (DSDV) [6] and Optimized Link State Routing (OLSR) [10].

b. **Reactive protocols (On-Demand):** In this category of protocol, nodes initialize a route discovery mechanism to find the route towards the destination node when the source node has data packets to send. The advantage of these protocols is that overhead messaging is reduced. One of the weaknesses of these protocols is the delay in discovering a new route. Examples are Dynamic Source Routing (DSR) [5] and Ad-hoc On-demand Distance Vector (AODV) [4].

c. **Hybrid protocols:** Hybrid routing protocols are a combination of both reactive and proactive routing protocols. These protocols use reactive approach with the nearest nodes and the proactive approach with farthest nodes. It was proposed to reduce the control overhead of proactive routing protocols and also decrease the latency caused by route discovery in reactive routing protocols. Examples of hybrid routing protocols are ZRP (Zone routing protocol) [10] and TORA (Temporarily Ordered Routing Algorithm) [7].

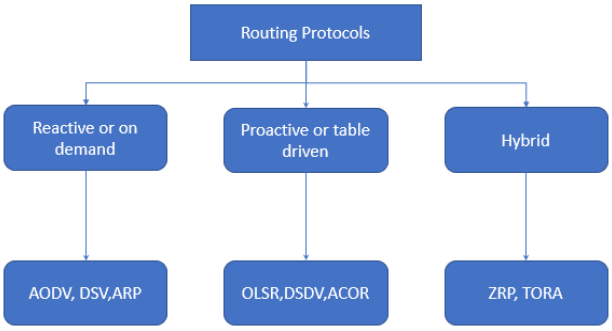

Figure 1. Sorting of routing protocols

From this brief description of different group of routing protocols. We can observe that nodes broadcast control packets in the whole network periodically or when needed, in order to find the route to the destination node. Indeed, this method generates a substantial amount of control packets that are often not needed. Which lead to a large consumption of network resources as energy and bandwidth, also it generates a considerable overhead of control packets. This problem increases considerably when the nodes in the network are mobile and the network topology changes frequently.

3. CLUSTERING

The clustering approach tends to partition the different node in the network into virtual groups, groups or clusters of nodes are created with respect to the closeness of nodes to each other and other factors that determinate that a node to be included or excluded from the cluster. Each cluster in the network can contain three types of nodes, such as cluster-head, cluster-gateway and cluster-member. Each type has a function or role assigned in the cluster. The cluster-head node it is like the manager and acts as location servers for all the nodes in the cluster by performing intra-cluster transmission arrangement, data forwarding, and so on. Cluster-gateway it is cluster-member with inter-cluster links, so it is like the way to other cluster that allow forwarding packet between clusters. Cluster-member is an ordinary node, which is a non-cluster-head or cluster-gateway [11-12]. Figure 2 presents a cluster structure illustration.

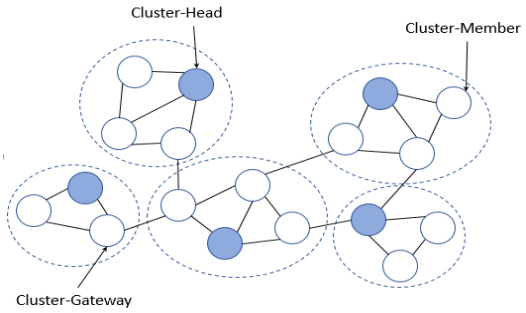

Figure 2. Cluster structure illustration

The use of clustering approach in Manet has many benefits, the topology updating information and routing information can be reduced to the exchange of aggregated information between various clusters and the exchange of detailed topology information to single clusters. Facilitates the spatial reuse of resources to increase the system capacity. A cluster structure makes an ad-hoc network appear smaller and more stable in the view of each mobile terminal. The clustering schemes of MANETs can be classified according to different criteria. In this paper, we classify the clustering protocols based on their objectives. According to this criterion, the proposed clustering schemes for MANETs can be grouped into six categories.

3.1. Dominating-Set-Based Clustering

The majority clustering techniques in mobile ad hoc networks are based on dominating sets. Distributed algorithms are designed in order to find small dominating sets. The term distributed means that each node only has information of the local structure of the network [13]. A set S is dominating if each node in the graph G=(V,E) is either in S or adjacent to at least one of the nodes in S. A dominant set in mobile ad hoc networks is formed by the set of the network cluster-heads. Since a large number of cluster-heads will increase substantially the number of routing hops causing higher communication overheads and extra energy consumption, the basic idea is to find a minimum dominating set. The minimum dominating set problem is formulated in the context of a network in order to find a minimum number of transmitters that allow all the other nodes to be within the range of at least one of the selected senders.

Authors of [14] propose a new Connected Dominating Set (CDS) algorithm for clustering in MANETs. the proposed algorithm is based on Wu and Li's [15] algorithm, authors provide significant modifications by considering the degrees of the nodes during marking process and also provide further heuristics to decrease the size of CDS. And showed that this improvement is remarkable when the number of nodes in the network is large, in a dense network. As in [16] authors describe a Connected Dominating Set-Energy Protocol (CDSEP) for MANET to optimize the problem of broadcasting in the network. The main concept introduced in this protocol is a distributed algorithm which computes the connected dominating set (CDS) based on node energy and node connectivity. The CDS nodes in the CDSEP protocol are selected to forward packets during the broadcasting process, and the information broadcasted in the network through these CDS is also about the CDS. Thus, a second optimization is achieved by minimizing the contents of the control packets broadcasted in the network. Hence, only a small subset of links with the nodes is declared instead of all the links and the nodes.

3.2. Energy-Efficient Clustering

Mobile nodes in MANET normally depend on battery power supply during operation, hence the energy limitation poses a severe challenge for network performance [17-18]. A MANET should strive to

reduce its energy consumption greedily in order to prolong the network lifespan. Also, a cluster-head bears extra work compared with ordinary members, and it more likely "dies" early because of excessive energy consumption. The lack of mobile nodes due to energy depletion may cause network partition and communication interruption [19]. Hence, it is also important to balance the energy consumption among mobile nodes to avoid node failure, especially when some mobile nodes bear special tasks or the network density is comparatively sparse.

Madhvi et al [20] propose an energy aware algorithm based on clustering to provide longer life time of MANET. The proposed algorithm would be an energy efficient clustering algorithm that uses both scalability and energy metric for cluster layout. An index number is assigned to each node taking in consideration its energy level, the node with higher energy level becomes a cluster head or the root of max-heap tree. The remaining nodes come under the cluster head or root head forming a tree. Each cluster head gets connected with the other cluster head in the network. Here the range of clusters is fixed to one hop or it can be considered as stable clusters with moving nodes. The communication in the network will occur directly among cluster heads, and there is no gateway node. As in [21] authors propose Energy Efficient Zone based Routing with Parallel Collision Guided Broadcasting Protocol (ZCG) that uses parallel and distributed broadcasting technique to reduce redundant broadcasting in the network and to accelerate the process of path discovery, while maintaining a high reachability ratio as well as keeping node energy consumption low. ZCG uses a one hop clustering algorithm that divided the network into groups led by reliable leaders that are mostly static and have plentiful battery resources.

3.3. Mobility-Aware Clustering

The property of mobility in mobile ad-hoc network has also an important impact on the stability of the clusters. So, taking into consideration the factor of mobility during the construction of the clusters structure, will have a significant impact on the stability of the clusters and thus other parameters of the network[22]. This technique tends to group the different node that has the same mobility model into the same cluster, in order to reduce the operation of the re-clustering also the re-affiliation of the cluster-member in the clusters.

Authors of paper [23] present a new routing protocol Mobility Prediction-Based Clustering (MPBC). This protocol contains two phases, the initial clustering phase and the cluster maintaining phase. The Doppler shifts associated with periodically exchanged Hello packets are used to estimate the relative speeds between neighboring nodes, and the estimation results are used as the basic information in MPBC. In the initial clustering phase, the nodes having the less relative mobility in their neighborhoods are selected as the cluster heads. In the cluster maintaining phase, mobility prediction strategies are introduced to control the various problems caused by node movements, such as possible association losses to current Cluster Heads and Cluster Head role changes, for extending the connection lifetime and giving more stable clusters.

3.4. Low-Maintenance Clustering

Among the problems of clustering, there is maintenance of the different clusters of the network. As in a clustered network requires a periodic exchange message for maintaining the clusters. In MANET, the topology of the network change frequently, resulting in increasing the control overhead of the network and consume a substantial amount of resources of the network like the bandwidth and the energy due to the maintenance operations of clusters[24].minimizing this problem is a necessary issue. Proposed low-maintenance clustering protocols tend to create stable cluster architecture by reducing the number of re-clustering in the network.

The paper [25] propose an algorithm based on the work presented in [26] type strategy for cluster formation and maintenance. Authors added some new features to the solution, so as to improve the stability of clustering. Like other clustering schemes the proposed scheme involves two phases: Cluster formation and cluster maintenance. In this proposed approach cluster formation phase involves general clustering and cluster improvement. General clustering is followed by cluster improvement which guarantees the maximum number of connected clusters. For cluster maintenance, follow the local clustering.

3.5. Load-Balancing Clustering

Load-balancing clustering algorithms believe that there are an optimum number of mobile nodes that a cluster can handle, especially in a cluster-head-based MANET. A too-large cluster may put too heavy of a load on the cluster-heads, causing cluster-heads to become the bottleneck of a MANET and reduce system throughput. A too-small cluster, however, may produce a large number of clusters and thus increase the length of hierarchical routes, resulting in longer end-to-end delay. Load-balancing clustering schemes set upper and lower limits on the number of mobile nodes that a cluster can deal with. When a cluster size

exceeds its predefined limit, re-clustering procedures are invoked to adjust the number of mobile nodes in that cluster.

Authors of [27] propose energy aware load balancing algorithm. Global reclustering is initiated when the network becomes significantly unbalanced i.e. if the variance of degree of the cluster heads in the network is greater than a pre-determined threshold. Degree of all cluster heads would be needed at each node to evaluate the average of degree of all cluster heads in the network, afterward the variance among themselves, which is not possible in adhoc network because of its distributed nature. For this, a formula is derived in which variance can be updated at each hop i.e. variance of N nodes can be expressed in terms of variance of N-1 nodes and average of N-1 nodes. Also in [28] authors used dynamic genetic algorithms such as Elitism-based Immigrants Genetic algorithm and Memory Enhanced Genetic Algorithm to solve dynamic load-balanced clustering problem. These schemes, select an optimal cluster head by considering the distance and energy parameters. The authors used Elitismbased Immigrants Genetic algorithm to maintain the diversity level of the population and Memory Enhanced Genetic Algorithm to store the old environments into the memory. It promises the energy efficiency of the entire cluster structure to increase the lifetime of the network.

3.6. Combined-Metrics Based Clustering

Combined-metrics-based clustering takes a number of metrics into account for cluster configuration, including node degree, residual energy capacity, moving speed, and so on. This category aims at electing the most suitable cluster-head in a local area, and does not give preference to mobile nodes with certain attributes, such as lowest ID or highest node degree. One advantage of this clustering scheme is that it can flexibly adjust the weighting factors for each metric to adjust to different scenarios. For example, in a system where battery energy is more important, the weighting factor associated with energy capacity can be set higher [29]. However, not all of these parameters are always available and accurate, and the information inaccuracy may affect clustering performance.

A centralized cluster formation and distributed cluster head selection based algorithm is proposed in [30] that adopts a centralized cluster formation and distributed cluster heads selection method. Using minimum energy clustering, the network is separated into energy-balanced clusters and takes in consideration energy and communication distance, optimal cluster heads are selected in order to prolong the network life time.

3.7. Summary

Table 1 summarizes the main features and objectives of some protocol that uses clustering schemes.

Table 1. Features of Clustering Schemes

clustering schemes	Based on	CHs Election	Cluster Stability	With clusterhead?	1-hop or multi-hop	Clusters Number	Objectives
Cokuslu [14]	CDS	Node degree	High	yes	1-hop	Moderate	Get a low number of nodes as dominating nodes to construct a CDS. reduce the number of nodes participating in routing and reduce the size of DS
Madhvi[20]	Energy	Highest energy	Low	yes	1-hop	High	Avoid node with low energy level and limit the time that a mobile node can serve as a clusterhead.
MPBC[23]	Mobility	Lowest mobility	High	yes	1-hop	Relatively Low	reduce the influence of mobile nodes' movement on cluster topology updates in terms of re-affiliation and re-clustering
Yousuf[25]	Low-maintenance	Node stability	Very High	yes	1-hop	Low	Limiting re-clustering situations and reducing clustering control overhead.
LBRA[27]	Topology	Node degree	Relatively High	yes	Multi-hop	Moderate	Balancing the traffic load in each cluster by limiting the number of cluster member
LEACH-LEACH-C [30]	Combined-metrics	Combined weight metrics	Very High	yes	1-hop	Low	Electing the most suitable clusterheads in local areas by considering several metrics and keeping a stable cluster structure by reducing re-clustering situations.

4. CONCLUSION

In this article, we first provided fundamental concepts about clustering, including the definition of cluster and clustering, the necessity of clustering for a large dynamic MANET, and the side effects and cost of clustering. We discussed each clustering scheme in terms of objective, mechanism, performance, and application scenario. With this work, we see that a cluster-based MANET has many important issues to examine, such as the cluster structure stability, the control overhead of cluster construction and maintenance, 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. As well, the different types of clustering may have a different focus and objectives. However, clustering cost always needs to be considered when discussing a clustering scheme, because clustering cost is important to evaluate the performance and scalability improvement of a clustering scheme no matter which specific objectives it bears.

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