An Efficient Load Balancing Clustering Algorithm for Mobile Ad Hoc Networks

Labdah ALGhafran and Zulkefli Bin Muhammed Yusof

***Abstract*—**Mobile Ad Hoc Networks (MANET) are a collection of mobile nodes without the assistance of any centralized structures. MANETs become a significant communication technology in modern life due to their flexibility. Clustering is a promising approach for MANETs because it enables efficient routing protocols and realization of MAC. In this paper, we propose a new load balancing clustering algorithm for MANETs and improvement in a well-known Weighted Clustering Algorithm (WCA). Our contribution is consideration the variance between communication workload of every mobile node when we perform the load balancing between Cluster Heads. Furthermore, we use variable transmission range of cluster Heads which help to prevent the network from re-clustering. This is aimed to reduce the computation and communication costs. We will use simulation model to show that our proposed algorithm improve the network stability by using load balancing technique between cluster heads.

***Keywords*—**A Mobile Ad Hoc Network, clusterhead, Load-Balancing, transmission range.

I. Introduction

MOBILE ad hoc networks (MANETs) represent a collection of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary, “ad-hoc” network topologies. This helps people and devices to create wireless networks in areas with no pre-existing communication infrastructure, e.g., emergency rescue, disaster relief, mobile conferencing, law enforcement, battle field communications. The main properties of MANETs are dynamic topology and decentralized connectivity which make network management a challenging task[1][2] .

Clustering has evolved for a significant study matter in MANETs since it enhances the system efficiency by increasing scalability, improving bandwidth utilization and reducing delays for route strategies.

In a clustering structure, nodes divided into interconnected groups with a dedicated node which called cluster head (CH). CHs are vested with the responsibility of the cluster management, for instant routing and scheduling the medium access[3]. After Clusters creation, every cluster will have a specific size (the number of nodes in that cluster), depends on cluster-heads' transmission range. Cluster size is not fixed, because every node can move from one cluster to another and the communication work load of nodes not equal. If a cluster size becomes very large with active nodes, cluster-head may become overloaded. On the other hand, there are cluster-heads which may be under loaded. Overloaded cluster-head batteries depleted faster, which may cause a re-election of the cluster-head and frequent information exchange among the participating nodes that result in high computation and communication overhead cost. If the service distribution and routing mechanism in an Ad Hoc Network is based on the cluster architecture, the service and routing performance will also be affected by overloaded cluster-head (decrease the throughput). An overloaded cluster-head problems cause a decrease in the networks performance [4].

The main objective of this paper is to distribute the load fairly between cluster-heads by using our proposed algorithm which called Cluster head Load Balancing Algorithm (CLBA). The proposed algorithm consists of two phases. The Cluster Formation phase performs initial partitioning of a network into clusters, while the Load Balancing phase updates the topology of a network as time goes on. By balancing the load between cluster heads, the average execution time can be minimized and the lifetime of the overloaded (cluster head) node can be maximized[5].

The remainder of this paper is organized as follows. Section two reviews recent works in load-balancing for MANETs. In Section three, we introduce CLBA algorithm in detail. Then, the performance of CLBA algorithm is discussed in Section four. Finally, we conclude the paper in section five.

II. Related Works

Recent works in load-balancing for MANETs aim to increase the performance of routing algorithm or increase the life of cluster-head in order to prevent MANET from re-election cluster-head.

In [6], they proposed a new algorithm for MANET to prolong the network lifetime by balancing the load between neighbouring cluster-heads. The algorithm uses two energy thresholds. One is used to achieve a local load balancing by distributing the load equally among the adjacent cluster-heads, while the other is used to trigger local re-clustering in the network.

Another algorithm is proposed by [7]. This algorithm is called Cross-layer based load balancing algorithm for DSR (CLB-DSR). The objective of that study was to balance and distribute the network load among nodes in the whole network

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to improve the network throughput and reduce the end-to-end delay.

In [8], they used the resizing of clusters to balance the load in the network by merging of clusters, splitting of clusters, or forming new clusters.

In 2011, there have been a number of studies scrutinizing load balancing. For example,[9] presented a green clustering algorithm to divide the network into a clustered architecture, where the number of nodes among clusters is balanced by using the adjustment transmission range between nodes. This helps to reduce the consumption of the limited battery power in exchanging messages and to balance the number of nodes among clusters. Another study used elitism-based immigrant's genetic algorithm (EIGA) to determine the cluster-head set, which can build up the load balanced cluster structure, meaning that every cluster-head possesses similar numbers of cluster members. The objective of this study is to determine the new optimal set of cluster heads after each topology undergoes quick changes [10].

In addition, [11] proposed a novel approach that can balance the load, while simultaneously discovering the services. Over lapping clusters algorithm (OCA) is proposed by [12] to realize both network reliability and load balancing.

Furthermore,[13] and [14] consider the load-balancing and energy-based in realizing the optimal cluster-head, which balances the consumption of energy among cluster members. This can help to increase the network's life time.

[15][16][17][18] attempted to provide a trade-off regarding the uniformity with the load handled through the cluster-heads together with the connectivity of the network by implementing a non-periodic process of cluster-head election which is invoked on-demand.

Moreover, autonomous decentralized structure formation technology based on the local-interaction of terminals has been proposed by [19] for power-saving and load-balancing.

Recently [20] proposed a Load Balanced Re-clustering Algorithm (LBRA). The main objective of (LBRA) is to prolong the network lifetime, when the network load imbalances between cluster heads by re-clustering the networking. The performance of the algorithm is evaluated by simulation. In clustering structure, re-clustering is an expensive operation.

III. Cluster-head Load-Balancing Algorithm (CLBA)

Clustering provides a convenient framework for resource management. It can support many important features such as code separation, channel access, routing and power control. Cluster-heads are nodes that are responsible for routing node messages within each cluster and managing power control and service distribution. Efficient communication between nodes can be supported by cluster-heads. If cluster-heads are loaded, the performance of other protocols based on the clustering architecture is decreased. There are different reasons for adding more loads on cluster-heads, such as the mobility of nodes and the activity difference between nodes. To increase network performance, we proposed Cluster-head Load-Balancing Algorithm (CLBA). This algorithm is used to redistribute the load between cluster-heads in MANET, by using dynamic transmission range. Highly Loaded cluster-head and lightly loaded cluster-head agree to share the load and distribute their nodes fairly. Loaded cluster-head will decrease its transmission range, at the same time unloaded cluster-head will increase its transmission range. By using the (CLBA) we increase the performance in the following aspects:

Saving bottleneck cluster-heads: a loaded cluster-head represents a bottleneck in the network. Loaded cluster-head may have a lot of active nodes. These nodes need to send and receive packets through that cluster-head. Loaded cluster-head cannot do its work efficiently. The (CLBA) will try to solve this problem by redistributing the loads between cluster-heads.

Decreasing the delay: Delay is the time needed to get reply when request is sent. This time may be increased if there is a high loaded cluster-head. To decrease the delay we can use (CLBA). By reducing the over-load on a certain cluster-head, the delay of sending and receiving packets through that cluster-head could be reduced as well.

Increasing throughput: loaded cluster-head cannot serve all activity nodes in its cluster. This will decrease the throughput in the network. Loaded cluster-head becomes unloaded cluster-head, when we use the CLBA. Because loads will be distributed between cluster-heads. This causes the throughput to increase.

A. Network Structure and Assumption

Mobile Ad hoc Network can be presented as graph G= (V, E), where V is the set of nodes and E is the set of logical edges. The total number of nodes is n=|V|. Direct connectivity between two nodes is possible only when two nodes are within the same geographically area, as a transmission needs to be received at least some minimum signal level to ensure some quality of service. Cluster-head predefined energy-threshold and load-threshold which depends on the number of active nodes can be serviced by cluster-head. Every cluster-head has all information about other adjacent cluster-heads in the networks, and it can exchange this information with other cluster-heads periodically or on-demand. We assume that cluster-heads can use adjustable transmission range. Each cluster has exactly one cluster-head which is one hop away from all its members and each cluster identified by the ID of its cluster-head and each normal node belongs to one cluster only. There are three status of any node: cluster-head, member and gateway (node that is within the transmission range of two cluster-heads). Once the network is established, every node diffuses its (ID) through a SETUP message which is noted down by all the other nodes in its transmission range. When the neighbours list of every node is ready, the clustering algorithm is executed. Each node maintains a record of its status: (cluster-head, member, and gateway). If it is not a cluster-head, it has to know which it is affiliated (CH-ID: Cluster-head Id). Regarding to the mobility nature of the nodes in MANETs, the nodes and the cluster-heads are likely to move through different directions, which causes any kind of disorganization of the network setting. The network needs to be updated from time to time. The updates are made when renewing cluster formation. If a node changes its affiliation from one cluster-head to another existing cluster-heads; in this case, we talk about re-affiliation. If a cluster-head doesn't receive any message from a node, it updates its members list. When a node is attached to another cluster-head, it updates its CH-ID and the corresponding cluster-head updates its members list. Once the cluster-head doesn't get any more messages of a node, it updates its members list. It is actually essential to know that, within this work, we come up with certain assumptions. The number of nodes for each cluster will be limited to avoid the cluster-head congestion and for better resources utilization. In all of the analyses done on the proposed algorithm, we assumed that all nodes are cooperative and trusted. Initially, each node stores the position information of itself and neighbour Cluster-Heads by Hello messages. Each node stores its ID, its position information in Cartesian coordinates (x, y), initial energy of a node, its load in a Hello message and broadcasts it periodically. Each node has the one-hop neighbour node table which stores the information of one-hop neighbour nodes received by Hello messages.

B. Cluster Formation in CLBA

In our work, a cluster-head is elected depend on some rules, such as mobility and power capacity. We make sure that the cluster-head has the highest energy and lowest mobility in its cluster. This is due to the power is critical resources in MANET and cluster-head consumes more energy than a normal node. In addition, mobility is a necessary issue in a cluster-head election to avoid frequent cluster-head changes.

- Find the neighbours of each node w (nodes within its transmission range). They are defined as follows: $d(w,w_1) = \{ w1 \neq w , dist(w, w_1) \leq Tx\}$ where Tx is the transmission range of node w.
- Compute the sum of the distances Dw with all neighbours

$$Dw = \sum_{w \in N} d(w, w1) \tag{1}$$

- Compute the average speed of every node; gives a measure of mobility Mw

$$Mw = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(x(t)-x(t-1))^2+(y(t)-y(t-1))^2} \tag{2}$$

Where $x(t) - x(t-1)$ and $y(t) - y(t-1)$ are the coordinates of the node (w) at time (t) and $(t-1)$

- For each node compute the residual energy (Er). We need to compute the energy consumed by the node in the network EC first by using these equations:

$$Ec = \sum_{i=1,j=2}^{n} M(ij) + Ep \tag{3}$$

Where:

Mij: Power needed to send packet from node i to node j.
Ep: Power needed to calculate the position by the node.
Ec: Power consumed by the node in the network.

$$Er = Et - Ec \tag{1}$$

Where:

Er : Residual energy of each node.
Et : Total power of a node.
Ec : Power consumed by the node in the network.

- Find the Current Load (Cl) of node (w)
- Find the Election Function EF(w) by using this equation:

$$EF(w) = \frac{(k1 \times Er)}{(k2 \times Dw) + (k3 \times Mw) + (k4 \times Cl)} \tag{5}$$

- Choose the node which has the highest value of the Election Function EF(w) as a cluster-head. All the neighbours of the chosen cluster-head can no longer participate in the election algorithm.
- Repeat steps 2-6 for the remaining nodes not yet assigned to any cluster.

The subsequent characteristics are viewed while in the cluster-head election algorithm. The nodes mobility will cause modification in the network topology. If at a given time a node is moved out from its current cluster and it is linked to another cluster, the corresponding cluster-heads will update their members' tables. If a node actually leaves its cluster and doesn't find another cluster to connect itself, the cluster-heads election algorithm is invoked.

The cluster-head will keep the data regarding its members (identifier ID, status, load, energy and position). It could discover another cluster-head is moved into its cluster. In such cases, one of these is restricted to give up its cluster-head's role. Within our case, it will be the one who has a smaller amount of energy.

A minimum amount of energy is determined for every cluster-head. When it is reached, the cluster-heads election algorithm is invoked locally.

C. The Load Balancing in CLBA

Step1: Each Cluster-head periodically calculates its current load (Lch).

$$Lch = \sum_{w \in M} Cl(w) \tag{6}$$

Where:

Lch : current Load of the Cluster-Head.
Cl(w) : Current Load of the node(w) .
M : the number of the cluster-heads' members.

Step2: Compare the Lch with load-threshold. A Cluster-head is considered over-loaded, when Lch > load-threshold and under-loaded when Lch < load-threshold, otherwise normal load.

Step3: If a cluster-head is over-loaded, it tries to distribute the extra-load to one of its under-loaded adjacent CHs.

Step4: The gateway nodes of the loaded Cluster-Head will try to find another unloaded Cluster-Head. When a node finds another cluster-head with a small load, it affiliates with it and sends request messages to its CH and Adjacent CH.

Step5: When loaded cluster-head receives a request messages from all gateway nodes in its cluster; it removes these nodes from its member table and recalculate its load by using the equation (6).

Step6: If Cluster-Head is still loaded, it will send CLBA-Message to all its adjacent Cluster-Heads.

Step7: When Cluster-Head receives CLBA-Message, it will compare its current load with load-threshold and it residual energy with energy-threshold. If it is unloaded and has enough energy, it will send Accept-CLBA which means that loaded Cluster-Head and unloaded Cluster-Head will agree to redistribute their loads by identifying the new transmission range of them as follows:

- *Low level:*

(If Er(CH) =< energy-threshold and Lch >= load-threshold)

- *High level:*
  (If Er(CH) > energy-threshold and Lch < load-threshold).

Step8: When loaded Cluster-Head becomes normal loaded, it will send End-CLBA to adjacent Cluster-Head to inform them to return the transmission into normal level.

IV. Discuss

The proposed Cluster head Load Balancing Algorithm (CLBA) will be compared with WCA [21] through simulations. The algorithm is implemented using Riverbed® Modeler. To measure the performance of the system, the algorithm focused on these parameters:

A. The average power Consumption

Saving the battery power of all nodes is the main concern of clustering algorithm for the MANET. Specially, the cluster heads that should not be loaded too much to ensure longer network life time. CLBA does not consider power consumption however; it does not have to deplete more power. This mean, the study has to monitor the power consumption of the network nodes. The model initializes network nodes with a full batteries and then tracks and updates them through the life time of the network

B. The average time a cluster head survives

In cluster-based approaches it is so important to keep the backbone nodes or the cluster heads unchanged for longer functioning time. This is to avoid the extra overhead caused by the re-election procedure and to minimize the re-gathering of the routing information inside the previously formed clusters.

C. The average route discovery time

The average route discovery time metric gives an idea about the performance of the routing protocol. It is important to make sure that concentrating on the cluster heads election and maintenance does not lead to a worse routing functioning.

D. The overhead of CLBA

The total number of node control messages sent metric is intended to measure the overhead exists in the network. Both CLBA and WCA use the node control messages to elect the cluster heads. The frequency of sending the control messages affects the nodes power and the overhead introduced into the network.

Proposed algorithm is under implementation and actual results will be compared as early as possible.

V. Conclusion

Motivated by the former research of clustering algorithm, the objective of this paper is to study a balanced work load between cluster heads in Clustering Algorithm for Mobile Ad Hoc Network (MANET), which can deal with work load of nodes. In the network, we could calculate the radius of cluster head based on its residual power and its work load, and take connectivity density and work load of nodes into account to redistribute the nodes between cluster heads. It is expected to perform better than WCA.

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