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Dual Head Cluster: A Single Cluster Environment for Large-scale Mobile Ad-hoc Networks

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Abstract— In addition to this, these techniques are also beneficial in extending the network life time. Clustering protocols proposed in existing literature uses a single Cluster Head (CH) for a group of nodes (Cluster). In these protocols, the CH performs a number of activities, such as data gathering, data aggregation and data forwarding. As a result, the CH depletes its energy quickly as compared to its member nodes. Hence, re-clustering is required frequently, which consumes considerable energy. This paper proposes a novel concept of a Dual Head Cluster Algorithm (DHCA) for MANETs. It uses a primary cluster head and a secondary cluster head for route management, inter and intra cluster communication, cluster maintenance and data aggregation, namely Cluster Head (CH) and Aggregator Head (AH) respectively. The introduction of these two heads reduces the frequency of re-clustering and end-to-end latency. Simulation results show that the DHCA outperforms conventional clustering protocols in terms of energy conservation, network life time and end- to- end latency.

Index Terms— DHCA, MANETs, Cluster-Head, Aggregate-Head, Clusters, Routing, Leach

1 Introduction

A mobile ad hoc network (MANET) is a collection of wireless mobile devices with restricted broadcast range and resources where communication is achieved by relaying data along appropriate routes that are dynamically discovered and maintained through collaboration between multiple nodes. MANET is a self configuring, dynamic, multi-hop radio network without any fixed infrastructure. It is a flexible networks expected to support emerging group applications such as spontaneous collaborative activities and rescue operations. MANETs provide communication between free-roaming mobile hosts without a fixed infrastructure. They operate under conditions of limited battery power and may also to the inherent unreliable and unstable nature of MANETs. They are especially in locations that lack a fixed communication infrastructure. To achieve zero configuration MANETs, and being aware of relative host mobility changes provides useful instability information of mobile hosts and helps in managing replicas.

Routing protocols proposed for MANETs can be broadly categorized as flat or hierarchal. Most of the hierarchal routing protocols use clustered network topology. Clusters/Groups can be made based on different metrics like energy level, processing/transmission power, mobility and QoS parameter. Cluster topology provides ease of network management, routing and resource sharing.

A number of data aggregation schemes have been proposed in existing literature [1, 5, 8] which produce aggregated data information and thus enhance network life time. In clustered networks the CH is also a controller for data collection and aggregation from member nodes. Apart from route management and aggregation a CH can also be responsible for topology management. As a result of aforementioned tasks, the energy of CH depletes quickly which forces frequent re-clustering. In order to avoid frequent re-clustering and to enhance the network life time, the task of route management and aggregation should be performed by two separate nodes within the cluster.

2 Related Work

Clustering in mobile ad hoc networks can be defined as the virtual partitioning of dynamic nodes into various groups. Groups of the nodes are made with respect to their nearness to other nodes. Two nodes are said to be neighbors of each other when both of them lie within their transmission range and set up a bidirectional link between them [2]. It is also an important approach to solving capacity and scalability problems in mobile ad hoc networks where no physical infrastructure is available. The connected dominating set (CDS) is a special cluster structure where the cluster heads form a connected network without using gateways. Certain nodes, known as cluster heads, are responsible for the formation of clusters each consisting of a number of nodes (analogous to cells in a cellular network) and maintenance of the topology of the network. The set of cluster heads is known as a dominant set. A cluster head does the resource allocation to all the nodes belonging to its cluster. Due to the dynamic nature of the mobile nodes, their association and dissociation to and from clusters disturb the stability of the network and thus the configuration of cluster heads is unavoidable. This is an important issue since frequent cluster head changes adversely affect the performance of other protocols such as scheduling, routing and resource allocation that rely on it. The choice of the cluster heads is here based on the weight associated to each node: the smaller the weight of a node, the better that node is for the role of cluster head.

In [3], the authors have proposed a distributed weighted clustering algorithm by making some modifications and improvements on some existing algorithms. They demonstrated

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that their algorithm reduces the cluster head formation and control messages overhead thus improving overall performance and reducing energy utilization. Here, authors claimed that since energy utilization is the most important criteria in cluster based routing schemes, their protocol provides better results than existing distributed clustering algorithm.

In [4], the authors propose a Weight Clustering Algorithm (WCA). This algorithm selects a cluster head according to the number of nodes it can handle, mobility, transmission power and battery power. To avoid communications overhead, this algorithm is not periodic and the cluster head election procedure is only invoked based on node mobility and when the current dominant set is incapable to cover all the nodes. To ensure that cluster heads will not be over-loaded a pre-defined threshold is used which indicates the number of nodes each cluster head can ideally support. WCA is composed of two parts: cluster head selection and formation of cluster members' set. The first part finishes once all the nodes become either a cluster head or a member of a cluster head. In the second part, for two clusters to communicate with each other, the authors assume that the cluster heads are capable of operating in dual power mode. A cluster head uses low power to communicate with the members in its transmission range, and high power to communicate with the neighboring cluster heads because of greater range. The drawbacks of WCA are discussed in the following sections.

In [6], using a heuristic approach, the authors provided some interesting equations for the cluster density and cluster order of homogeneously distributed nodes running the DMAC algorithm [9]. Since the DMAC structure is unique, the equations also hold in a mobile scenario if the used mobility model retains the homogeneous distribution of the nodes. If the nodes are not homogeneously distributed, the cluster density will decrease. The authors claimed that the validity of their result is not restricted to the DMAC algorithm. It also holds for other algorithms that limit the cluster size to two hops.

In [1], the authors introduced a new type of algorithm called Enhancement on Weighted Clustering Algorithm [EWCA] to improve the load balancing and the stability in the MANET. The cluster head that is selected efficiently based on these factors like, high transmission power, transmission range, distance mobility, battery power and energy. Since the cluster head will not be changed dynamically, the average number of cluster formation will be reduced. By applying the load balancing factor, the overhead in the cluster is reduced.

Low Energy Adapted Clustering Hierarchy (LEACH) performs cluster head selection based on probability of equal load energy distribution [11]. In this way everyone has a chance to become cluster head depending on its energy residual. LEACH is said to focus on the problem of fixed or pre-deployed cluster head by introducing cluster head rotation. Clustering phenomenon and cluster heads in LEACH are selected on rotation from networks node and each nodes contend to become cluster head depending upon the residual energy. It was also stated that LEACH operates in two phase i.e. the negotiation phase and the steady state phase. 5% of nodes in the negotiation phase are CH and clusters are formed. In the steady state phase, member nodes sends message to their cluster head after defining their environments, the cluster head then aggregate the received data and sends it to the base station.

In [12], Sensor Protocol for Information via Negotiation was proposed (SINP). Unlike LEACH, SPIN also operates in two ways, i.e. negotiation phase and resource adaptation phase. Before transmitting data, SPIN node negotiates with each other to ensure the transfer of useful information only. The nodes describe the kind of data they observe for successful negotiation. In the resource adaptation phase, each node select its resource prior to communication. Every node has a resource manager which is responsible for keeping the resource and the use of these resources.

The motivation for the present work is three-fold. Firstly, some weakness in [3, 4, 6, 9, and 1] have been identified, where the authors declared that according to their notation, the number of nodes that a cluster head can handle ideally is bounded by a value. Secondly, another weakness in [3, 4, 6, and 9], was also identified, where the authors computed for every node the degree-difference to ensure that cluster heads are not over-loaded. Thirdly, the stability is overlooked in WCA.

This paper focuses on the improvement of a single cluster environment using the dual cluster head algorithm to reduce the number of re-clustering, end-to-end latency and network lifetime.

3 System Model

3.1 Dual Head Clustering Algorithm

Cluster Heads Selection

Assume that the numbers of nodes are set to M, and all the nodes are aware of the total number of node within the single cluster.

1) Each node calculates its weight by calling the weight calculation algorithm.
2) • Each node finds its neighbors and builds a neighbor hood table.
3) Each node broadcast its capacity, including current residual energy, free storage space and weight to its neighbors.
4) On receiving a cluster head message a node checks all the nodes from which it receive the message. The node with the maximum weight becomes the cluster head of that node.
5) Cluster head now select the next higher node with capacity lower than itself and higher than order nodes to be the Aggregator Head.
6) Random value between 0 and 1 is assign to each node and a threshold is taken.
7) If the random value assigned to a node is greater the threshold value, then set mobile = 1, otherwise 0.
8) If a node = 1, then set mobile = 0.
9) If mobile = 1, set value of direction randomly. Increment or decrement the value of x and y depending upon the direction to show mobility
10) In case a new node is added, it calculates its weight

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by calling weight calculation algorithm and repeats step 3, 4, 5.

11) In case cluster head fails, the algorithm is repeated.

Weight Calculation Algorithm

- Find connectivity c for each node which is the number of neighbors of each node.
- Find the energy e remaining for each node
- Compute mobility M for each node running average speed until the current time

$$M_v = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2} \qquad (1)$$

a) Compute the sum of distances d with all its neighbors for each node.

b) Calculate the combined weight W as:

$$W = w1 * c + w2 * e - w3 * M + w4 * d \qquad (2)$$

Distributed Information Directory on Mobility

A node must send hello packet at fixed intervals to its current cluster head in order to keep the cluster head and aggregator head up to date.

- If a cluster head fails to collect a hello packet in three consecutive times, then it assumes the node has left or disconnected from the network.
- When a node moves to a new cluster environment, it register itself and the new cluster head broadcast the ID of its newest member to other cluster heads in different cluster environment.
- If the old cluster head receives a broadcast message with its old member ID, then it routes the pending query reply to the new cluster head for delivery.
- If no further reply of that object remains in the old cluster head then it flushes all related information from its LRC, and sends un-register message to the replica keeper to update its GRC.

4 Simulation Result

In the simulation environment, DHCA assumes an error free error free communication. This paper has simulated an existing system that uses a single cluster head and that of the proposed system which uses a dual cluster head. Both systems where compared to show that the proposed system is more efficient in terms of energy efficient data aggregation in MANETs. Table 1 below showcased the parameter used in the simulation.

TABLE 1
SIMULATION PARAMETERS

Scenario dimension	1000 x 1000
Traffic Application	CBR
Antenna Type	Omni-Antenna
Transport Protocol	TCP
Number of nodes	200
Wireless MAC interface	IEEE 802.11
Propagation model	Two way ground
Packet size	2000 (bits)

A. Network Life Time

Network life time is the time between the deployment and the destruction of a network. The graph for the number of nodes alive in a single cluster verses number of rounds using LEACH, and DHCA is shown in Figure 1. It is obvious from the graph that as time passes the number of nodes alive is more in DHCA than LEACH. This occurred because of the load balancing among nodes when the Aggregator Head was introduces into the single cluster environment.

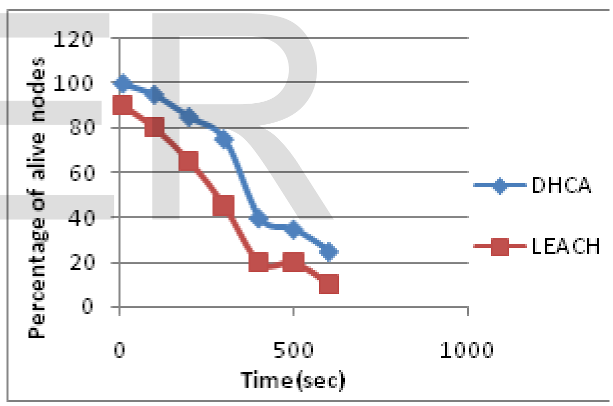

Fig.1. Network Life Time

The DHCA cluster head is maintained longer than that of a single cluster head (LEACH) because the proposed system provides load balancing, and reduces the number of data propagation which causes increase in network life time.

B. Cluster Head Life Time

Cluster head life time is the time a node remains as the cluster head within the network after it has been elected as the cluster head. The graph for residual energy of a single cluster head verses time using, DHCA and LEACH is shown in Figure 2. It is apparent that as time proceeds, the CH in DHCA conserves more energy than LEACH; this is because of the introduction of AH. On the other hand, LEACH only uses a single cluster head for coordinating data within the group cluster.

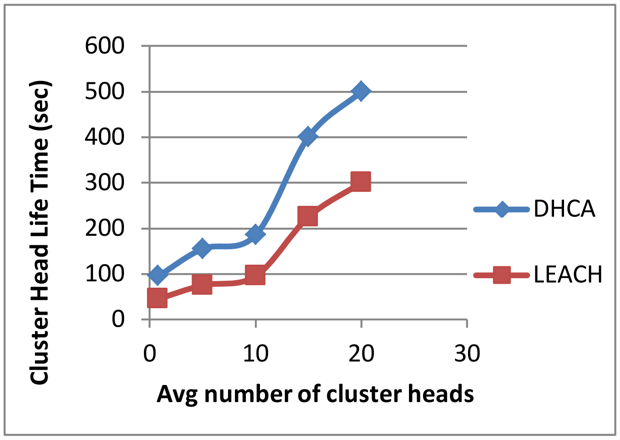

Fig. 2. Cluster Head Life Time

C. Network Latency
Network latency is the amount of time taken by packet to reach its destination. Figure 3 shows that DHCA performs with low latency as compare to that of a single cluster (LEACH). The network performance was improved and this was as a result of using two different heads within a single cluster environment. The cluster head acts like a router and is not burden with data collection and aggregation which was taken care of by the aggregator head. Therefore, congestion at cluster head in DHCA is low which results in low latency. The Figure 3 clearly shows the low latency graph of the DHCS as compared to LEACH.

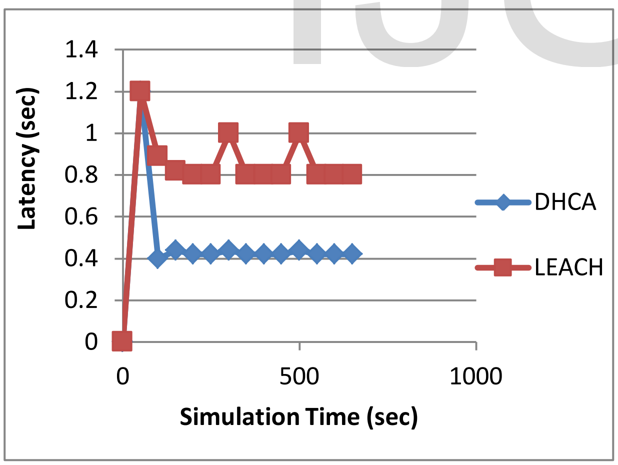

Fig.3. Network Latency

D. Network Average Energy
Average node energy is the amount of energy consumed by all nodes divided by the number of nodes within the network. The average node energy consumed with the passage of time is shown in Figure 4. It is comprehensible from the graph below that the DHCA consumes less energy as compared to LEACH. The overhead of frequent re-clustering is very low in DHCA but high in LEACH because the single cluster head in LEACH is responsible for a number of activities, such as data gathering, data aggregation and data forwarding. As a result, the CH depletes its energy quickly as compared to its member nodes. Hence, re-clustering is required frequently, which consumes considerable energy.

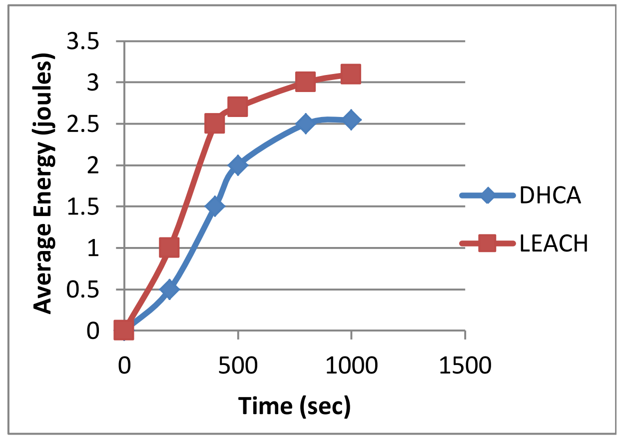

Fig.1. Network Average Energy

5 Conclusion

Our main contribution to this paper is that of an optimized Dual Head Clustering Algorithm (DHCA) which is based on an existing clustering scheme. The introduction of this algorithm, stated in section III can reduces the frequency of re-clustering and end-to-end latency in a single cluster environment.
DHCA concept was introduced for an efficient data aggregation in cluster based environment. This algorithm was used to select an efficient dual heads cluster within a single cluster environment. It calculates the weight, and performs distributed directory information on mobility of nodes for appropriate routing. The DHCA employs two cluster heads; Cluster Head and Aggregator Head. Both heads divide the duty of single head among each other. The jobs of the CH are cluster maintenance, and data forwarding, while the duties of AH is to collect data from the field via cluster members and aggregate the collected data for transmission. In the selection process, the CH is selected for a specified period of time.
After proper consideration and observation of both existing and proposed system, our simulation results have shown that DHCA i.e. the proposed system outperforms conventional protocols i.e. existing system, in terms of cluster head life time, network life time, network average energy, and network latency. This algorithm is only limited to a single cluster environment but for the future work, it can be extended in other accommodate scalability. The Distributed Information Directory on mobility could also be enhanced to avoid possible overhead.

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