SCAM: Scenario-based Clustering Algorithm for Mobile Ad Hoc Networks

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Abstract*—This paper proposes a scenario based, adaptive and distributed clustering algorithm SCAM (Scenario-based Clustering Algorithm for Mobile ad hoc networks). A distributed algorithm based on $(k, r) - Dominating\ Set$ is used for the selection of clusterheads and gateway nodes, here k is the minimum number of clusterheads per node in the network and r is the maximum number of hops between the node and the clusterhead. From among the k dominating nodes, the non-clusterhead node can select the most qualified dominating node as its clusterhead. The quality of the clusterhead is calculated based on various metrics, which include connectivity, stability and residual battery power. Long-term service as clusterhead depletes their energy, causing them to drop out of the network. Similarly, the clusterhead with relatively high mobility than its neighbours leads to frequent clusterhead election process. This perturbs the stability of the network and adversely affects the performance of the network. Load balancing among clusterheads and correct positioning of clusterhead in a cluster are also vital to increase the life span of the network. The proposed algorithm periodically calculates the quality of all dominating nodes and if it goes below the threshold level it resigns the job as clusterhead and sends this message to all other member nodes. Since these nodes have k dominating nodes within $r - hop$ distance, it can choose the current best-qualified node as its clusterhead. SCAM uses techniques to maintain the cluster structure as stable as possible with less control messages.

Keywords: Ad Hoc Networks, Clusterhead, Scenario-based, Cluster Management, Dominating set, Local stability.

I. INTRODUCTION

Ad hoc networks are wireless, infrastructure less, multi-hop, dynamic networks established by a collection of mobile nodes. This type of network is highly demanding due to the lack of infrastructure, cost effectiveness and easiness in installation. Mobile ad hoc network (MANET) has many emerging applications, which include commercial and industrial, war front applications, search and rescue operations, sensor networks and vehicular communications. The major issues in cluster based MANETs are (i) mobility management (ii) topology assignment (iii) clustering overhead (iv) frequent leader re-election (v) overhead of clusterhead (vi) depletion of battery power (vii) security and (viii) Quality of Service (QoS).

Destination Sequenced Distance-Vector (DSDV) [15], Dynamic Source Routing (DSR) [16] and Ad hoc On demand Distance Vector (AODV) [17] are some popular protocols proposed for multi-hop routing. These flat routing schemes suffer from scalability problems. The signaling overhead of the routing algorithms based on proactive and reactive routing schemes increase with the size and mobility of the network. The expensive message flooding schemes for route discovery and maintenance can be reduced in hierarchical routing with clustering. With clustering, the mobile nodes are divided into a number of virtual groups called clusters. Nodes in a cluster can be of type clusterhead, gateway or ordinary node. The clusterhead is the coordinator for the operations within the cluster. Cluster based virtual network architecture requires many information exchanges to perform routing as well as to create and maintain clusters. A stable clustering algorithm should not change the cluster configuration frequently. The advantages of clustering include (i) shared use of application within the group (ii) provision for optimization in routing mechanism (ii) efficient handling of mobility management (iv) spatial reuse of resources (v) virtual circuit support (vi) better bandwidth utilization (vii) aggregation of topology information and (viii) minimize the amount of storage for communication [21].

In this paper we propose a distributed Scenario based Clustering Algorithm for Mobile ad hoc networks (SCAM). In this algorithm, the clustering set up phase is accomplished by a distributed $(k, r) - Dominating\ Set$ finding algorithm for choosing some nodes that act as coordinators of the clustering process. While selecting the dominating nodes, redundancy is achieved by choosing the value of parameter k greater than one and parameter r allows increasing local availability. These two parameters can be conveniently set depending on the requirement. Dominating nodes are potential nodes to become clusterheads and during the cluster formation phase, the ordinary nodes select their best as the clusterhead. This selection is based on quality, which is a function of parameters such as stability of the dominating node with respect to its neighbors, remaining energy with the node and connectivity. Selection of clusterhead based on these parameters help in maintaining the structure of the created cluster as stable as possible thus minimizing the topology changes and associated overheads during clusterhead changes.

The rest of the paper is organized as follows. Previous work done in the area of cluster based routing is reviewed in Section II. Section III discusses the design issues. Section IV presents details of the SCAM algorithm. Section V deals with cluster formation and management. The performance of the algorithm is evaluated in Section VI. Finally, Section VII concludes this paper.

II. Related Works

A number of clustering algorithms for mobile ad hoc networks have been proposed in the literature. In Link Cluster Algorithm [1], the clusterhead selection is based on the highest identity number among a group of nodes (each node is identified by a unique number). The Lowest-ID algorithm [2] and Maximum-connectivity algorithm (or H-DEGREE) [3] are two earlier popular algorithms in which the clusterhead selection is on the basis of the lowest virtual identification number and maximum number of neighbour nodes, respectively. These two metrics alone are not sufficient for the selection of clusterhead in a dynamic environment. Many modifications to these algorithms were proposed to make the clusterhead selection and cluster management more stable and power efficient. The Least Cluster Change (LCC) [6], 3hBAC (3-hop Between Adjacent Clusterhead) [7] and Lin and Gerla's algorithm [8] are examples in this category.

One of the prominent characteristics of MANET is its mobility [18, 20]. Prithwish Basu [4] proposes the MOBIC routing algorithm in which each node calculates the relative mobility values with respect to the neighbouring nodes and these values are considered for the clusterhead selection. Another major challenge in the MANET performance is the energy limitation. Energy depletion leads to partitioning of networks and interruption in communication. Ryu [5] proposes an energy conservation-clustering scheme. To provide pseudo optimum power saving clustering, he proposes two heuristic schemes, namely, single phase and double phase clustering schemes. All the above algorithms create clusters in such a way that the maximum distance between any two nodes in the cluster is at most two hops. Such types of algorithms are more suitable for MANETs, where the nodes are densely organized and they form large number of clusters.

In DCA (Distributed Clustering Algorithm) [22], a new weight based criterium is introduced for the selection of clusterhead. In DCA, each node is assumed to have a unique weight but the technique of assigning weights has not been discussed. Stefano Basagni [22] introduces a distributed algorithm that partitions the nodes of a multi-hop wireless network into clusters. The algorithm is proved to be adaptive to changes in the network topology. Distributed Mobility Adaptive Clustering (DMAC), Generalized-DMA [24], Backbone Protocol [25] are evolutions of the above category. Stefano Basagni et al [21] provide a thorough simulation based comparison of some of the most representative ad hoc clustering protocols. Rituparna Ghosh et al [26] explore the impact of node mobility on DMAC. They consider various mobility models such as Random Way Point, Random Walk and Manhattan models. Weighted Clustering Algorithm (WCA) [23] is a combined weight metric based clustering approach to form single hop clusters. All nodes in the network have to compute their weights and have to know the weights of all other nodes before starting the clustering process. This process can take a lot of time. Also limiting the cluster dimensions to single hop reduces the scalability for large scale networking environment.

An important issue in wireless ad hoc and sensor networks is the selection of nodes to form a virtual backbone that supports routing. Selection of clusterhead and gateway nodes is crucial since they are the service providers of the network. Single clusterhead concept enforces over work for the clusterhead in the communication process. Using more than one clusterhead for a single cluster can reduce this overloading. In dominating set based clustering, the dominating nodes work as the clusterheads to relay routing information and data packets. Wu [9] proposes a distributed algorithm to find a Connected Dominating Set to design efficient routing schemes for a MANET. Chen et al. [10] present independent dominating sets for computing clusters such that the minimum distance between the clusterheads is $k+1$ hops from each other. Spohn et al. [11] explore KR and Distributed-KR (DKR) algorithms for the $(k, r)-Dominating\ Set$ problem. KR is a centralized solution and is appropriate for wired networks (requires that the entire topology be known), whereas DKR is a distributed solution. The $(k, r) - DS$ problem is defined as the problem of selecting minimum cardinality subset D of vertices V of a graph $G = (V, E)$, such that every vertex v not in D is at a distance less than or equal to r from at least k vertices in D.

III. Design of Scenario based clustering

In this section we present the concepts and design of Scenario-based Clustering for MANETs.

A. Basic Concepts of Scenario Based Clustering

A MANET is represented using a graph $G = (V, E)$, where V represents a set of wireless mobile nodes and E represents a set of edges. An edge between two nodes indicates that both are within their transmission range. The first step in this algorithm is finding out the $(k, r) - DS$. A distributed algorithm is preferred for the computation of $(k, r) - DS$. The two parameters used here are k and r, where k represents the minimum number of clusterheads per node and r is the maximum distance between nodes and their clusterheads. There are many approximation algorithms for finding the dominating set [11] and connected dominating set [12, 13] of nodes in a MANET. The problem of finding $(k, r) - DS$ of minimum cardinality for arbitrary graph is NP-complete [14]. A centralized solution for finding $(k, r) - DS$ can be used if all nodes in the network know the topology of the network. Distributed algorithms are suitable for synchronous and asynchronous networks [11]. Nodes in $(k, r) - DS$ are potential candidates to become clusterhead. The cost of finding $(k, r) - DS$ is a function of n, d and r, where n is the total number of nodes in the network, d is the maximum value of node degree and r is the distance parameter.

The second step is finding the quality of dominating nodes using various metrics such as degree of the dominating node, battery power and mobility of the dominating node with respect to the neighbouring nodes. Bi-directional connectivity between nodes and capability of nodes in measuring its signal strength are assumed for all nodes.

The degree of the node v is the total number nodes within the transmission range of v. The degree of v, DG_v is computed using the formula

$$\sum_{u \in V, u \neq v} \{D_{uv} < T_x, transmission\ range\} \tag{1}$$

A dominating node with high residual battery power, B_v, can perform well as clusterhead for a longer duration. Hence residual battery power is a better measure than consumed battery power [18] or the cumulative time during which the node acts as clusterhead [23]. But long-term service as a clusterhead can cause reduction in the battery power and hence B_v of the current clusterhead is to be calculated periodically. This is essential because if it goes below a certain threshold level, all member nodes need to select the next qualified dominating node as the new clusterhead if possible, otherwise a new dominating set finding step is to be initiated. Our objective is to avoid the total collapse of the current network topology and reduce the number of clusterhead elections and cluster formations.

The third metric is the mobility of the node. To compute this, each node in the dominating set needs to find out the distance from its neighbouring nodes. For distance computation, Friis [19] free space propagation model is used.

The received power, P_r

$$P_r = P_t * G_t * G_r * \frac{\lambda^2}{(4 * \pi * R)^2} \tag{2}$$

P_r- power received by the receiving antenna, P_t- power input to transmitting antenna, G_t and G_r- gain of transmitting and receiving antennas, λ- wavelength, R- distance. P_r is inversely proportional to the square of distance.

Instead of finding the exact physical location, an approximate distance at time t between nodes v and u is calculated from (2).

$$D_t^{v,u} = \frac{k}{\sqrt{P_r}}, \tag{3}$$

where $v \in$ dominating set DS, u is an element of set of neighbouring nodes of v and k is a constant. $D_t^{v,u}$ is the distance between v and u at time t. Relative mobility between v and u indicates whether they are coming closer to or moving away from each other. The relative mobility of node u with respect to v at time t is as shown in (4).

$$RM_t^{v,u} = D_t^{v,u} - D_{t-1}^{v,u} \tag{4}$$

$RM_t^{v,u}$ is positive, if the node u is moving away from v and negative if u is coming near to v. Distance from v to u is measured at certain time interval for N times and $RM_1^{v,u}, RM_2^{v,u}, ...RM_N^{v,u}$ are calculated. The standard deviation of relative mobility gives the variation of distances over a time period, T as

$$SDRM = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(RM_i - \overline{RM})^2} \tag{5}$$

where

$$\overline{RM} = \frac{1}{N}(RM_1^{v,u} + RM_2^{v,u} + ... + RM_N^{v,u})$$

The local stability of a node $v \in$ dominating set DS, $LSTAB$, with respect to all its neighbours is the mean of standard deviation of relative mobilities of all its neighbouring nodes. A low value of this is an indication of a stable node. This stability is either due to less mobility or due to group mobility (the node v and all its neighbouring nodes move in the same direction with more or less same velocity). Inverse of $LSTAB$ is $ILSTAB$. The quality of a node in the dominating set to work as a clusterhead is computed using (6).

$$Q_y = W_1 * DG_v + W_2 * B_v + W_3 * ILSTAB \tag{6}$$

here W_1, W_2 and W_3 are weights associated with various factors affecting the quality. Suitable values can be assigned to W_1, W_2 and W_3 based on the required application.

B. Design Principles

The proposed algorithm, SACM is a dominating set based, adaptive and scenario based clustering algorithm. The main objective of this algorithm is the creation of clusters in such a way that they are stable for a reasonable amount of time. A stable cluster formation avoids frequent clusterhead election process and thereby reduces the overhead involved in this process. For creating a stable cluster, the clusterhead election scheme must be designed in such a way that the elected clusterhead can do its job for a long period. To select the most powerful node as clusterhead, various parameters are to be considered.

The first parameter is the degree of a node. The degree of a node is high if it has more number of nodes within its transmission range. The position of the clusterhead is relevant in the cluster-based approach. A node with high degree is an indication that it is centrally located. A large cluster may put too heavy load on the clusterhead and reduces system throughput. However, small clusters increase the size of the backbone structure. Hence setting upper and lower limits on the number of nodes connected to a clusterhead are important for load balancing.

The second parameter is the residual battery power of the clusterhead. Since the clusterheads play the leading role in the communication process, their energy consumption is more compared to the ordinary nodes. The "earlydeath" of clusterhead increases the number of clusterhead elections, which increases the traffic of control packets in the network. Therefore a node with sufficient battery power is to be selected as clusterhead to reduce the amount of overhead incurred due to clusterhead re-election and to avoid nodes dropping out of the network prematurely. Stability of clusterhead is another important parameter in selecting the clusterhead. Selection of a less mobile node as clusterhead considerably reduces the number of re-affiliations. The weighted sum of these metrics determines the quality of the dominating node. Depending on the requirement different weight values can be associated with stability, degree and the residual battery power. In SCAM dominating nodes alone have to compute its quality.

The parameter r determines the diameter of the cluster and the parameter k determines the number of clusterhead per node. Among the k dominating nodes, each node can select the most powerful dominating node as its clusterhead. On the failure of the clusterhead due to its mobility, low battery or link failure, each member node re-affiliates to the next powerful dominating node. This local re-affiliation increases the lifespan of the network before requiring a backbone re-computation.

IV. Scenario based Clustering Algorithm for Mobile ad hoc Networks

Major steps of the algorithm are as follows:

1) Find $(k, r) - Dominating\ set$ using any greedy approximation algorithm.
2) Dominating nodes computes its quality by assigning various weights to different parameters such as degree of the node, battery power and mobility.
3) Dominating nodes send the message containing the quality to other nodes within r-hop distance.
4) Each node in the network other than dominating nodes, selects the most qualified dominating node as its clusterhead. They send NODE_JOIN_REQ (NJ) message to the most qualified node.
5) On receiving the NODE_JOIN_REQ message, the dominating node accepts the request by sending NJ_ACK packet if the degree (number of accepted cluster members) of that dominating node does not exceed the threshold.
6) If a dominating node does not receive any NODE_JOIN_REQ message for a specified time interval it can select the most qualified dominating node within r-hop distance as its clusterhead and can join with that cluster (Cluster merging). But the status of this node is quazi-dominating and can change to dominating node when required. This is possible only if that dominating node has k other dominating nodes within r-hop distance. This will reduce the total number of clusters created.
7) If the ordinary node does not receive any NJ_ACK messages within the stipulated time it can send NJ message to the next qualified dominating node within r-hop distance.
8) If a node does not receive any NJ_ACK messages even after k attempts and if it does not receive any new CLUSTER_HEAD_ADVERTISEMENT (CHA) message during the above period then that node can declare itself as a clusterhead.
9) In case of clusterhead failure or if the battery power of the clusterhead goes below the minimum desired level, clusterhead sends this using CHA message. All the nodes attached to that clusterhead select the next qualified dominating node as its new clusterhead.

The pseudocode for SCAM cluster formation is

```
procedure SCAM_CLUSTER_FORMATION
    call Find_Dominating_Set( G, k, r )        ▷ select suitable values for k and r
    if (STATUS == Dominating) then
        Broadcast_ FIND_NEIGHBOUR();           ▷ with TTL = r
        Start_Find_Neighbour_Timer();
    end if
    if ((Packet_Received == FIND_NEIGHBOUR) and
     (TTL(Packet_Received) >= 0) and
     (STATUS == Dominated)) then
        Send_FN_NEIGHBOUR_ACK(CACHE_PATH);
        Start_Fn_Ack_Timer();
    end if
    while (Find_Neighbour_Timer() <= FN_TH) do
        if ((STATUS == Dominating) and
        (Packet_Received == FIND_NEIGHBOUR_ACK)) then
            Update_Neighbour_List();
        end if
        if (Find_Neighbour_Timer() >FN_TH)
        and ((STATUS == Dominating)) then
            Compute_Quality();
            Create_CHA_Packet();
            Multicast_CHA_Packet(Neighbour_List);
        end if
    end while
    while (Fn_Ack_Timer()<= FN_TH) do
        if (((Packet_Received == CHA)
        and (STATUS == Dominated)) then
            update_Cluster_Head_List();
        end if
        if ((Fn_Ack_Timer() >FN_ACK_TH)
        and ((STATUS == Dominated)) then
            Cluster_H = Find_Most_Qualified_Node(Cluster_Head_List);
            Send_NJ_Packet(Cluster_H);
        end if
    end while
    if ((Packet_Received == NJ)
        and (STATUS == Dominated)) then
        if (DEGREE <Thresh_degree) then
            Send_NJ_ACK();
            Update(Cluster_member);
            Increment DEGREE;
            Start_NJ_Ack_Timer();
        end if
    end if
    while (NJ_Ack_Timer() <= NJ_ACK_TH) do
        if ((Packet_Received == NJ_ACK)
        and (STATUS == Dominated)) then
            Update(Current_CH);
            Start_CH_Timer();
        end if
    end while
    if (NJ_Ack_Timer()>NJ_ACK_TH) then
        Cluster_H=Find_Next_Qualified(Cluster_Head_List);

        Send_NJ_Packet(Cluster_H);
    end if
end procedure
```

Consider the example shown in figure 1. Which is an arbitrary network consists of 15 nodes. Apply the first stage of the algorithm, which is for finding dominating set. Using $(k, r) - DS$ algorithm with parameter (2,2), the dominating nodes are C, F, L, H and O. These nodes can act as clusterhead nodes. Each non-clusterhead node has at least 2 clusterhead nodes within 2-hop distance. Node A has three dominating nodes (H, C and F) within 2-hop distance. Instead of considering H, C and F as clusterhead nodes, only the node with best quality is selected as clusterhead for node A. Figure 2 shows the cluster formation in SCAM.

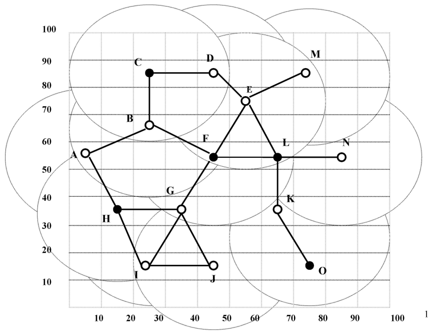

Fig. 1. (2,2)-DS of the network

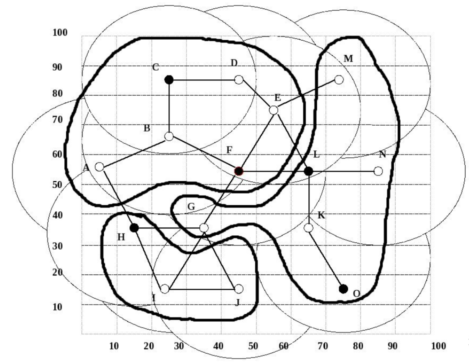

Fig. 2. Cluster Formation using SCAM

V. CLUSTER FORMATION AND MANAGEMENT

The clusterhead computation, assignment of clusterhead and cluster maintenance are discussed in this section.

A. Computing the cluster head

The dominating nodes send FIND_NEIGHBOR packets to all neighbouring nodes within r-hop distance. On receiving FIND_NEIGHBOR packet from dominating node, each node within r-hop distance sends N number of FN_NEIGHBOR_ACK packets one in each round. The details of these packets are used for the calculation of quality of the dominating node. The dominating node waits for $2r$ + $(N-1)$ rounds after sending FIND_NEIGHBOR packet (where N is the number of time slots which is used for calculating local stability of dominating nodes) and then compute its quality. A dominating node uses a list to store the details of all neighbouring nodes within r-hop distance and creates the Neighbour_List data structure. After computing the quality of the clusterhead it advertises its quality by sending the CHA (CLUSTER_HEAD_ADVERTISEMENT) packets.

B. Clusterhead Assignment

Cluster heads periodically send CHA messages to prove its presence. On receiving the CHA messages, the ordinary nodes create/modify its Clusterhead_List. Nodes those are able to hear the CHA select the clusterhead with the highest quality and send NODE_JOIN (NJ) request to the selected cluster head. If the total number of nodes attached with that clusterhead is below the maximum allowable number then the clusterhead accepts this request and sends NJ_ACK packet. The NJ_ACK packet with STATUS true indicates successful clusterhead assignment. Otherwise, the node should send the NJ message to the next qualified node.

C. Cluster Maintenance

Whenever a new node is switched on, it waits for CHA packets. There are two possible cases depending on the number of CHA packets received.

Case 1: If the number of CHA packets received with different N_ID is greater than or equal to k, then the new node selects the most qualified node as its clusterhead and sends NJ packets to the selected clusterhead. If the new node receives at least one pair of CHA packets with different Cluster ID then this node acts as a gateway node.

Case 2: If the number of CHA packets received is less than k then the new node acts as a clusterhead and enters into the quality finding state.

All dominating nodes have a list of neighbours within r-hop (stored in its Neighbor_List data structure) and it can broadcast its quality. Non-dominating nodes select the most qualified dominating node among k of such a set as its clusterhead. The selected dominating node continues to act as clusterhead only if it has the best quality. The member nodes of any cluster re-affiliate to another clusterhead if its quality is greater than the current clusterhead. This improves the load balancing among the clusterheads.

VI. PERFORMANCE EVALUATION

The performance of SCAM is evaluated through simulations. Various parameters used for the simulation are listed in TABLE I. The IEEE 802.11 has been used as MAC layer. Nodes in the simulation move according to Random Waypoint Model. It is assumed that each clusterhead can handle a maximum of 7 nodes without much degradation in the performance of the system (according to blue tooth specification). But this number can be suitably adjusted depending on quality and data rate of the clusterhead and the system requirement. The values assumed for k and r are $k = 1$ or 2 and $r = 1, 2, 3$ or 4. Suitable values are assumed for W_1, W_2 and W_3. The highest weight is assigned for mobility and lowest weight for degree. These values can be adjusted depending on the various scenarios.

It is observed that the number of dominating nodes increases with the increase in total number of nodes as shown in Fig. 3. The number of dominating nodes created decreases with increase in the cluster diameter. This is because with increase in the value of r, more number of nodes is covered. When the

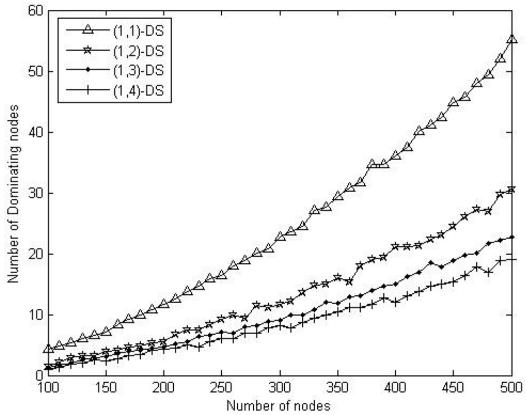

Fig. 3. Number of dominating nodes for k = 1 and r = 1,2,3 and 4

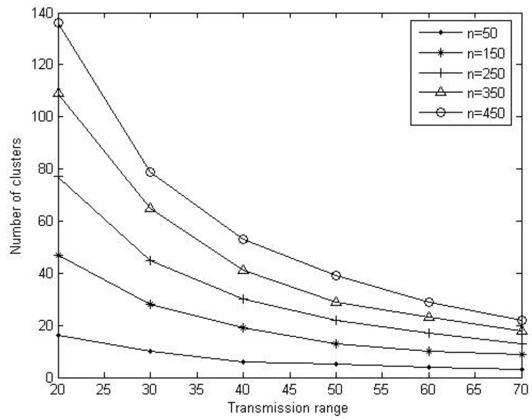

Fig. 4. Transmission range Vs No. of clusters

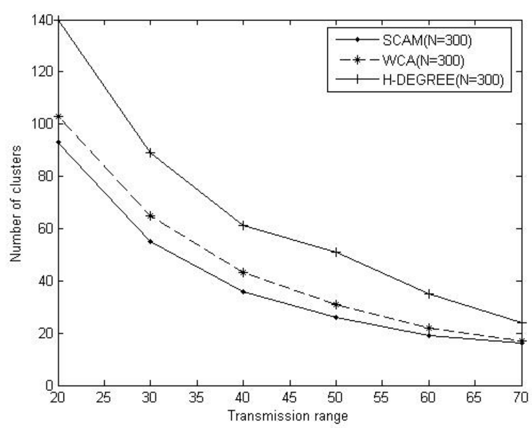

Fig. 5. Number of clusters in SCAM, WCA and H-DEGREE

value of r is increased from 1 to 2, the number of dominating nodes is reduced by 51%, which results in the reduction of total number of clusters created.

Fig.4. shows the average number of clusters is relatively high when the transmission range is small. When the transmission range increases, more and more nodes are connected to the same clusterhead and thereby reduces the number of clusters created. A smaller backbone is desirable for minimizing the routing overhead. Hence in heterogeneous environment the transmission power of a node can also be considered to find the quality of dominating nodes.

TABLE I
SCAM PARAMETERS

Parameter	Value in SCAM
Number of nodes	10-500
Network Size	100 X 100 m^2, 500 X 500 m^2
Transmission Range	10m-150m
Max Speed of Node Movement	20 m/sec
W_1, W_2 and W_3	$0.5, 0.3$ and 0.2

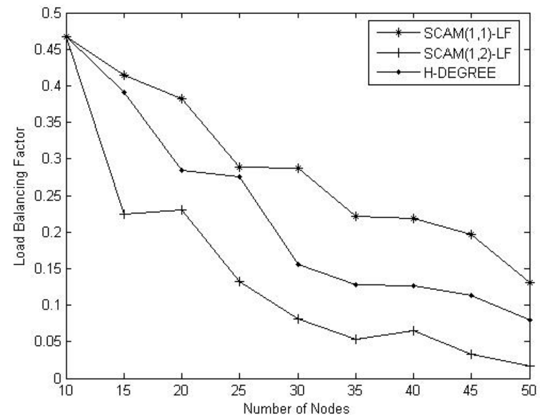

Fig. 6. Load balance factor in SCAM and H-DEGREE

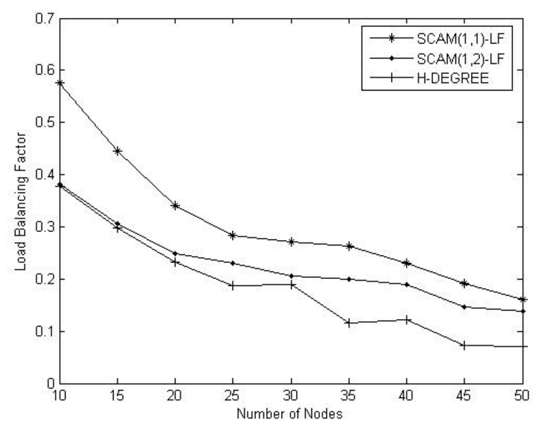

Fig. 7. load balancing after putting a limit on member nodes

Fig. 5. shows the number of clusters formed for SCAM, WCA and H-DEGREE as a function of transmission range. SCAM (with k = 2 and r =2) creates less number of clusters compared with WCA and H-DEGREE. This is because SCAM forms less number of clusters with increase in the value of r. But increase in the value of r leads to increase in cluster size, which adversely affects the performance. So selection of r is critical.

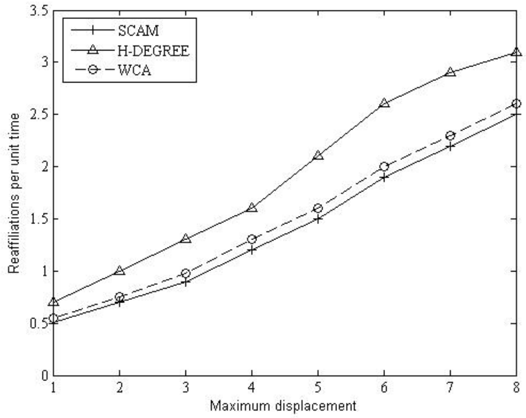

Fig. 8. Number of re-affiliations per unit time

The algorithm achieves load balancing by assigning various time slots for the different clusterheads based on its quality and by specifying an agreeable threshold on the number of nodes that a clusterhead can handle. Fig. 6. shows the Load Balancing Factor for SCAM with $k = 1$ and $r = 2$, SCAM with $k = 1$ and $r = 1$ and H-degree (Maximum connectivity). The LBF is the inverse of the variance of the cardinality of the clusters [23]. A higher value of LBF signifies a better load distribution. Fig. 7. shows the effect of putting a limit on total number of nodes that a clusterhead can handle. This mechanism is used to prevent the clusters from growing too large and clusterhead can manage its cluster members without much degradation in the performance. SCAM algorithm out performs because SCAM is multi-clusterhead and bounded distance clustering algorithm.

The created clusters preserve its structure for a longer period than highest connectivity algorithm. It is observed that the number of re-affiliations increase with increase in number of nodes and higher values of displacement as shown in Fig. 8. Hence the number of clusterhead election process invoked is less in SCAM compared with WCA and H-DEGREE.

VII. Conclusion

In this paper we proposed a scenario based, adaptive and distributed clustering algorithm SCAM. The goal of the proposed protocol is to create clusters in such a way that the created clusters remain stable over a long period of time. The clusterhead election in this algorithm is based on the $(k, r) - Dominating\ Set$ computation. To achieve scalability SCAM allows variable diameter clusters (with the parameter r) and clusterhead redundancy (with the parameter k). Suitable values are assigned to parameters k and r depending on node density of the network and application. The selection of clusterhead is based on its quality, which is a function of its degree, residual battery power and stability. Different weights are assigned to each parameter depending on the application. Our approach is adaptive in nature as it adapts easily to the dynamic topology of the network as well as the node density of the network. Proper load balancing is achieved by putting a limit on the maximum number of nodes a clusterhead can handle and re-affiliation with another clusterhead based on the quality. The algorithm is scenario based as it creates stable clusters by accepting various parameters and weights.

SCAM uses techniques to maintain the cluster structure as stable as possible with less control messages. In SCAM, intra-cluster routing requires a table driven strategy and inter-cluster routing is on demand basis. SCAM outperforms H-DEGREE and WCA algorithms in terms of number of re-affiliations. The reduction in number of re-affiliations improves the stability of the network topology under different scenarios.

Incorporating security, providing guaranteed quality of service and enhancement for use in heterogeneous mesh networks are topics suggested for further research.

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