A ROBUST CLUSTER HEAD SELECTION BASED ON NEIGHBORHOOD CONTRIBUTION AND AVERAGE MINIMUM POWER FOR MANETs

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Abstract

Mobile Adhoc network is an instantaneous wireless network that is dynamic in nature. It supports single hop and multihop communication. In this infrastructure less network, clustering is a significant model to maintain the topology of the network. The clustering process includes different phases like cluster formation, cluster head selection, cluster maintenance. Choosing cluster head is important as the stability of the network depends on well-organized and resourceful cluster head. When the node has increased number of neighbors it can act as a link between the neighbor nodes which in further reduces the number of hops in multihop communication. Promisingly the node with more number of neighbors should also be available with enough energy to provide stability in the network. Hence these aspects demand the focus. In weight based cluster head selection, closeness and average minimum power required is considered for purging the ineligible nodes. The optimal set of nodes selected after purging will compete to become cluster head. The node with maximum weight selected as cluster head. Mathematical formulation is developed to show the proposed method provides optimum result. It is also suggested that weight factor in calculating the node weight should give precise importance to energy and node stability.

Keywords:

Adhoc Networks, Clusters, Stability

1. INTRODUCTION

Adhoc network is a collection of two or more electronic device equipped to connect with the help of wireless network able to communicate with the device in radio range or beyond the range through intermediate devices. Since it is self organizing and adaptive it takes different forms. The dynamic topology of the ad hoc network entails the multihop communication using different links. However nodes within the transmission range can communicate directly. Individual node movements cannot be predicted which leads to link breakage that also increases the overhead in the network. An additional problem is Selfish nodes. Thus a centralized controller is required for managing the instantaneous network. Since there is no back bone the centralized controller have to be selected and a subset of nodes in the networks should be monitored. Grouping of these nodes in ad hoc manners is called clustering.

With the coordination of nodes a special node is elected among them referred as cluster head. Electing the Cluster head involves many factors like energy, transmission range, memory capacity and prominently it should be in the range of another cluster head. A gateway node is used to connect with the inter cluster nodes i.e. communication between two clusters takes place with the help of gateway nodes. Reconfiguring the clusters is inevitable as the topology is highly unstable in nature. The distance between cluster head and members of the cluster will not be greater than one hop. Thus resource allocation like channel, bandwidth within the cluster is fulfilled by the cluster head.

Advantages of Clustering:

- Reduces the size of the routing table and better bandwidth utilization.
- Easy to implement localized scheduling algorithms
- Energy consumption is less
- Improves throughput and spatial reuse.

Issues of Clustering:

- Scalability of the network is uncertain.
- Requires more resource to evade gateway conflicts
- Cluster formation and maintenance demands high cost.
- The uneven power consumption between cluster members, gateway and cluster head may lead to reduced network lifetime.

2. RELATED WORK

Clustering techniques are used in most of the information technology problems. Clustering in MANETs is explicitly surveyed by Roberto Carlos Hincapi´e, et al [2]. Familiar clustering algorithms like Lowest-ID heuristic and Highest degree heuristic, k-CONID, Max-min d-cluster, MobDhop were chosen for review to endorse stability of the network. They also discussed about the optimization of routing and topology management. The primary concepts also reveal the importance of clustering techniques in MANETs.

A systematic classification of clustering algorithms is done by Ratish Agarwal and Dr. Mahesh Motwani [6]. They reviewed the methods to organize the network hierarchically. The parameters to be used for selecting the cluster head decide the stability of the network. The survey reveal significant problems involved with the computation and communication cost for electing the cluster head. Important aspects like energy consumption, cluster configuration, avoiding selfishness, choosing the acceptable head for evenly distributed traffic load are identified.

Clustering can be done in different ways using the information available in the network like neighborhood information, mobility information, topology information, energy information etc. Nevertheless maintaining and making this

information available throughout the network is an overhead and clustering based on single information does not harmonize with all the environments. Therefore it is advisable to contemplate and focus on weight based clustering algorithms. With the available information the weight calculated can be used to create the cluster. Momentous progress is that parameters applied in calculating the weight can vary with the environment and the available information. Thus the focus is on weight based clustering algorithms

Naveen Chauhan et al [7] proposed an optimized clustering algorithm by modifying the Distributed Weighted Clustering Algorithm for Mobile Ad Hoc Networks algorithm proposed by W. Choi and S. Adabi [1], [3]. The approach is based on combined weight metric. Node degree, transmission range, energy and mobility of the nodes are the parameters considered. If the number of cluster heads between source and destination is more it increases the hop count. To minimize the resource utilization minimum number cluster heads are chosen. Thus the algorithm reduced the energy utilization by reducing the overhead in configuring and applying the cluster. However opting for the cluster head is limited to single hop neighbors. Performance of the algorithm was evaluated through simulation in various network situations and the results show that proposed algorithm provides enhanced performance.

S.Karunakaran et al proposed service discovery architecture based on clustering. Power level, connectivity and stability were the features considered. Service discovery is limited to cluster member. Workload is distributed based on the availability of the resources. Therefore resource utilization is minimized. [8] They also proposed an adaptive weighted cluster based routing algorithm in which the node with minimum weight is chosen as the cluster head. When a node becomes the cluster head, the node or its members is marked as "considered". Then the election process is carried out with all "unconsidered" nodes. Once all the nodes have been considered the election algorithm gets terminated.

In [9] Zouhair El-Bazzal focused on the stability of the clusters. In a dynamic environment performance can only be improved by dissipating fewer resources for topology and cluster maintenance. Thus the proposed FWCA algorithm provides stable clusters with increased network life time. It is compared with the WCA and proves better performance. But does not consider the overheads generated and has not evaluated its impact on the network and in inter-cluster communications.

Yu-Xuan Wang et al. [10] proposed an improved weight based clustering algorithm. Entropy is used to ensure the stability of the network. The topology is well maintained by applying tabu search on entropy based WCA to find the near optimal dominant set. When a node breaks its link with the cluster it searches to reach other clusters. If a new cluster is found in its range then it enrolls with the new cluster. This process is called as reaffiliation. The proposed algorithm proved improved performance with respect to the original WCA, especially on the number of clusters and the reaffiliation frequency.

In [11] R. Pandi Selvam and V. Palanisamy 2- hop clustering algorithm claims to be more stable and flexible against topology changes but which requires more information during the cluster construction. The proposed algorithm also increases the number of nodes, transmission range and maximum displacement. Weight of each node is compared with 2-hop neighbors to elect the cluster head. Node with maximum weight will be considered as cluster head. They demonstrated that it outperforms than the existing LID, HD and WCA and increase the number of nodes, transmission range and maximum displacement.

In M. Rezaee and M. Yaghmaee proposed a protocol which uses clustering's structure to decrease average end-to-end delay and improve the average packet delivery ratio [12]. Routing is faster and reduced errors. Recreating of clusters is rarely executed. The simulation results show improvements in packet delivery ratio over traditional routing protocol and better performance than other routing algorithms.

In [3] Sahar Adabi et al proposed a new Distributed Score Based Clustering Algorithm (DSBCA). Linear algorithm is used find the cluster considering the parameters like energy, number of neighbors, stability. The electing the cluster heads is performed in a distributed manner with latest information about current status of neighbor nodes. The results of algorithm were compared with WCA and DCWA. The proposed algorithm outperformed existing algorithms in terms of end to end throughput and overhead considerably.

In [13] Amritha Sampath et al used ant colony optimization for choosing the cluster head. It is a combination of different approaches. ACO is particularly used to reduce the number of clusters. It is performed similar to finding the minimum dominating set in graph theory. With number iterations equal to number of nodes it is possible to find minimum number of cluster heads. Thus increased stability in the network

A node quality based clustering algorithm was proposed by [16] Mohamed Aissa et al. Al. They optimized the existing weight based clustering algorithms. Focus of proposed algorithm is on most inconsistent parameter node degree. Two models had been proposed the benefit of combining those models is exploited. They framed a node degree based stability and load balancing clustering parameters to improve the Quality of Service. It also overcomes the drawbacks present in the existing WCA algorithm.

A New Improved Clustering Algorithm Based on Cluster Congestion for Mobile Ad Hoc Networks was proposed by [18] Mohammad Shayesteh et al. Two stage cluster head selection was taken into account. Primary weight calculation is the first stage and relative mobility in present as well as future based weight calculation in the second stage. Thus it increases the lifetime of mobile nodes in the network. Threshold for number nodes to be accepted by a cluster head is assumed to improvise the MAC function but arriving to the threshold is difficult task as network changes with environment.

A Weight Cluster-Based Hybrid Routing Algorithm of ZigBee Network by [19] Yan Li et al. Heterogeneous nodes in the network differs in energy management. Therefore energy is considered for cluster head selection. A cluster-tree routing algorithm is used to optimize the local network. Latency and overhead is controlled by AODVjr algorithm. The results exhibit decreased energy consumption and increased network lifetime.

Danish Shehzad et al. [20] proposed An Enhanced Weight Based Clustering Algorithm for Mobile Adhoc Networks. The divergence in the algorithm is the parameters chosen for the

selection cluster head. Nodes is similar weights competes for the cluster head and randomly one of the node is selected but in the proposed algorithm hash function is used to select the cluster head when there are nodes with same weight.

Abbas Karimi et al [21] proposed A Novel Clustering Algorithm for Mobile Ad Hoc Networks Based on Determination of Virtual Links' Weight to Increase Network Stability. The adjacent node information is considered for weight calculation to improve the stability of the clusters. Virtual link weight is assessed that reflect on final weight of the node. Mathematical simulations deliver high availability. Simulations show that VLWBC algorithm increases the stability and decreases the energy consumption.

In this paper cluster formation based on weight of each node calculated using various parameters is discussed. Impact of energy and neighborhood contribution is analyzed. Mathematical formulation is revealed. Process in involving these parameters in selecting the cluster head is conferred.

3. CLUSTERING MODEL

Consider a graph G (V, E) with Vertices represents nodes n_i and Edges refers to links e_i. The weights of the edges wij is that flows from n_i to n_j of the graph. The nodes that are within the transmission range are considered as neighbors and number of neighbors to a particular node is Δ_i. where $d(n_i, ne_i)<$ transmission range of n_i. Neighborhood contribution percentage is $cp_{n_i} = \dfrac{1}{\Delta_i}$ provides the contribution of node n_i to its neighbor nodes.

3.1 NODE CLASSIFICATION BASED ON Δ_i

Robust nodes must be considered for cluster head selection that could stabilize the cluster, diluted nodes requires more number of clusters to be created which further increases the overhead. It is identified through the number neighboring nodes connected. A node can be identified as robust node if

$$\Delta_i >= C_i + P_{c_i} \ where \ C_i = (100\Delta_i Z + y_2)/(10yz) \tag{1}$$

Closeness C_i is obtained with, x = number of neighbors, y = total number of nodes, z = maximum no of clusters to be created. Proximity coefficient $P_{ci} = y/10z$. If $\Delta_i = 1$ then the node is called Gateway node.

3.2 ENERGY AND DISTANCE

Residual energy of a node is also an important factor to consider [15]. Possibly energy consumption could be classified as energy required for transmitting and receiving packets, in idle state and in sleep state. If EN_i is the energy consumption of node i then es_i is the energy consumed in each state by node i.

$$EN_i = \sum_i^m es_i \tag{2}$$

where, $es_i = ep_i * t_i$, ep_i energy consumed in a state and t_i time duration of a node in a particular state. The cost of each packet is calculated as cost = $m * size + b$, m is the incremental cost proportional to the packet size, b is channel acquisition cost.

The distance between two nodes can be determined by the Euclidean distance,

$$D_p = \sqrt{(N_{xi} - Nxj)^2 + (N_{yi} - N_{yj})^2} \tag{3}$$

where, N_i, N_j are nodes to find the distance.

3.3 MINIMUM ENERGY REQUIRED

The Average minimum power required to maintain the cluster stability is,

$$AMP = \frac{\sum_{i=1}^{n} \min(N_i)}{n} \tag{4}$$

$\min(N_i)$ is the minimum power required for a node to reach the cluster head, n is the number of nodes.

3.4 DISTANCE AND MOBILITY BETWEEN TWO NODES

The permanence of the link will also improve the solidity of the cluster. Each link's stability can be recognized by the displacement of the node and velocity of its dislocation. Each link's duration can be estimated [97] by,

$$LD = \frac{-(ab+cd) + \sqrt{(a^2 + c^2)r^2 - (ad - bc)^2}}{a^2 + c^2} \tag{5}$$

where, $a = v_i\cos\theta_i - v_j\cos\theta_j$, $b = x_i - x_j$, $c = v_i\sin\theta_i - v_j\sin\theta_j$, $b = y_i - y_j$ and v_i, v_j are speeds of mobility.

To determine the node's stability, some information from GPS is required. LD (Link Duration) is calculated and then reversed. Stability of the link between nodes,

$$N_s = e - LD \tag{6}$$

Smaller value of N_s gives more stable link. The final net weight is premeditated as,

$$NW_i = \sum_{i=1}^{np} (f_i * P_i) \tag{7}$$

where, $P = \{cp, N_s, EN_i, D_p, NV\}$, f_i is the weight factor of the particular parameter P_i and $\sum f_i$ is equal to one.

4. CLUSTER FORMATION

Step 1: Nodes will broadcast their weight to other nodes in the range

Step 2: Discover the cluster head

    2.1: Identify robust node by node classification using Δ_i

    2.2: Energy of the node should be greater than AMP

    2.3: Calculate the net weight of the nodes that satisfies 2.1 & 2.2

    2.4: Find the node with maximum weight.

    2.5: If the nodes with have same maximum weight then choose the node with maximum energy and less velocity.

Step 3: Broad cast the weight information

Step 4: Node with maximum weight will be selected as cluster head

Step 5: Cluster head broadcasts the information to neighboring clusters

Step 6: Cluster head identifies and updates the gateway nodes

Table.1. Node Weight calculation with the identified Parameters

Node No.	No. of Neighbors	Neighborhood Contribution %	Energy %	Node Stability	Distance	Velocity	Net Weight
n1	5	20.00	40	20	50	30	32
n2	2	50.00	60	40	40	60	52
n3	3	33.33	70	50	40	40	46
n4	4	25.00	30	40	20	30	29
n5	4	25.00	50	60	30	80	49
n6	4	25.00	70	70	50	70	57
n7	4	25.00	90	80	80	60	67
n8	2	50.00	40	90	60	40	56
n9	5	20.00	30	40	70	50	42
n10	3	33.33	80	50	50	60	54
n11	4	25.00	90	60	50	80	61
n12	3	33.33	40	80	40	70	52
n13	2	50.00	60	70	20	80	56
n14	2	50.00	70	80	40	60	60
n15	3	33.33	50	60	50	30	44
n16	3	33.33	40	30	10	10	24
n17	4	25.00	90	40	60	50	53
n18	2	50.00	50	50	70	20	48
n19	2	50.00	60	80	80	30	60
n20	2	50.00	40	60	40	50	48

5. CLUSTER MAINTENANCE

1. A node leaves a cluster

   If a nodes leaves a cluster it should rejoin with another cluster by sending a request to new cluster heads. When acknowledgements from various cluster heads are received, node should join the cluster with in which the cluster head has highest weight among received replies.

2. A cluster head leaves a cluster, new cluster head can be elected in different ways

   a. New cluster head formation can be initiated and the process can be done from the scratch but that will an overhead to start from beginning.

   b. Cluster head about to leave can suggest a reliable node based on the legacy data available with the head but the reliability of the legacy data is an uncertain.

   c. In the previous cluster selection process the second highest can be selected but dynamic changes in the network does not allow us to use the legacy data

   d. Periodic updates of calculated weight from each node allow selecting cluster head at any instance but increase the computational cost, overhead and identifying the periodicity is a difficult task.

3. A Gateway nodes leaves a cluster, at worst case the network can be partitioned, topology reconfiguration has to be done for the entire network

6. RESULTS AND DISCUSSION

To choose the cluster head from set nodes, they are assessed with the parameters considered for calculating the weight.

The weight factor plays a vital role in calculating the weight when the nodes are homogenous. Table.2 shows high-quality nodes have higher weight than the other nodes.

Table.2. Identifying Robust Node with Minimum Required Energy

Node No.	No. of Neighbors	Closeness	Robust node	AMP	Eligible for Cluster Head
n1	5	3	Yes	No	No
n2	2	1	No	Yes	No
n3	3	2	Yes	Yes	Yes
n4	4	2	Yes	No	No
n5	4	2	Yes	No	No

n6	4	2	Yes	Yes	Yes
n7	4	2	Yes	Yes	Yes
n8	2	1	No	No	No
n9	5	3	Yes	No	No
n10	3	2	Yes	Yes	Yes
n11	4	2	Yes	Yes	Yes
n12	3	2	Yes	No	No
n13	2	1	No	Yes	No
n14	2	1	No	Yes	No
n15	3	2	Yes	No	No
n16	3	2	Yes	No	No
n17	4	2	Yes	Yes	Yes
n18	2	1	No	No	No
n19	2	1	No	Yes	No
n20	2	1	No	No	No

After identifying the robust nodes which is also above the AMP, the remaining nodes can be purged from the set. If AMP is 50% then in the above table nodes n3, n6, n7, n10, n11, n17 will be remaining in the set for selecting as cluster head shown in Table 2. Through scrutinizing the weight and broad casting it to the neighbors cluster head is selected.

It can be inferred from the Fig.1 when the importance is given to energy and optimum results for node stability can be obtained by recommending the precise nodes for cluster head selection.
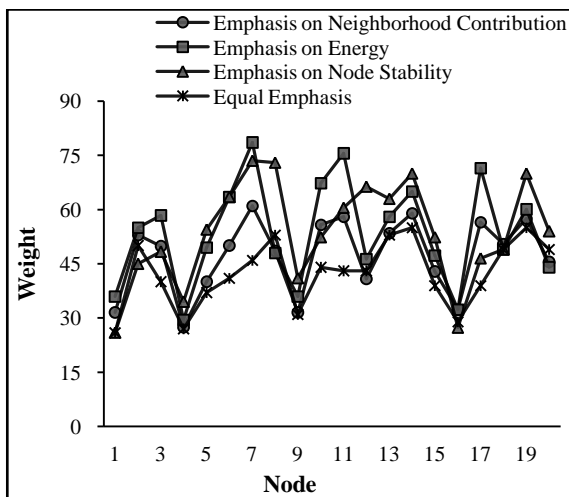

Fig.1. Impact of Various Parameters on Cluster Head Selection

7. CONCLUSION

Cluster head selection considering neighborhood contribution and average minimum power is proposed in this paper. Parameters considered for weight calculation contributed to the stability of the clusters. Although the requirement varies between different networks the weight estimation remains same and the weight factors can be changed to use the prominence of a particular parameter.

Avoiding the nodes which has less number of neighbors and energy compared to other nodes will reduce the overhead in selecting the head. It is made known that most optimum cluster head can be selected using the proposed method. Future work is to focus on route maintenance using optimization techniques.

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