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Comparison of Cluster Formation Algorithms Based on Fuzzy Logic Rules

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Abstract: ***In Mobile Ad-hoc Networks (MANET's), clustering is one of the best approaches to deal with the communication issues arising in the transmission of the packets from source to destination. The complete network is divided into the number of clusters and members in each cluster operate under the supervision of a node called cluster head thus, it becomes important to partition the network effectively so that maximum number of nodes can be covered by using a particular cluster head. Different strategies have been proposed till date. In this paper an earlier proposed strategy called Ant colony Based Cluster head selection algorithm have been compared to the existing lowest id based algorithm using the fuzzy logic rules.***

Keywords: MANET, Clustering, Cluster head, Fuzzy, Ant Colony.

1. Introduction

In Mobile Ad-hoc networks, Cluster based protocol [1][2] for communication provides an example of hierarchical routing protocol. Cluster based protocols divide the network nodes into several small areas called clusters and the members of each cluster are lead by a special node called cluster-head. Communication medium between the two clusters is accomplished by the gateway node. In short, the nodes in Cluster based protocols are classified into three different types of nodes – cluster head, gateway, and ordinary nodes. A node is selected as a cluster head based on the cluster head selection algorithm. Various existing cluster-head selection algorithm are Lowest id based, the highest degree connectivity, K-CONID, the Least cluster change (LCC) etc.

According to Lowest id based algorithm, a tie is broken using the lowest id selection among the member nodes. Clustering provides an efficient mechanism to allocate bandwidth, which is a limited resource, thereby improving reuse and helps in proper resource utilization. All member nodes of a cluster are directly reachable by a cluster-head with a one hope distance. Cluster head provides coordination among nodes that fall under one cluster. In the second section of this paper the earlier proposed Ant colony Based Cluster head selection algorithm [3] and least id algorithm have been discussed. The third section of this paper provides the comparison of the two protocol based on the fuzzy logic rules. The fourth section of the paper presents the future scope of the work in form of a further improvement that can be employed in the Ant colony Based Cluster head selection algorithm.

2. Algorithms for Cluster Head Selection

There are number of approaches present for cluster formation in Ad-hoc networks but they suffers from limitation like overhead due to transmission of large number of packets .Here an approach called ABC [3] have been discussed. The algorithm for cluster formation can be explained as follows

1. Initially each node will broadcast a forward ant packet with a hop limit of 1 (neighbor node), with every node accepting at most 1 forward ant and rejecting the forward ant packets received afterwards.
2. Every node which will be getting a forward ant as in step 1 will produce a backward ant packet back to the source. Hence leading to the formation of disjoint clusters as shown in figure 1.
3. After step 2 the Cluster Head can be decided by counting the number of backward ant received on each node in the cluster. The node with maximum number of backward ant packet will be the Cluster Head.
4. Thus each node in the cluster can be assigned a Cluster Head id corresponding to the id of the cluster head decided from the step 3.

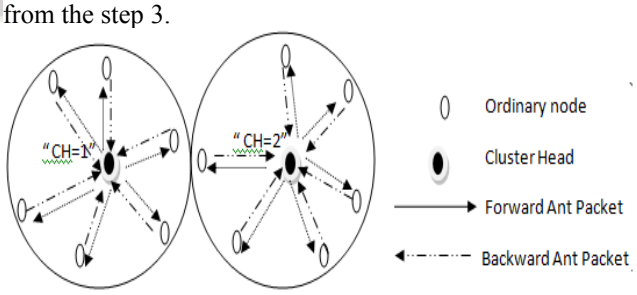

Figure 1: Formation of clusters.

Lowest-Id clustering [4][5][6] is based on the idea of assignment of a unique ID to each node in the network and then broadcasting the ID to all the neighbor nodes. In the next step, the IDs that have been error-freely decoded are compared and the node having the lowest ID is chosen as the cluster-head, while its single-hop neighbors become the cluster members. If a node belongs to multiple clusters, it may be viewed as a gateway between clusters. This algorithm is attractively simple and the construction of clusters may be promptly completed, but the number of cluster-heads may become undesirably high. Furthermore, owing to the uneven distribution of nodes within a cluster, the packet delivery delay may become excessive. Finally, the selection of cluster-heads has to be frequently updated, which may be expected to impose a high control overhead**.** However the major limitation with this protocol is its rigidity. It is a much rigid approach in way that it does not

takes into consideration the number of nodes connected to a particular node and the mobility of nodes.

3. Fuzzy Logic Rule Based Comparison

In this section firstly a fuzzy rule based implementation of both the cluster formation algorithm has been provided. In fuzzy logic [7], we are required to give some input parameter and output is provided by fuzzy logic system based on the fuzzy rules. In this paper we have used MATLAB fuzzy tool. Both Ant colony based cluster head selection and lowest id selection algorithm are compared on MATLAB Fuzzy tool.

3.1 Ant colony Based Cluster head selection algorithm

Ant colony Based Cluster head selection algorithm selects a node receiving highest number of Back Ant packet, Hence a node with highest number of Back Ant Packet is named as cluster head of cluster**.**

P(Xi) $\propto$ (Total No. of Back ANT Pkt) Xi

P(Xi) = Probability of selection of a node as cluster head.
Here in this paper we use fuzzy logic approach to see how probability of selection varies with mobility of node. For this purpose following parameters are given as input in fuzzy logic system**.**
Fuzzy Input Variable: Back ANT Pkt, Mobility,
Fuzzy Output variable: Probability (P (Xi)),
Fuzzy Rule Base: There are two input variable so the total no. of fuzzy rule generated are 3^2= 9 rules for fuzzy rule base which are shown in following table:

Table 1: Fuzzy Rule Base

Back Ant Packet	*Mobility*	*Probability*
Less	Less	Low
Less	Medium	Low
Less	High	Vlow
Medium	Less	Medium
Medium	Medium	Low
Medium	High	Vlow
High	Less	Vhigh
High	Medium	High
High	High	Medium

3.2 Lowest ID based Algorithm

Lowest Id based clustering algorithm selects a node having lowest Id among all nodes. Hence a node with lowest id becomes the cluster head of the cluster.

P(Xi) $\propto$ 1/ ID

P (Xi) = Probability of selection of a node as cluster head.

In this paper we are using fuzzy logic tool to see how lowest id algorithm varies with mobility. Following parameter are given as input to the fuzzy logic system.
Fuzzy Input Variable: Identifier, Mobility.
Fuzzy Output variable: Probability (P (Xi)).
Fuzzy Rule Base: There are two input variable so the total number of fuzzy rules generated are 3^2= 9 rules for fuzzy rule base which are shown in following table:

Table 2: Fuzzy Rule Base

Identifier	Mobility	Probability
Less	Less	Vhigh
Less	Medium	Vhigh
Less	High	High
Medium	Less	High
Medium	Medium	Medium
Medium	High	Medium
High	Less	Low
High	Medium	Low
High	High	Vlow

3.3 Discussion of Results

The lowest id algorithm with input parameter like identifier and mobility (I and M respectively) and Ant colony Based Cluster head selection algorithm with input parameter as Back Ant Packet and Mobility (B and M respectively) are compared based on the fuzzy rules on the MATLAB tool. We know that LID has high probability only when identifier has low value and vice versa and Ant colony Based cluster head selection algorithm has high probability only when Back Ant packet are more and vice versa, so in order to analyze the performance in case of mobility of nodes we have taken mobility as a common input parameter to see how probability really varies. Mobility is an important parameter to be considered in MANET. A node with high mobility degree of mobility in its surrounding should not be chosen as cluster head. Output probabilities for lowest id and ABC selection algorithm are shown in table 3 and table 4 respectively.

Table 3: Lowest ID Algorithm

S. No.	*Input[I,M]*	*Output (%) [Probability]*
1.	[4,2]	70
2.	[5,4]	49.8
3.	[5,6]	50
4.	[6,8]	50

Table 4: ABC Algorithm

S. No.	Input [B,M]	Output (%) [Probability]
1.	[4,2]	49.8
2.	[5,4]	29.8
3.	[5,6]	29.5
4.	[6,8]	9.5

Figure2.graphically shows how probability varies with mobility in case of Lowest Id cluster head selection algorithm. It can be seen that probability of selection does not vary too much with mobility of node; hence algorithm follows a rigid approach as it only checks for the lowest identifier of node while not taking into consideration the other factors. Figure 3 graphically shows how probability varies with mobility in case of Ant colony Based Cluster head selection algorithm. Clearly probability of selection decreases as mobility of node increases. Hence algorithm is quite sensitive to the mobility factor and thus is an efficient algorithm for selection of a node as a cluster head. Results of both algorithms are compared in Figure 4. Hence Ant colony

based cluster head selection algorithm is better than lowest id algorithm.

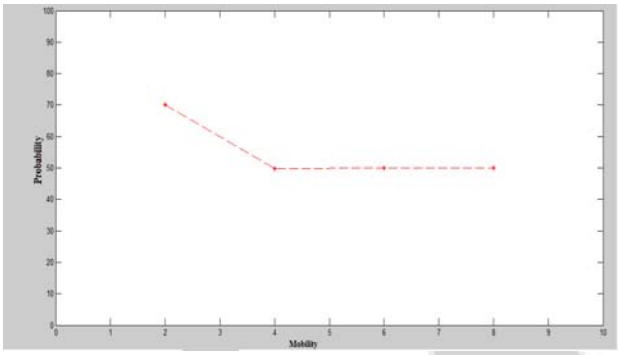

Figure 2: Lowest id algorithm variations with mobility

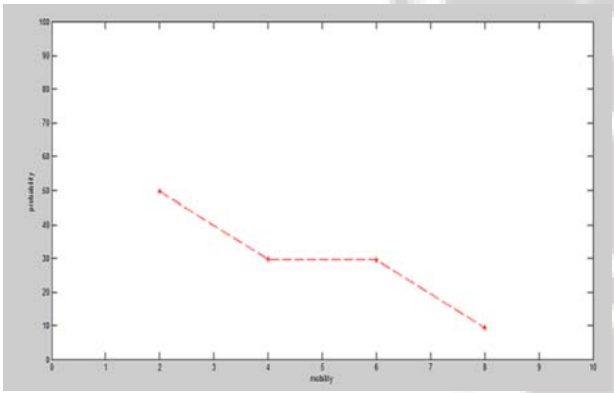

Figure 3: Ant colony Based Cluster head selection algorithm variation with mobility

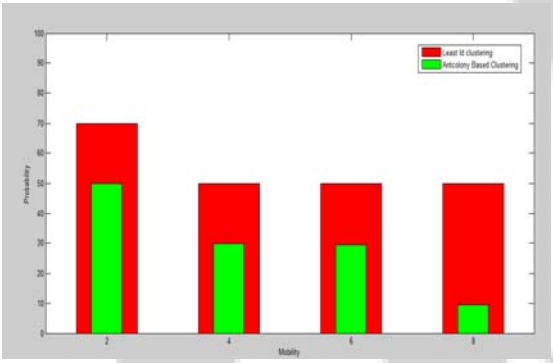

Figure 4: comparisons of ABC selection algorithm and LID algorithm based on mobility

4. Future Scope

In case of Cluster Based Algorithm, we need to consider the fact that the cluster formed initially may not remain valid for too long because of the topological changes. So we should have certain mechanism to determined whether the inter cluster communication between two cluster head is still valid. The main reasons for a route between two cluster head becoming stale can be as follows:

1. Either the failure of gateway node i.e. Gateway node do not have sufficient energy with it to carry on the communication.
2. The second reason can be change in topology which may have occurred in the network due to the mobility of the nodes of the network.

Thus both these situation may force us to redefine the clusters in a network by using a cluster formation algorithm. But before doing that we may try to explore other alternative if available for the communication between the two cluster heads.

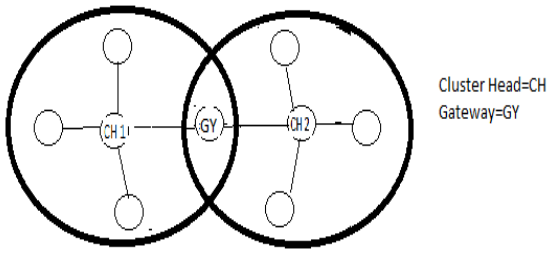

Figure 5: Gateway node Repairment locally

Thus over all process may work as follows:

Step1. If the gateway node GY is not working for a possible communication between the CH1 and CH2 then it will return an error to the CH1. In order to deal with this situation CH1 may send a route discovery packet with CH2 as its destination and with HOP LIMIT field equal to 2 (the logic for setting the hop limit equal to 2 is that if the CH2 can be reached from CH1 through a route discovery packet of hop limit equal to 2 then there is only node which is acting as the intermediate between the two cluster heads, this intermediate node can now be treated as the new gateway node).

Step2. If the Route Discovery Packet reaches the CH2 i.e. route to CH2 is discovered using the Route discovery packet then Set the intermediate node between the two cluster heads as the new gateway.

Step3. If the Route Discovery becomes unsuccessful with the hop limit equal to 2 then it can be deduced that there do not exist any gateway node between the two cluster heads and thus the topology of network have changed and in order to deal with this situation we need to call here the cluster formation algorithm previously discussed i.e. Ant colony Based Cluster head (ABC) selection algorithm so that new clusters can be defined according to new topology of the network.

Thus the above procedure may be used along with the Ant colony based cluster head selection algorithm to reduce the overhead problem further .The work done in this direction may also deal with the inter cluster communication issues. But the applicability of the above procedure and its effect on the various metrics for performance measurement needs to be checked.

5. Conclusion

In this paper a comparison of the cluster head selection algorithms have been provided based on the fuzzy logic rules and it is concluded that the lowest id based approach for the cluster head selection is a much rigid approach which does not takes into consideration the degree of the nodes and mobility of nodes. Whereas the Ant colony based cluster head selection can be clearly seen as an approach which is sensitive to effect of mobility. This can be clearly seen that in Ant colony based cluster head selection algorithm, with

increase in the mobility of node probability of particular node for selection as a cluster head decreases, hence this algorithm is quite effective as compared to least cluster id algorithm..

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