Performance Analysis of MANET Clustering Algorithm in Group Mobility Model

Xiao-Hui Kuang Gang Zhao
Beijing Institute of System and Engineering
AnXiang Road, HaiDian District, Beijing
China

Abstract: -. Mobile ad hoc network (MANET) is the network that has no fundamental structure and of which the communication node of system is connected and organized with distributed protocols. Group communication is the major mode of communication in MANET. Many mobile ad hoc network applications depend upon hierarchical structure. Clustering is the most popular method to impose a hierarchical structure in the ad hoc networks. This paper aimed at clustering algorithm performance analysis in group communication application. Based on analyzing the characteristics of the mobility module and typical clustering algorithms, six major one-hop clustering algorithms are compared and evaluated using group mobility module RPGM in the paper. Limitation of current clustering algorithms in group mobility module is pointed out and the implications on clustering algorithm in group communication application are discussed in the end. The results show that the performance of MACA is much higher than that of other algorithms.

Keywords: - Mobile ad hoc networks, clustering, performance analysis, group mobility model

1 Introduction

Mobile ad hoc networks are comprised of wireless nodes and require no fixed infrastructure. Mobile ad hoc networks have the potential to serve as a ubiquitous wireless infrastructure capable of interconnecting thousands of devices with a wide range of capabilities and usability. In order to achieve this purpose, mobile ad hoc networks must evolve to support large numbers of heterogeneous systems with a wide range of application requirements[1].

Obtaining a hierarchical organization is a well-known and studied problem in mobile ad hoc networks [3]. It has been proven effective in the solution of several problems, such as minimizing the amount of storage for communication information (e.g. routing and multicast tables), reducing information update overhead, optimizing the use of network bandwidth, service discovery, network management and security etc. [2,3,5-10] In the cluster organization, certain nodes known as clusterheads are responsible for the formation of clusters, each consisting of a number of nodes, and also for maintenance of the network topology. The set of clusterheads is known as a dominate set. Due to the dynamic nature of mobile nodes, their association and disassociation to and from clusters perturb the stability of the network and thus reconfiguration of clusterheads is unavoidable. Therefore, it is desirable to have a minimum number of clusterheads that can serve the network nodes, and to have a lower re-affiliation of nodes. An optimal selection of clusterheads is an NP-hard problem [11]. Therefore, various heuristics have been designed for this problem and many clustering algorithms have been proposed, such as Lowest-ID[5], WCA[13], Lowest-SPEED[9], MIX[12] and Max-Degree[8].

In mobile ad hoc networks, there are many situations where it is necessary to model the behavior of node as they move together. For example, many groups of soldiers in military scenario may be assigned the task of searching in a particular plot of land, destroying land mines, capturing enemy attackers or simply working together in a cooperative manner to accomplish a common goal.Little research work was done in peformance analysis of clustering algorithms in group mobility scenario.

In this paper, we focus on researching the performance of clustering algorithms in group mobility model, including a novel clustering algorithm named MACA we proposed. MACA makes use of link stability as heuristics to choose clusterhead and maintain cluster, The peformance is much higher than that of other clustering algorithms in group mobility model, which was manifested by the result of simulation experiments sufficiently.

The rest of the paper is organized as follows: Section 2 gives a brief overview of simulated protocols. Section 3 describes the experimental setup. In section 4, different scenarios have been discussed for performance measurement, conclusion and future work are given in section 5.

2 Simulated Protocols

A. Lowest-ID[5]

Lowest-ID algorithm is one of the earliest clusting algorithm. In this alogrithm as proposed in[5], each node is assigned a distinct ID. A node declares itself to be a clusterhead if it has the lowest id among the uncovered nodes in its 1-hop neighborhood. In Lowest-ID, a highly mobile node with low ID will cause server re-clustering while if the node moves into another region may pose danger to an exiting cluster. The performance of the two algorithms is studied in [4].

B. Max-Degree[8]

The Max-Degree algorithm based on the degree of each node is presented in [8], where the nodes with the highest degrees in local areas are voted as clusterheads. In the Max-Degree algorithms, depending on node's movement and traffic, the criterion values used in the selection process can keep on varying for each node, and hence result in instability. The performance of the two algorithms is studied in [13].

C. MIX[12]

C.R Lin et. al. combined the Lowest-ID algorithm and Max-Degree algorithm and proposed MIX algorithms which choose the nodes with high connectivity first, if the degree of nodes are equal, then select clusterhead based on ID of nodes. Since connectivity degree is still considerred as the main factor for clusterhead selection, the stability of cluster in MIX is improved less.

D. WCA [13]

Based on Lowest-ID algorithm, Chatterjee et al. proposed a new clustering algorithm named Weighted Clustering Algorithm (WCA), in which, each node is assigned weights in accordance with its suitability of being a clusterhead and the ideal degree, transmission power, mobility, and battery power of mobile node are taken into acount. A node is selected to be a clusterhead if its weight is higher than any of its neighbors'; otherwise, it joins a neighboring clusterhead. Although WCA considers many factors to choose clusterhead, the measurement criterion of them are not unified. So it is difficult to confirm its proportion of factor in weight to get better performance in applications. In addition, the cost of computing the weights is expensive in WCA.

E. Lowest-Speed

the Lowest-Speed Algorithm is proposed in[9], in which a node with the lowest speed is selected to be clusterhead. In this algorithm, the advantage of clusting method is to improve the stability of cluster and make chance of clusterhead selection more reasonable for each node, the disadvantage is that no consideration of relative movement of nodes is taken, hence high change frequency of clusterhead is appeared.

F. MACA

In order to enhance the stability of cluster formed, we proposed a new clustering algorithm named Maximum Associativity Clustering Algorithm, which take into account of relative mobility.

The basic idea of MACA is that the clustering process should be aware of the mobility of the individual nodes with respect to its neighbors. A node should not be elected a clusterhead if it is highly mobile relative to its neighbors, since in that situation the probability that a cluster will break and that re-clustering will happen is high. MACA selects a node as clusterhead that has maximum stable links. The link stability can be identified by the associativity "ticks", which is updated by data link layer protocol of the node. Every node periodically transmits beacons to identify itself and constantly updates its associativity ticks for every link in accordance with the node sighted in its neighborhood. A node is said to exhibit a high state of relative mobility when it has low associativity ticks. On the other hand, if high associativity ticks of a link are observed, the node is in the stable state with its neighbor even it has high speed.

3 Simulation Study

3.1 Simulation setup

To analyze the performance of these six algorithms, Lowest-ID, WCA, Lowest-SPEED, MIX, Max-Degree and WACA, over mobile ad hoc networks, we did a comprehensive simulation study using the Network Simulator (ns-2) developed at Lawrence Berkeley Laboratory[17]. The Reference Point Group Mobility Model given by Tracy Camp et al. [18] was used for simulation. To measure the performance of clustering algorithm, we identify four metrics (i) the number of re-affiliations, (ii) the number of clusterheads updates, (iii) the number of clusterheads, and (iv) load balance of clusterhead. The re-affiliation count increases when a node gets dissociated from its clusterhead or becomes a member of another clusterhead. The number of clusterheads updates increases when a node becomes a clusterhead or gives up being a clusterhead, at the same time the node gives the number of clusterheads. To quantitatively measure how well balanced the clusterheads are, Chatterjee et. al.[4] introduce a parameter called *load balancing factor*, but its value tends to infinity for completely balanced clusters. So we improve on the definition as following:

$$LBF = \frac{1}{1+\sum_i (x_i - u)^2}$$

where x_i is the number of cluster members in cluster i, and $u = \frac{N-n_c}{n_c}$ is the average number of members of a clusterhead, N is the total number of nodes and n_c is the number of clusterheads, then $LBF \in (0,1]$. The higher the value, the better the load distribution is.

In our simulation experiments, the network size is 50 nodes; the size of scenario is calculated according to transmission ranges and network size. There are two parameters studied for varying: the transmission range varies between 30 and 180m, and the maximum speed varies between 0 and 50 m/s in Random Waypoint Mobility Model and average speed varies between 0 and 24m/s in Reference Point Group Mobility Model.

For MACA, Th_{member} is defined as half of the average of neighbors, and $TickTheshold = {2*range}/{speed}$. In WCA, the weight of degree-difference, sum of distances, mobility and battery power marked respectively 0.7, 0.2, 0.05 and 0.05 separately; they were used to compare with other algorithms by Chatterjee et. al..

3.2 Experimental Results in Group Mobility Model

Many group mobility models are proposed to simulate cooperative characteristics of MANET application . The most general one of group mobility model is the Reference Point Group Mobility (RPGM) model.

RPGM model is used to simulate the clustering algorithms. In this model, the reference point separation is 100m, the node separation from reference point is 50m and the pause time varies from 2s to 6s. Average speed is 16 m/s in simulation when transmission range is varying, transmission range is 150m when average speed is varying.

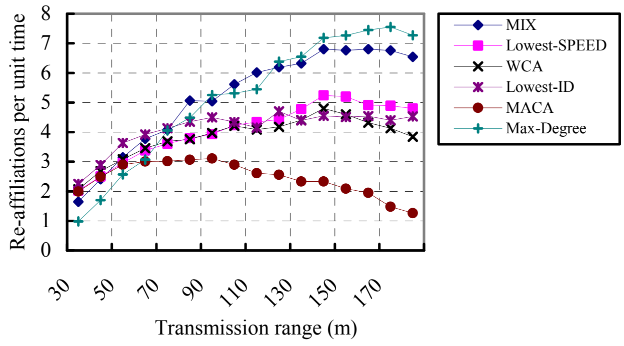

Figure 6. Re-affiliations per unit time vs. transmission range

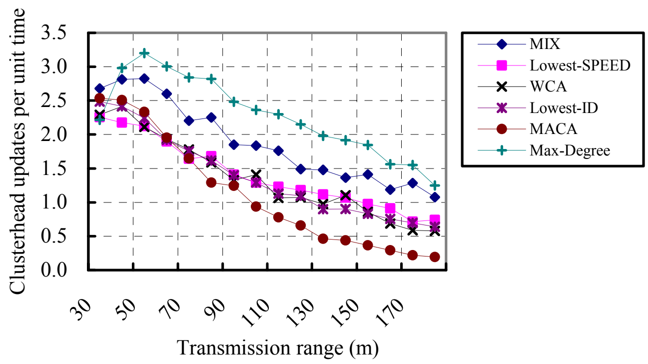

Figure 7. Clusterhead updates per unit time vs. transmission range

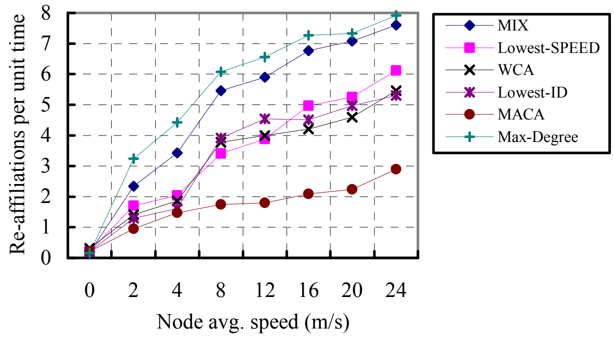

Figure 8. Re-affiliations per unit time vs. average speed

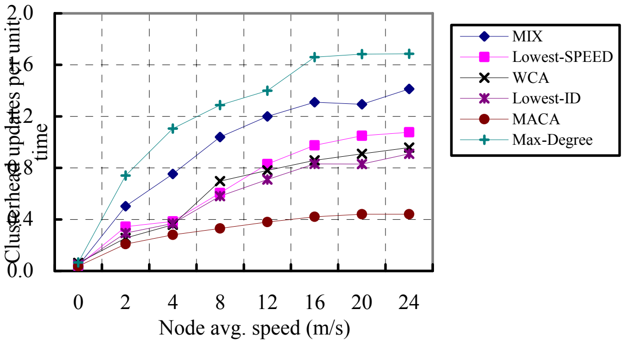

Figure 9. Clusterhead updates per unit time vs. average speed

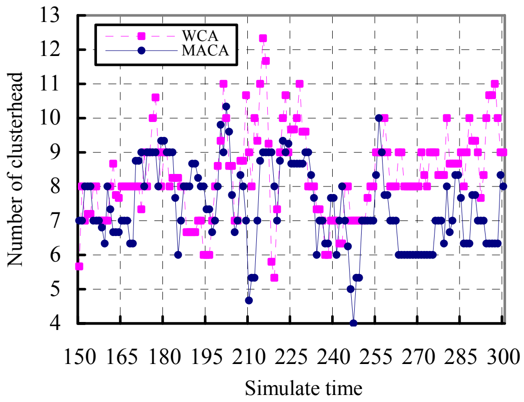

Figure 10. Number of clusterhead vs. simulate time

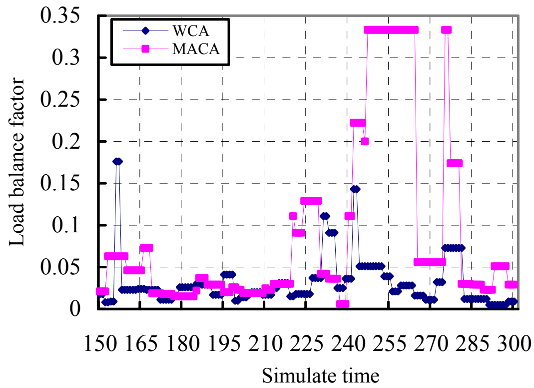

Figure 11. LBF vs. simulate time

Figure 6 and figure 7 show the relative performance of MIX, WCA, Lowest-ID, Lowest-SPEED, MACA and Max-Degree in Group Mobility Model where average speed of node is 16m/s. Figure 8 and 9 shows the relative performance of these algorithms where average speed of node varies from 0 and 24m/s. We can observe that the number of re-affiliations and clusterhead updates in MACA is at most half the number obtained from other clustering algorithms, and the larger the transmission range or speed is, the greater the gap between the performances of other clustering algorithms and that of MACA is. The main reason is that the relative mobility in group mobility model is common, the heuristic of MACA be unacted on it.

Figure 10 and 11 show the relative performance of WCA and MACA in terms of number of clusterhead and LBF at different simulation time. We can see that the number of clusterhead in MACA lower than WCA, and LBF of MACA is better than that of WCA

From the above results, we can easily conclude that MACA is highly suitable for stable cluster formation in situations involving both low and high mobility in Random Waypoint Model and Group Mobility Model. Sine it is based on link stability which measures relative nobility in the neighborhood of every node, it adapts well to varying levels of mobility. Especially in Group Mobility Model, the performance of MACA is better than previous algorithms largely.

4 Conclusions

Group motion occurs frequently in ad hoc networks and mobility impacts on cluster stability heavily. But little research work about performance of clustering algorithms in group mobility model work has been done. In this paper, we evaluate the performance of many clustering algorithms including a novel algorithm named MACA, in most popular group mobility model named RPGM. The results manifest the performance of MACA is much higher than that of other algorithms in group mobility scenario.

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