A NOVEL OPTIMIZED CLUSTERING SCHEME FOR MOBILE AD-HOC NETWORKS

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ABSTRACT

In a Mobile Ad-Hoc Network (MANET) hosts communicate with each other without any centralized control. Due to various constraints like scarcity of resources, excessive routing overhead etc, the cluster routing protocol in MANETs becomes less reliable. In this paper, we present an efficient algorithm for cluster formation and selection of optimal clusterhead and thus forming the optimal cluster taking weighted metrics like battery life, robustness, bandwidth and SNR. Further, our paper provides a realistic mobility model of the user, whose results are validated against simulations to adapt to the dynamic changes in network topology.

I. INTRODUCTION

Deployment of Mobile Ad-Hoc Networks (MANETs) can be an economic and useful way for communication in war-front applications, search and rescue operations, wireless conferences for large scale meetings [1] where infrastructure is hard to establish. A lot of research works have been presented over the past few years regarding routing protocol, end-to-end QoS support, and mobility distribution in a MANET. A brief review of the routing protocols can be found in [3]. In this paper, we propose a new scheme for setting up a MANET with the help of some optimized factors, which control the efficiency of an ad-hoc network. Since, in flat hierarchy, routing tables could grow to an immense size, clustering techniques are expected to achieve better scalability as most of the topology changes within a cluster are hidden from the rest of the network [2].

In order to scale our model with respect to real life scenario, we define a parameter called Optimum Node Performance Factor (*ONPF*), which is calculated by assigning different weights to different metrics like bandwidth, robustness, battery life, SNR. These parameters reflect the essential features in a clustering algorithm, which are responsible for the effective usage of the scarce resources. On the basis of *ONPF*, we select clusterhead, tackle the clusterhead's overhead and ensure an adaptive routing protocol for MANET.

The rest of the paper is organized as follows. In section II, we present an overview of the clustering schemes. Next, Section III provides the proposed scheme and optimization techniques and deals with the mobility issue. Section IV provides our simulation results and analysis. Finally we conclude in Section V.

II: RELATED WORKS:

There are several studies regarding clustering algorithm for wireless ad-hoc networks, such as Linked Cluster Algorithm (LCA) [6], Maximum Connectivity Clustering (MCC) [7], Least Clusterhead Change (LCC) [8] and MOBIC [9]. All of the above algorithms create two-hop clusters in MANETs and these clusters may not be able to achieve effective topology aggregation [5].

In Gravitational Cluster Routing (GCR) [1], the clusterhead has been selected on the basis of number of neighbors surrounding a node. Though this protocol gives a centralized scheme, the resulting cluster may be unstable if the clusterhead cannot provide optimum performance towards routing.
A good number of papers present schemes to support QoS. One of these is [1], which shows a hybrid selection scheme for providing multihop wireless internet access. Optimization schemes have also been addressed in few papers.

III. THE PROPOSED OPTIMIZED CLUSTERING SCHEME

A successful dynamic clustering algorithm should achieve a stable cluster topology with minimal communication overhead and computational complexity [5]. Therefore, the main design goals of our clustering algorithm are as follows-

1. The algorithm supports formation of small clusters considering group mobility pattern.
2. The algorithm reduces route maintenance overhead and can easily adapt to the changing network topology.
3. Optimized clustering scheme involves both stability of a cluster over a considerable period of time with an effective routing implementation for scarce resources.

III.1 Cluster Formation: The Initial Setup Phase

Let us consider an ad-hoc scenario where mobile users desire to setup a cluster for information sharing. The first step in the algorithm is that every node in the network will try to determine its neighborhood set $N_g(n)$. In order to accomplish this, the nodes will start broadcasting 'hello' messages. The collision between the adjacent messaging will be taken care of using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). Each 'hello' message will have a time stamp (TS) and a life time (LT) field. When one or more nodes receive the message from a particular sender, they will check the TS and LT. If (TS+LT) is greater than the receiving time of the packet, they will send an acknowledgement (ACK) to the sender; otherwise the message will be discarded. On receiving this ACK from a particular receiver, the sender will in turn send a node identifier packet (NIP), which will contain the several fields regarding battery life over the threshold power, it's processing speed etc. When the receiver receives this NIP, it will estimate the signal strength, bandwidth available over the channel and the extent of SNR using a checksum check. Now, it will make this node a member of $N_g(n)$ and will assign a temporary id to it.
Before moving to the next step, we define the following terms for clarity:

Metrics (M_i):

- $B(n)$: Battery life of a node over a threshold value below which the node fails to provide optimal performance.
- $S(n)$: Signal strength of a sender node, which is a measure of the maximum distance of tolerance between any hop.
- $BW(n)$: Bandwidth estimated by a node while receiving the NIP over a wireless channel.
- $SNR(n)$: Signal to Noise Ratio measured over a noisy channel.
- $PS(n)$: Processing speed of a node, which defines the robustness of a node based on the length of its processing queue.

Definitions:

- $Deg(n)$: Degree of a node is defined as the number of neighboring nodes, which select it to be the best neighbor of that node.
- *Unit*: The unit is defined as a group of nodes which are at the ith hop from the clusterhead and is denoted by $N^{i}(u)$. For example, $N^{1}(u)$ indicates the unit of nodes, which are at single hop communication from the clusterhead.

Since QoS is an agreement to provide guaranteed service such as bandwidth, delay and packet delivery rate to users, we argue that the first three metrics defined above serve as the QoS metrics.

III.2 Clusterhead Selection

After receiving NIPs from different neighbors, a node completes its $N_g(n)$ set. At this stage, we define Optimum Node Performance Factor (*ONPF*), which is used by the nodes to select the optimal clusterhead under a constrained situation of scarce resources:

$$ONPF = \frac{\sum_i C_i M_i}{\sum_i C_i} \quad (1)$$

where M_i denotes the metrics discussed in section III.1 and C_i are the different weights assigned to the different metrics. After completing its $N_g(n)$ set, the nodes calculate *ONPF* of all the members in $N_g(n)$. Out of these, it selects three best nodes and sends a 'request to join' (RTJ) packet to the best one. The node whose *Deg (n)* is greatest will declare itself to be the clusterhead and it will include those nodes to the cluster, which have a value of *ONPF* above the level set by it. It then informs all the users and $N^1(u)$ about the three best nodes with respect to the clusterhead. Here, we can argue that the selection of the three nodes will have a close matching with that of the other members at $N^1(u)$ since *ONPF* indicates towards a centralized clusterhead selection. In the overlapping region of two or more clusters, gateways can be selected using the same algorithm.

III.3 Clusterhead Maintenance and Resource Utilization:

In this subsection, we discuss the efficiency of our model to encounter usual hazards in MANETs, which include frequent link failure, new link setup and effective resource management. We consider the critical situation when the clusterhead of a newly setup cluster fails to provide its function to the $N^1(u)$ nodes. Clearly, this is the critical case and handling this disruption correctly assures the similar changes for other nodes also. The situation depicted above can be easily handled as we construct the following theorems.

Th 1: A 'clusterhead fall' does not require restructuring of the entire cluster.

Th 2: The new topology created between $N^0(u)$ and $N^1(u)$ units ensures loop free communication.

Th 3: The QoS metric *B (n)* reserves an optimal value under the proposed scheme.

The first two theorems deal with the capability of the scheme for effective routing under the condition of a critical node failure while the third one deals with the resource management of a node in a dynamic topology. The proofs of these theorems are beyond the scope of this paper due to limitation of page.

III.4 Mobility Issue

Any mobile ad-hoc network is characterized by the dynamic change in topology due to mobility of the member nodes. A good number of mobility models have been proposed such as Random Way-Point Model (RWP), Random Way-Point on Border (RWBP), Random Gauss-Markov (RGM) model, Reference Point Group Mobility Model (RPGM). However, most of the models regarding the mobility issue are simple in nature and arbitrarily configured on the basis of random movement of the nodes over a geographic location. As a result, these distributions fail to incorporate the node-specific environment with the mobility models. To clear this issue, we design a new mobility pattern based on [4] and discuss it under Section IV.

IV. SIMULATION RESULTS

To obtain quantitative information about the proposed clustering scheme, we have simulated our algorithm for an ad-hoc environment under certain constraints. We consider an ad-hoc environment of 800m x 800m area where nodes are arbitrarily placed. Following the algorithm stated in III.1, an initial cluster is formed consisting of eight nodes and the clusterhead is chosen using the optimization techniques mentioned in III.2. Since, the failure of each node is an independent event, we have found out the dwelling time of the clusterhead considering other nodes as active. The simulation results show that the proposed optimized model exhibits better clusterhead performance than [1], which we cannot present here due to page limitation.

Regarding the mobility issue, we have considered an ad-hoc environment in which we have arbitrarily placed a node as a group center (G_c), velocity of which indicates the overall cluster velocity or group-velocity. The transmission range of G_c has been considered to be 250 meters and other mobile nodes are placed randomly around it with about 80% of the nodes within this range.

A node is said to be within the group if it is within the transmission range of G_c. Now, we have considered an indicator variable (I_v) through out the simulation process, which is defined as:

I_v = 1; if the node is within the range.

= 0; if the node is out of the group.

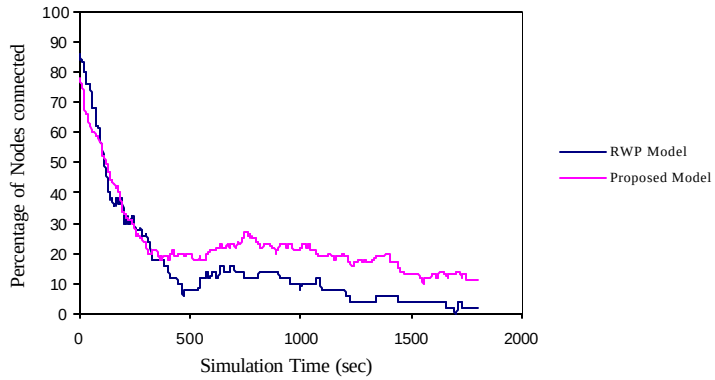

Fig.1: Connectivity of Mobile Nodes

Under this scenario, we have placed 10 nodes in an arbitrary fashion with a velocity within the range 1-3 m/s. The group center has been assigned a velocity within the range 0-1 m/s. Nodes (including G_c) move in a random direction with an angle $q \in [0,2p]$ and after a random interval of time it takes a pause-time generated from [4]. Again, a node is connected to a group at a particular time if the value of I_v for the node is 1 at that instant. Readings have been taken at an interval of 5 sec to measure the number of nodes connected to the group. In Fig.1 above, we present a mobility distribution of nodes based on [4] which shows better connectivity of nodes than RWP model.

V. CONCLUSION

In this paper, we have presented a new optimized clustering scheme based on the optimal clusterhead selection using QoS metrics like bandwidth, robustness, signal strength etc. Unlike [1], it avoids arbitrary selection of clusterhead on the basis of degree of neighbors and can sustain even at the condition of clusterhead failure. Use of this model to determine the lifetime of a newly setup cluster is left as a future work.

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