Scenario-Based Cluster Formation and Management in Mobile Ad Hoc Networks

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ABSTRACT

This article proposes a scenario-based algorithm for cluster formation and management in mobile ad hoc networks. Depending on the application a centralized or 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. The non-clusterhead node can select the most qualified dominating node as its clusterhead from among the \(k\) dominating nodes. The quality of the clusterhead is a function of 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 neighbors leads to frequent clusterhead election process. This perturbs the stability of the network and adversely affects the network performance. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: Ad Hoc Networks; Clusterhead; Cluster Management; Dominating Set; Load Balancing; Local Stability

INTRODUCTION

A Mobile Ad hoc Network (MANET) is a self-configuring wireless, multi-hop, dynamic network consists of mobile nodes that operate without the need for any established infrastructure. This type of network is highly demanding due to the lack of infrastructure and easiness and cost effectiveness in installation. MANET has many emerging applications, which include commercial, industrial and war front applications, search and rescue operations, sensor networks and vehicular communications. The major issues in cluster based MANETs are mobility management, topology assignment, clustering overhead, frequent leader re-election, overhead of clusterhead, depletion of battery power, security and Quality of Service (QoS).

Destination Sequenced Distance-Vector (DSDV) (Perkins, 1994), Dynamic Source
Routing (DSR) (Johnson, 1996) and Ad hoc On demand Distance Vector (AODV) (Perkins, 1999) are some popular protocols proposed for multi-hop routing. These flat routing schemes encounter scalability problems with increased network size. The signaling overhead of the routing algorithms based on reactive and proactive 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. Hierarchical architecture helps to increase the life time of the network and increase the network scalability. 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 form and maintain clusters. A stable clustering algorithm should not change the cluster configuration frequently. The advantages of clustering include (i) efficient handling of mobility management (ii) provision for optimization in routing mechanism (iii) shared use of application within the group (iv) spatial reuse of resources (v) better bandwidth utilization (vi) aggregation of topology information (vii) virtual circuit support (viii) makes dynamic topology appear less dynamic by considering cluster stability when they form (Mc Donald, 1999) and (ix) minimize the amount of storage for communication (Basagni, 2006).

In this article we propose a scenario based algorithm for cluster formation and management in mobile ad hoc networks. 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 even during the topology changes and thereby reduces the overhead incurred during clusterhead changes.

The rest of the article is organized as follows. Previous work done in the area of cluster based routing is reviewed in the second Section. Section three discusses the design issues. Section four presents details of $(k, r)$ -DS algorithm and clusterhead association with example. Section five presents cluster formation and management. The performance of the algorithm is evaluated in Section six. Finally, last section concludes this article.

**RELATED WORKS**

Many clustering algorithms for mobile ad hoc networks have been proposed in the literature to choose clusterhead. In Link Cluster Algorithm (LCA) (Baker, 1981), the clusterhead selection is based on the highest identity number among a group of nodes (each node is identified by a unique number). In LCA the cluster radius is one hop, since all cluster members are connected directly to the clusterhead. The lowest-ID algorithm (Ephremides, 1987) and Maximum-connectivity algorithm (Parekh, 1994) are two earlier popular algorithms in which the clusterhead selection is based on the highest identity number among a group of nodes (each node is identified by a unique number). In LCA the cluster radius is one hop, since all cluster members are connected directly to the clusterhead. The lowest-ID algorithm (Ephremides, 1987) and Maximum-connectivity algorithm (Parekh, 1994) are two earlier popular algorithms in which the clusterhead selection is based on the lowest virtual identification number and maximum number of neighbor nodes, respectively. These two metrics alone are not sufficient for the selection of clusterhead in a dynamic environment due to the high overhead associated with clusterhead change over. Many modifications to these algorithms were proposed to make the clusterhead selection and cluster management more stable and power efficient. The Least Cluster Change
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