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Clustering-based Routing Protocols in Ad hoc Networks

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Abstract: The *clustering* means dividing geographical region into smaller areas in which each area is represented by a resource rich leader node, called *clusterhead*. The clustering has several benefits such as reducing the communication and computation overhead. In this paper, we discuss how the clustering concept can highly benefit the *efficient routing* and examples of routing protocols using clustering concept in wireless ad hoc networks.

Keywords: clustering, routing, ad hoc networks.

Introduction

There are two types of network topologies: infrastructured and infrastructureless. As an example of infrastructured network, the cellular networks (see Figure 1), have emerged as the most widely used wireless networks that can support mobile users. Due to several limitations of the infrastructure networks led to the initiation of infrastructureless networks which can be deployed very quickly for a short period of time and does not need an infrastructure. Such networks are called mobile multi-hop radio networks, or *ad hoc networks* or *peer-to-peer* networks. These networks are created dynamically on-the-fly in an *ad hoc* way. They are basically used as a better alternative to wired networks in scenarios such as law enforcement operations, battle field communications, disaster recovery situations, and so on. These situations demand a network where all the nodes including the base stations are potentially mobile, and communication must be supported untethered between any two nodes.

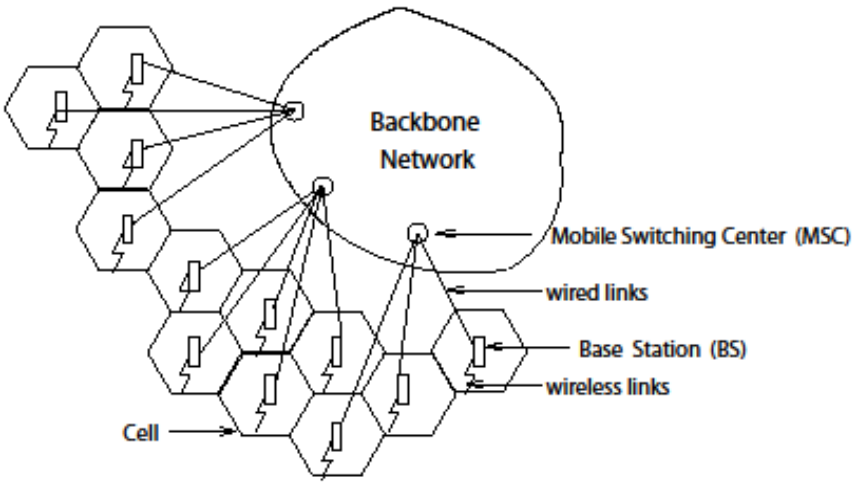

Figure 1. Cellular Network [1]

Special nodes, known as *clusterheads*, are responsible for the formation of *clusters* each consisting of a number of nodes (analogous to cells in a cellular network [6**]**.) While the base stations are static, the clusterheads are mobile. The lusterheads are responsible for managing the nodes and doing the resource allocation to all the nodes within that cluster, just as a base station of a particular cell in a cellular network.

Clustering

The concept of clustering has been presented implicitly in [14]. Any node potentially can become a clusterhead if it has the required resources such as computing and communication power. Those nodes who are not elected to become the clusterheads become members of neighboring cluster. Two nodes can communicate if they are within the transmission range of each other. These nodes are called *neighbors* of each other.

Due to the mobility of the network, the clusterheads may change dynamically, meaning that their association and dissociation to and from clusters perturb the *stability* of the network. If the clusters change very often, it can adversely affect the performance of other protocols such as scheduling, routing and resource allocations. Since choosing clusterheads optimally is an NP-hard problem [5], existing solutions to this problem are based on heuristic (mostly greedy) approaches [1, 2] and none attempts to retain the stability of the network topology [5, 8]. A good clustering scheme should preserve the graph structure as much as possible; otherwise, re-computation of clusterheads and frequent information exchange among the participating nodes will result in high computation and communication overhead.

Clustering for Efficient Routing

Clustering concept has been used for routing efficiency in many of the routing protocols such as *CBRP (Cluster Based Routing Protocol)* and *TORA (Temporally Ordered Routing Algorithm)*. Temporally Ordered Routing Algorithm (TORA) is a routing algorithm developed by Park and Corson [17] for mobile ad hoc networks which was adopted from a loop-free routing algorithm named GB by Gafni and Bertsekas [11] where they provide two algorithms for building a destination-oriented DAG (directed acyclic graph) for a network with possible link failures. In both cases, a unique height is assigned to each node that comes from a totally ordered set such that each link between two nodes is directed from the higher height to the lower height one so that the destination would be the only sink in the DAG constructed by these directions. In this scenario, when a node rather than the sink loses its entire outgoing links due to failure or change in neighboring node's height, a new height is calculated. However, this approach would cause an infinite cycle of messages to be sent out since the nodes in the system are not informed that a piece of the network has been partitioned such that a node can no longer be reached. This is where the advancement in TORA plays a role; partition from the current leader is detected using TORA. The mechanism detects network partitions in such a way that if there no longer exists a path to a particular node, then the node that first detected the partition sends out signals to all the rest of the nodes in its component (cluster) so that they would stop executing height changes and end sending futile messages.

Cluster Based Routing Protocol (CBRP) is a routing protocol for mobile ad hoc networks, which are built for dynamically changing topologies due to mobile nodes. Consequently, routing protocols that discover routes dynamically such as DSR [15], TORA [17], ABR [18], and so on are preferred over distance vector routing protocols [13]. The main idea is to divide the nodes in a given network into a number of overlapping or disjoint 2-hop diameter clusters where a clusterhead is elected for each cluster to keep the membership information which in turn would be used in discovering inter-cluster routes. Another important concept is the use of uni-directional links for both intra-cluster and inter-cluster routing in order to reduce network partitions and improve routing performance considerably.

CBRP has several features some of which include fully distributed operations, and clear utilization of uni-directional links as well as ability of repair broken or sub-optimal routes locally without rediscovery. Once the clusters are defined, all the nodes within a cluster are said to be the members of that cluster except one and only one node called *clusterhead* for each cluster is elected; however, a node can have several host clusters. This clusterhead node will have full knowledge about group membership and link state data in the cluster within an enclosed time after the topology stabilizes as well as having bi-directional link to every other member of the cluster. The clusterheads will also have the complete knowledge of all its bi-directionally linked adjacent clusters even if there are no actual bi-directional links between them. The idea behind formation of cluster is to provide certain level of structure for the disorganized underlying network. The algorithm is adopted from the cluster formation that was proposed in [12] with the difference of focusing on the use of clusters in the routing process. The algorithm is a variation of the ``Lowest-ID'' clustering algorithm [3, 4, 10]. It can be run on various channels to provide different sets of clusters for each channel. In return, the routing would also be done independently on each of these sets of clusters.

There are several examples of using clusters in routing within the literature as it is given in [9, 16]. In these scenarios, the source routing is taken as a base, which consists of route discovery and actual data packet routing. The clusterheads are flooded in the discovery process in order to locate the destination. It is vital to point out that the use of clustering provides less flooding traffic during the dynamic route discovery, apart from the improvement of the network connectivity since certain uni-directional links are discovered and used. In other words, the numbers of times nodes are disturbed are considerably less. For detailed survey of ad hoc routing algorithms, refer to [7].

CONCLUSIONS

Clustering means partitioning the network into different clusters and each managed by a superior node called "clusterhead" and the election of these special nodes is similar to leader election algorithms in distributed systems. In this paper, we have discussed the how the clustering in mobile ad hoc networks can be beneficial for ad hoc routing protocols.

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