Routing Protocols for Wireless Ad Hoc Networks
Hierarchical routing protocols

Theofanis Kilinkaridis
tkilinka@cc.hut.fi

Abstract
This paper presents two hierarchical routing protocols. Hierarchical state routing protocol and Fisheye state routing protocol. The former is a multilevel routing protocol that provides nodes' clustering in multiple levels, while the latter uses the fisheye technique to reduce the routing overhead. They both employ a hierarchical control structure and try to provide better routing solutions.

1. Introduction

Due to mobility of ad hoc networks and the lack of fixed infrastructure, routing protocols have to be very flexible in order to deal with this dynamically changing environment. However, because of the small size of these networks, ad hoc protocols can be categorized based on the routing topology. One class of these protocols is the flat and the hierarchical protocols. Two particular hierarchical routing protocols are presented in this paper. Each one of them employs different approaches which will be examined further.

2. Hierarchical Routing Protocols

Unlike flat protocols where each node has its unique global address and all the nodes are peers, in hierarchical protocols nodes are grouped into clusters. Every cluster has a cluster head which election is based on different election algorithms. The cluster heads are used for higher level communication reducing the traffic overhead. Clustering may be extended to more than just two levels having the same concepts of communication in every level. The use of routing hierarchy has a lot of advantages. It reduces the size of routing tables providing better scalability.

2.1 Hierarchical State Routing Protocol

The Hierarchical State Routing (HSR) protocol [1] is a distributed multi-level hierarchical routing protocol which provides nodes' clustering in multiple levels. HSR employs clustering in different levels. Here, every cluster has its leader which is elected through different algorithms. The clustering is organized in levels and can be physical or logical. The first level of physical clustering is done between nodes that have physical wireless one-hop links between them. At this level, each cluster has its cluster leader. The second level of physical clustering is done between the leaders of the first level clusters. Once again, every cluster elects its leader. However, besides physical clustering, HSR defines also the concept of logical clustering. Here the links between the nodes are not physical. The links are based on certain relations.

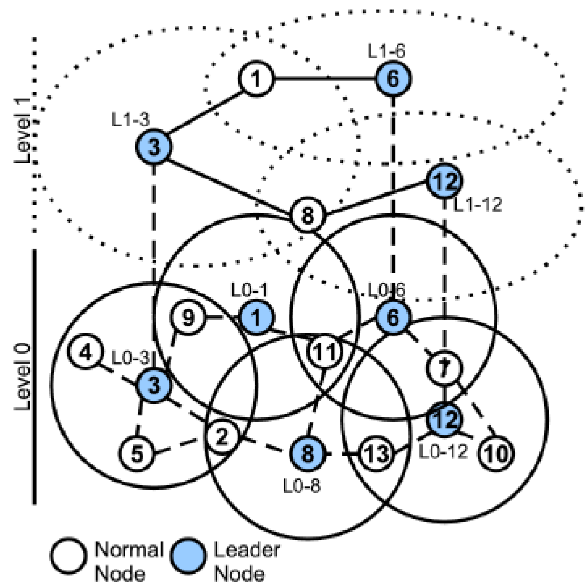

Figure 1**:** HSR multi-level clustering

Figure 1 illustrates an example of HSR multi-level clustering. The lowest level defines five clusters with five different cluster leaders 1, 3, 6, 8 and 12. A cluster leader node is always responsible for exchange of routing information and handling of link breaks. Node 8 for example is described as L0-8 which means that its ID is 8 and it leads a cluster at zero level. Nodes that are located in more than one cluster are called cluster gateway nodes. The second level(level 1) of clustering is done among the cluster leaders of the first level. At this level we have three clusters with cluster leaders in each of them: L1-3, L1-6 and L1-12.

In HSR protocol, every node maintains information about its peers' topology and the status of links to them. This information is broadcast to all the members of the cluster periodically. Just as all the other nodes, cluster leaders exchange similar information with their peers, which are also cluster leaders of the same level. Based on this information, higher-level clusters are built. After receiving topology information from its peers, each cluster leader broadcast the information to the lower level informing all the nodes about the hierarchical topology of the network.

The path between two cluster leaders is called virtual link. This link consists of many physical wireless links between low level nodes. The status of this link is characterized by the status of the physical links that comprise it. The path between L1-3 and L1-12 in Figure 1 consists of the physical wireless links 3 – 2 – 8 – 13 – 12. Addressing in HSR is achieved by combining the hierarchical ID(HID) and the node ID. HID of a node is the sequence of all its cluster leaders starting from the higher level to its lower level. Node ID is its unique network ID usually referred to its MAC address. So the hierarchical address of node 10 in Figure 1 is <HID – node ID> = <12,12 - 10>. Every node's hierarchical address is stored in an HSR table and indicates its location in the hierarchy. HSR table is updated by the routing update packets. Every time a packet needs to be delivered from one node to another, it is forwarded to the highest node in the hierarchy of the source and then is sent to the highest node in the hierarchy of the destination. After, the packet is forwarded from this node to the destination node.

Utilizing the above mentioned hierarchy, HSR greatly reduces the routing table size. Also the storage required in hierarchical protocols is much less than in flat topologies. However, the process of exchanging information concerned all the levels of the hierarchy as well as the process of leader election in every cluster makes it quite problematic for ad hoc networks. It is more suitable for larger networks and especially for military networks.

2.2 Fisheye State Routing Protocol

The Fisheye State Routing (FSR) protocol [1] [2] uses the fisheye technique to reduce the routing overhead. The eye of the fish can capture pixel information with greater accuracy near its eye's focal point. The accuracy decreases as the distance from the focal point increases. In ad hoc networks, this ability is translated to maintaining accurate information about near nodes and not so accurate about far-away nodes. Even though FSR is a proactive routing protocol and maintains the topology of the network at every node, it does not flood the network with topology information. Instead, nodes maintain a link state table based on information received only from their neighbors. Hence, the complete network information resides in every node, something that provides quick and efficient routing establishment.

When the size of the network becomes bigger, the update messages sent between the nodes could consume a lot of bandwidth. In order to reduce the size of these messages, routing scopes are defined in FSR. Scope is a set of nodes who can reach each other in given number of hops. Figure 2 shows the scopes of the node 11 with one, two or three hops.

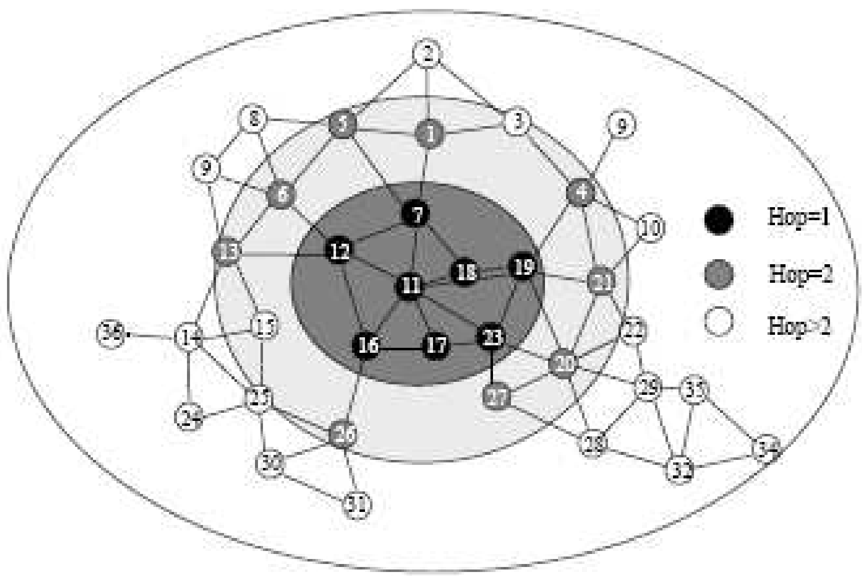

Figure 2**:** Scope of fisheye

Another characteristic of FSR is the different frequencies that it uses for exchanging link state information. The smaller the scope is the higher the frequency of the exchanges. The exchanges in smaller scopes are more frequent than in larger. That makes the topology information about near nodes more precise than the information about farther nodes. The path information about distant nodes may be inaccurate in FSR. However, as the packet approaches the destination, the route becomes more and more accurate.

Generally, FSR is suitable for large and highly mobile network environments. No control messages are initiated after a link break. Broken links will just not be included in the next link state message exchange. This means that a change on a link far away does not necessarily cause a change in the routing table. FSR reduces significantly the consumed bandwidth as the link state update packets are exchanged only among neighbouring nodes. Also FSR manages to reduce the message size of the topology information due to removal of topology information concerned far-away nodes. That makes FSR more suitable for large mobile networks where the bandwidth is low. The choice however, of the number of scope levels and the radius size has great influence on the performance of the protocol. Hence, having small ad hoc networks provides poor protocol performance.

Conclusion

Summarizing, it is obvious that besides the reduction of the traffic control, hierarchical protocols are more suitable for large networks. They provide quick network restoring after a link break and reduce significantly the size of the topology information messages. However, as the size of the network decreases, these protocols' performance degrades to the performance of simple proactive and reactive ones.

References

[1] C. Siva Ram Murthy and B.S. Manoj. Ad Hoc Wireless Networks: Architectures and Protocols.

[2] Guangyu Pei Mario Gerla Tsu-Wei Chen. Fisheye State Routing in Mobile Ad Hoc Networks.