A Geometric Deployment and Routing Scheme for Directional Wireless Mesh Networks

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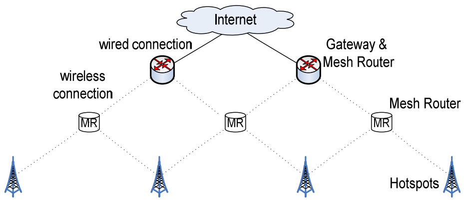
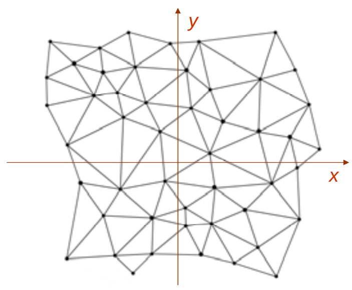
1. Wireless mesh networks

Wireless mesh networks (WMNs) constitute the backbones to connect the wireless hotspots in a metropolitan area. WMNs consist of a set of mesh routers that communicate with wireless links and form a mesh topology. (see figure below)



2. The geometric scheme

In recent years, the WMNs have evolved into a new architecture where the mesh routers are equipped with directional antennas, thus enabling the point-to-point communication among them and eliminating the interference largely. Hence, if we depict the mesh routers on a (x, y) plane and draw a straight line for every communication link between them, we will get a geometric graph. (see figure below)



Based on the above architecture, we propose a geometric scheme for the WMNs, which advocates that the position information (i.e., the (x, y) coordinates) of the mesh routers will play a major role in the deployment and routing of the WMNs, thus simplifying its operations. Within this scheme, we propose a joint geometric deployment and routing strategy, and also give a concrete approach to validate this strategy.

The motivations for this scheme are twofold: (1) the Simplicity Principle: “Complexity is the major factor that impedes the scalability and increases the expenditures of the networks”, which is stated in RFC 3439 “Some Internet Architectural Guidelines and Philosophy”; (2) since the geometric scheme has been used in the applications of vehicles and robots, and a network packet is analogous to a vehicle/robot, we also want to try this scheme for WMNs.

3. The joint deployment and routing strategy

This strategy is to first deploy the WMNs in certain kind of geometric graphs, and then design a geometric routing protocol by exploiting the routing properties of this graph, so as to achieve simplicity.

The rationales behind this strategy are threefold: (1) the (x, y) coordinates of mesh routers can be easily obtained by the GPS devices; (2) recall that the Internet uses the IP addresses to perform routing. However, since the Internet turns out to be deployed haphazardly, the IP addresses cannot reflect the actual locations of routers or computers; however, for the WMNs, the (x, y) coordinates of mesh routers can achieve this purpose; (3) with the deployment planned, the network graph will possess certain routing properties, which will simplify the routing protocol.

4. The concrete approach

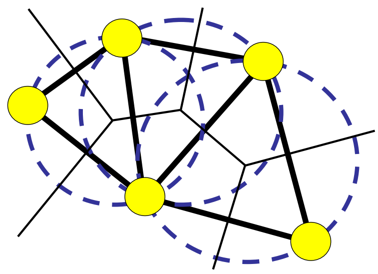
The concrete approach consists of the following two parts:

1) A geometric graph generation algorithm.
2) A geometric routing protocol on top of the above graph.

Both parts are characterized by simplicity and possess appealing properties.

5. The graph generation algorithm

The graph generation algorithm is based on a class of geometric graphs called Delaunay triangulations, which are triangulation graphs with no nodes inside the circumcircle of any of its triangles. (see figure below)



We prove the following two properties of this graph generation algorithm:

1) Simplicity: the algorithm has a low complexity of $n \cdot \log(n)$.
2) The generated graphs are backward-free, meaning that in this graph, no matter where you are, no matter where the destination is, you can always move to a neighbor node closer to the destination.

6. The geometric routing protocol

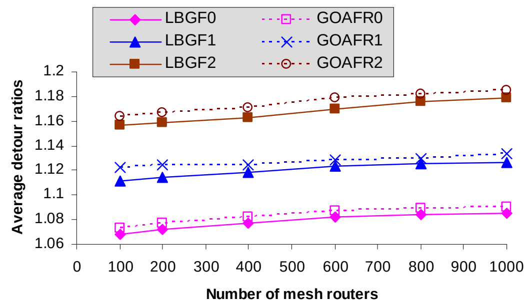
Our geometric routing protocol extends the well-known greedy forwarding protocol in the following two ways:

1) allowing the delivery of a packet farther from the destination in limited number of times.
2) proactively detecting two kinds of loops to reduce the packet drop ratio.

We name our routing protocol the Limited Backward Greedy Forwarding (LBGF) protocol, and prove the following two properties of it.

1) Simplicity: it does not need a routing table and only needs local information to perform routing, so it has a constant complexity in both time and space at a mesh router.
2) Loop-free: packets will not fall in an infinite loop even when some links in the network graph fail.

One of our main simulation results using ns-2 shows that the LBGF protocol achieves low detour ratios (the length of the path found by LBGF versus the length of the actual shortest path), and performs better than another state-of-the-art geometric routing protocol called GOAFR. (see the figure below, where the labels 0, 1, 2 indicate the increasing level of network dynamics.)



7. Significance of our work

The significance of our work lies in the use of geometric graphs to scheme the WMNs, plan in advance, and simplify during the operation, thus achieving efficiency and scalability. We believe that when the WMNs reach a large network size (e.g., with more than 100 mesh routers), our geometric scheme will show its advantages significantly. Moreover, we are the first to scheme the WMNs with such a geometric perspective, and many new interesting problems in this direction will emerge for people to tackle.

Reference

W. Si et al., A position-based deployment and routing approach for directional WMNs, Proc. of ICCCN, 2008.

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