Routing in Mobile Wireless Networks

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A major challenge in the design of wireless ad hoc networks is the need for distributed routing algorithms that consume a minimal amount of network resources. This is particularly important in dynamic networks, where the topology can change over time, and therefore routing tables must be updated frequently. Such updates incur control traffic, which consumes bandwidth and power.

Geographic routing schemes (*e.g.,* [1], [2]) base routing decisions directly on the Euclidean coordinates of nodes. Their performance depends on how well the Euclidean coordinate system captures the connectivity graph, and these approaches can therefore fail in the presence of node or channel inhomogeneity. Another important issue with geo-routing is that the positions of the nodes need to be stored in a distributed database in the network, to allow sources of messages to determine the current position of the destination. This database is called a *location service* (see [3]) and incurs additional overhead to be updated and queried.

Topology based routing schemes (see [4] and [5]) do not utilize the underlying geometry of wireless connectivity graphs, but instead compute routes based directly on that graph. Despite various optimizations, topology-based approaches suffer from the large overhead of frequent route discovery operations in large and dynamic networks. This issue was, in fact, the reason why geo-routing approaches have reached prominence.

Recently, approaches (see [6] and [7]) were proposed for *static* wireless networks which build a virtual coordinate system over which routing takes place. In [8], we studied routing on *dynamic* networks using a virtual coordinate system. These heuristics were shown through simulation to allow efficient routing without the need to discover all routes. These results raised interesting theoretical questions. In particular, one can ask what properties of a wireless connectivity graph make its topology easy to capture and hence allow low-overhead routing schemes with guarantees on the route stretch.

This geometric property is captured by the *doubling dimension* of the connectivity graph. The doubling dimension of a metric space is the number of balls of radius R needed to cover a ball of radius $2R$. Therefore, the doubling property has the potential to enable us to design and analyze algorithms for a general class of wireless networks. Moreover, for a large class of mobility models, the sequence of graphs arising due to topology changes are all doubling (for specific wireless network models). Since there are only "local" connectivity changes due to mobility, there is a smooth transition between these doubling graphs. We can utilize the locality of topology changes to develop lazy update methods to reduce signaling overhead.

Our main results (see [9]) are the following. (i) For a smooth geometric sequence of connectivity graphs, we develop a routing strategy based on a hierarchical set of beacons with scoped flooding. We also maintain cluster membership for these beacons in a lazy manner adapted to the mobility model and doubling dimension. (ii) We develop a worst-case analysis of the routing algorithm in terms of total routing overhead and route quality (stretch). We can maintain constant stretch routes while having an average network-wide traffic overhead of $O(n \log^2 n)$ bits per mobility time step. A load-balanced algorithm would require $O(\log^3 n)$ bits per node, per mobility time.

To the best of our knowledge, this is the first analysis in terms of overhead of a routing scheme for doubling mobile networks. While for homogeneous topologies the performance is comparable to geographical routing with a location service, our scheme comes with guarantees for a far larger class of graphs, including networks with inhomogeneous topologies (walls, holes, etc.).

References

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