Ad Hoc Mobile Wireless Networking

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Abstract: The growing interest in mobile ad hoc network techniques has resulted in many routing protocol proposals. Scalability issues in ad hoc networks are attracting increasing attention these days. In this article a survey brings out the different routing protocols that address scalability. Quality of Service (QoS) in ad hoc networks seldom considers the scalability issues. So, at the end of the paper, bandwidth management and congestion control so achieved by the routing protocols has been discussed.

Index terms: Mobile/Wireless network, Routing protocols, Quality of Service.

I. INTRODUCTION

Wireless networks are an emerging new technology that will allow users to access information and services electronically, regardless of their geographic position. Wireless networks can be classified in two types: - infrastructure network and infrastructure-less (ad hoc) networks. While the infrastructured cellular system is a traditional model for a mobile wireless network, here focus has been on a network that does not rely on a fixed infrastructure and works in a shared wireless media. Such a network, called a mobile ad hoc network (MANET) [1], is a self-organizing and self-configuring multihop wireless network, where the network structure changes dynamically due to member mobility. Ad-hoc wireless network are self-creating, self-organizing and self-administering.

II. AD HOC ROUTING PROTOCOLS

The growing interest in mobile ad hoc network techniques has resulted in classifying the routing protocols in three broad categories:

- Flat routing schemes, which are further classified into two classes: proactive and reactive, according to their design philosophy
- Hierarchical routing
- Geographical position assisted routing

A. *Routing in a Flat Network Structure*

The protocols we review here fall into two categories: proactive and on-demand routing. Many proactive protocols stem from conventional Link State (LS) routing.

1) *Proactive (Table Driven) Routing Protocols*: Proactive routing protocols share a common feature, i.e. background routing information exchange regardless of communication requests. The protocols have many desirable properties, especially for applications including real-time communications and QoS guarantees, such as low-latency route access and alternate QoS path support and monitoring. The different examples of proactive routing protocols are:

- *Dynamic Destination-Sequenced Distance-Vector (DSDV) Routing Protocol:* The DSDV Routing Algorithm [2] is based on the idea of the classical Bellman-Ford Routing Algorithm with certain improvements.

- The Wireless Routing Protocol (WRP): In the Wireless Routing Protocol (WRP) [3], each node in the network maintains a Distance table, a Routing table, a Link-Cost table and a Message Retransmission list.

- *Global State Routing (GSR):* Global State Routing (GSR) [4] is similar to DSDV. It takes the idea of link state routing but improves it by avoiding flooding of routing messages.

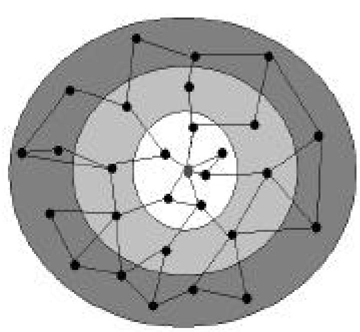

Fig. 1. Accuracy of information in FSR

- *Fisheye State Routing (FSR):* Fisheye State Routing (FSR) [5] is an improvement of GSR. Each update message does not contain information about all nodes. First, FSR exchanges the entire link state information only with neighbors instead of flooding it over the network. Second, the link state exchange is periodical instead of event-triggered Fig.1 defines the scope of fisheye for the center node. The scope is defined in terms of the nodes that can be reached in a certain number of hops. The center node has most accurate information about all nodes in the white circle and so on. Similar work is also presented in Fuzzy Sighted Link State (FSLS) routing [6]. FSLS includes an optimal algorithm called Hazy Sighted Link State (HSLS), which sends a link state update (LSU) every $2^k * T$ to a scope of 2^k, where k is a hop distance and T is the minimum LSU transmission period.

- *Topology Broadcast Based on Reverse Path Forwarding (TBRPF):* Topology Broadcast Based on Reverse Path Forwarding (TBRPF) [7, 8] consists of two separate modules: the neighbor discovery module and the routing module. The TBRPF routing module operates based on partial topology information obtained through both periodic and differential topology updates. Operation in full topology is provided as an option by including additional topology information in updates.

- *Optimized Link State Routing Protocol (OLSR):* The protocol uses multipoint relays (MPRs) [9] to reduce the number of "superfluous" broadcast packet retransmissions and also the size of the LS update packets, leading to efficient flooding of control messages in the network. A node, say node A, periodically broadcasts HELLO messages to all immediate neighbors to exchange neighborhood information (i.e., list of neighbors) and to compute the MPR set. From neighbor lists, node A figures out the nodes that are two hops away and computes the minimum set of one-hop relay points required to reach the two-hop neighbors. Such set is the MPR set.

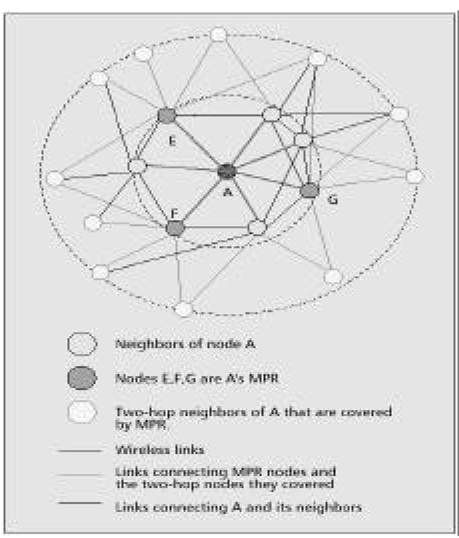

Fig. 2. An illustration of Multipoint relays.

2) *On Demand Routing Protocols:* On-demand routing is a popular routing category for wireless ad hoc routing. The design follows the idea that each node tries to reduce routing overhead by only sending routing packets when a communication is awaiting. Examples include Ad Hoc On Demand Distance Vector Routing (AODV) [10], Associativity-Based Routing (ABR) [11], Dynamic Source Routing (DSR) [12], Lightweight Mobile Routing (LMR) [13], and Temporally Ordered Routing Algorithms (TORA) [14]. Among the many proposed protocols, AODV and DSR have been extensively evaluated in the MANET literature and are being considered by the Internet Engineering Task Force (IETF) MANET Working Group as the leading candidates for standardization.

In AODV, on receiving a query, the transit nodes "learn" the path to the source (called *backward learning*) and enter the route in the forwarding table. The intended destination eventually receives the query and can thus respond using the path traced by the query. This permits establishment of a full duplex path.

An alternate scheme for tracing on-demand paths is DSR. DSR uses source routing, that is, a source indicates in a data packet's header the sequence of intermediate nodes on the routing path. In DSR, the query packet copies in its header the IDs of the intermediate nodes it has traversed. The destination then retrieves the entire path from the query packet, and uses it (via source routing) to respond to the source, providing the source with the path at the same time. Promiscuous listening (overhearing neighbor propagation) used by DSR helps nodes to learn as many route updates as they can without actually participating in routing.

B. Hierarchical Routing Protocols

Typically, when wireless network size increase (beyond certain thresholds), current "flat" routing schemes become infeasible because of link and processing overhead. One way to solve this problem, and to produce scalable and efficient solutions is hierarchical routing. Wireless hierarchical routing is based on the idea of organizing nodes in groups and then assigning nodes different functionalities inside and outside a group.

1) *Clusterhead-Gateway Switch Routing (CGSR): CGSR* [15] is typical of cluster-based hierarchical routing. A stable clustering algorithm, Least Clusterhead Change (LCC), is used to partition the whole network into clusters, and a clusterhead is elected in each cluster. A mobile node that belongs to two or more clusters is a gateway connecting the clusters. Data packets are routed through paths having a format of "Clusterhead–

Gateway Clusterhead– Gateway…" between any source and destination pairs.

2) *Hierarchical State Routing (HSR):* HSR [16] is a multilevel clustering based LS routing protocol. It maintains a logical hierarchical topology by using the clustering scheme recursively.

3) *Zone Routing Protocol (ZRP):* ZRP [17] is a hybrid routing protocol that combines both proactive and on-demand routing strategies and benefits from advantages of both types. The basic idea is that each node has a predefined zone centered at itself in terms of number of hops. For nodes within the zone, it uses proactive routing protocols to maintain routing information. For those nodes outside of its zone, it does not maintain routing information in a permanent base.

4) *Landmark Ad Hoc Routing Protocol (LANMAR):* LANMAR [18] is designed for an ad hoc network that exhibits group mobility. The advantage of this LANMAR uses an IP-like address consisting of a group ID (or subnet ID) and a host ID: <Group ID, Host ID >. LANMAR uses the notion of landmarks to keep track of such logical groups. Each logical group has one dynamically elected node serving as a landmark.

C. Geographic Position Information Assisted Routing

The advances in the development of Global Positioning System (GPS) nowadays make it possible to provide location information with a precision within a few meters. It also provides universal timing. While location information can be used for directional routing in distributed ad hoc systems, the universal clock can provide global synchronizing among GPS equipped nodes. Research has shown that geographical location information can improve routing performance in ad hoc networks. Additional care must be taken into account in a mobile environment, because locations may not be accurate by the time the information is used.

1) *Geographic Addressing and Routing (GeoCast):* GeoCast [19] allows messages to be sent to all nodes in a specific geographical area using geographic information instead of logical node addresses. A geographic destination address is expressed in three ways: point, circle (with center point and radius), and polygon (a list of points, e.g., P(1), P(2), …,P(n–1), P(n), P(1)).

2) *Distance Routing Effect Algorithm for Mobility (DREAM):* DREAM [20] is a proactive routing protocol using location information. It provides distributed, loop-free, multipath routing and is able to adapt to mobility. It minimizes the routing overhead by using two new principles for the routing update frequency and message lifetime. The principles are distance effect and mobility rate**.** In DREAM, each node maintains a location table (LT). The table records locations of all the nodes. Each node periodically broadcasts control packets to inform all other nodes of its location.

3) *Location-Aided Routing (LAR):* LAR protocol presented in [21] is an on-demand protocol based on source routing. The protocol utilizes location information to limit the area for discovering a new route to a smaller request zone. As a consequence, the number of route request messages is reduced. The operation of LAR is similar to DSR. Using location information, LAR performs the route discovery through limited flooding (i.e., floods the requests to a request zone). LAR provides two schemes to determine the request zone.

Scheme 1: The source estimates a circular area (expected zone) in which the destination is expected to be found at the current time. The position and size of the circle is calculated based on the knowledge of the previous destination location, the time instant associated with the previous location record, and the average moving speed of the destination.

Scheme 2: The source calculates the distance to the destination based on the destination location known to it. This distance, along with the destination location, is included in a route request message and sent to neighbors. When a node receives the request, it calculates its distance to the destination.

4) *Greedy Perimeter Stateless Routing (GPSR):* Greedy Perimeter Stateless Routing (GPSR) [22] is a routing protocol that uses only neighbor location information in forwarding data packets. It requires only a small amount of per-node routing state, has low routing message complexity, and works best for dense wireless networks. In GPSR, beacon messages are periodically broadcast at each node to inform its neighbors of its position, which results in minimized one-hop-only topology information at each node. To further reduce the beacon overhead, the position information is piggybacked in all the data packets a node sends. GPSR uses two data forwarding schemes: greedy forwarding and perimeter forwarding**.** The former is the primary forwarding strategy, while the latter is used in regions where the primary one fails. Greedy forwarding works this way: when a node receives a packet with the destination's location, it chooses from its neighbors the node that is geographically closest to the destination and then forwards the data packet to it. This local optimal choice repeats at each intermediate node until the destination is reached. When a packet reaches a dead end (i.e., a node whose neighbors are all farther away from the destination than itself), perimeter forwarding is performed.

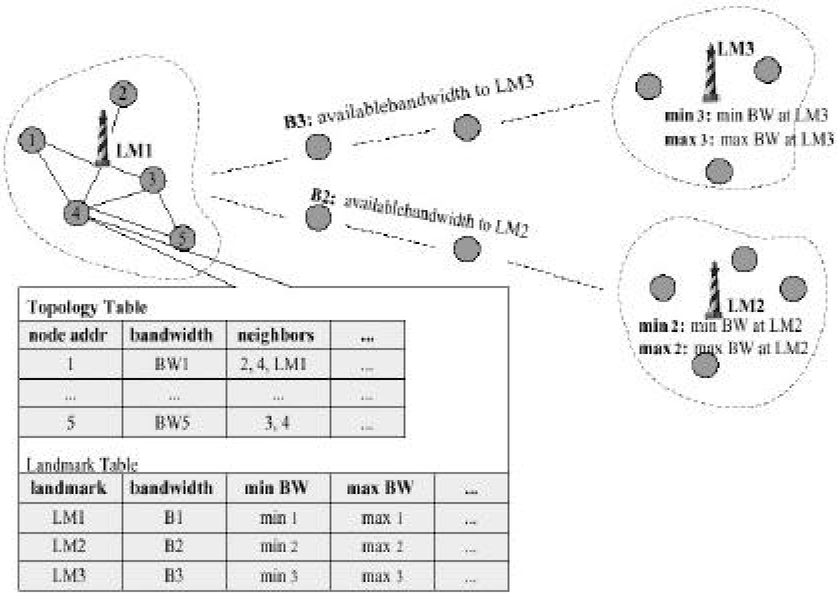

Fig. 3. Illustration of QoS Extended LANMAR Routing.

III. CONGESTION CONTROL AND SCALABLE QoS ROUTING

We use bandwidth information as the metric of choice for QoS provisioning. In QoS architecture, each node will continuously estimate its available bandwidth. Now, the QoS architecture has four basic components, namely adaptive bandwidth management, scalable QoS routing, call admission control and congestion control. After correctly measuring the available bandwidth at each node, we then want to extend the ad hoc routing protocol to include bandwidth information. LANMAR has been selected as the underlying routing protocol for supporting QoS architecture. Fisheye's QoS extension is quite easy and also applied. With the support from the underlying QoS routing, the source node can then decide whether to admit a new real-time flow. This is usually referred to as call admission control (CAC). Since QoS-LANMAR is basically a proactive routing protocol, the bandwidth information is already available at each node. With the help of the scalable LANMAR routing protocol, the proposed QoS scheme works efficiently in large-scale ad hoc network with thousands of nodes. Moreover, to improve scalability, attempt has been made to incorporate the QoS architecture with physical, hierarchical ad hoc networks, known as the mobile backbone network (MBN) [23]. Simulation results show that the scheme has great potential to provide good QoS provisioning for future military wireless networks. LANMAR routing consists of two mostly independent routing protocols, the local scoped routing and the landmark distance vector routing. To include the bandwidth information, modification made in the Landmark Update is as:

- Each landmark computes the minimal and maximal available bandwidth (min_{BW} and max_{BW}) to any other node within its landmark group. This can be done with the help of the local scoped QoS routing.

- The landmark distance vectors carry the min_{BW} and max_{BW} calculated by each landmark and are then propagated throughout the network.

The distance vector routing of the landmark information propagation also needs QoS extension. Each distance vector then adds one more QoS field to record the minimal bandwidth to the corresponding landmark. This is exactly a QoS distance vector routing.

IV. CONCLUSIONS

Protocols described in this article reveal the influence of underlying network structure on the routing protocols. The drawbacks of proactive schemes are constant bandwidth consumption due to periodic routing updates. On-demand routing schemes overcome this problem by searching for available routes to destinations only when needed, thus keeping bandwidth usage and routing table storage low. On the other hand, on demand schemes incur huge amounts of flooding packets in large networks in search of destinations. All protocols address the challenges of scalability. Since ad hoc networks will be used in various applications ranging from military to commercial, diversity in routing protocol designs is inevitable. In this article we provide descriptions of the protocols No protocol emerges as the winner for all scenarios. All the previously mentioned schemes offer different, competitive, and complementary advantages, and are thus appropriate for different applications. Routing protocols capable of adapting to various application domains are desirable in future designs. With the recent rapid growth of ad hoc networks, future research will face even more challenges in the attempt to find the best match between scalable routing and media access control, security, and service management.

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