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Routing Protocols for Multi-hop Wireless Networks

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Abstract: **In this paper, we perform a simulation and performance study on some routing protocols for ad hoc networks. Distributed Bellman-Ford, a traditional table-driven routing algorithm, is simulated to evaluate its performance in multi-hop wireless networks. In addition, an on-demand routing protocol (Dynamic Source Routing (DSR)) with distinctive route selection algorithm is simulated in a common environment to quantitatively measure and contrast their performance. The final selection of an appropriate protocol will depend on a variety of factors, which are discussed in this paper.**

I. INTRODUCTION

Bandwidth and power constraints are the main concerns in current wireless networks because multi-hop, ad hoc mobile wireless networks rely on each node in the network to act as a router and packet forwarder. This dependency places band-width, power, and computation demands on mobile hosts which must be taken into account when choosing the best routing protocol. In recent years, protocols that build routes based on demand" have been proposed. The major goal of on-demand routing protocols is to minimize control traffic overhead. In this paper, we perform a simulation and performance study on some routing protocols for ad hoc networks. Distributed Bellman-Ford, a traditional table-driven routing algorithm, is simulated to evaluate its performance in multi-hop wireless networks. In addition, an on-demand routing protocol, Dynamic Source Routing (DSR) with distinctive route selection algorithm is simulated in a common environment to quantitatively measure and contrast their performance. We have chosen these two protocols for the following reasons: (i) to evaluate the performance of a conventional table-driven routing scheme (DBF) in multi-hop wireless networks, and (ii) to study the performance of different routing metrics in dynamic ad hoc networks. The final selection of an appropriate protocol will depend on a variety of factors, which are discussed in this paper.

II. ROUTING PROTOCOLS REVIEW

Distributed Bellman-Ford

Distributed Bellman-Ford (DBF) algorithm was developed originally to support routing in the ARPANET. A version of it is known as RIP (Routing Internet Protocol) [1] and is still being used today to support routing in some Internet domains. It is a table-driven routing protocol, i.e., each router constantly maintains an up-to-date routing table with information on how to reach all possible destinations in the network. For each entry, the next router to reach the destination and a metric to the destination are recorded. The metric can be hop distance, total delay, or cost of sending the message. Each node in the network begins by informing its neighbors about its distance to all other nodes. The receiving nodes extract this information and modify their routing table if any route measure has changed. After recomputing the metrics, nodes pass their own distance information to their neighbor nodes again. After a while, all nodes/routers in the network have a consistent routing table to all other nodes.

This protocol does not scale well to large networks due to a number of reasons. One problem is the so called “count-to-infinity" problem. In unfavorable circumstances, it takes up to N iterations to detect the fact that a node is disconnected, where N is the number of nodes in the network. Another problem is the increase of route update overhead with mobility. RIP uses time-triggered (periodic, about 30sec interval) and event-triggered (link changes or router failures) routing updates.

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Mobility can be expressed as rate of link changes and/or router failures. In a mobile network environment, event-triggered routing updates tend to out-number the time-triggered updates, leading to excessive overhead and inefficient usage of the limited wireless bandwidth.

Dynamic Source Routing

Dynamic Source Routing (DSR) [2] is a direct descendant of the source routing scheme used in bridged LANs. It uses source routing instead of hop-by-hop packet routing. Each data packet carries the list of routers in the path. The main benefit of source routing is that intermediate nodes need not keep route information because the path is explicitly specified in the data packet. DSR does not require any kind of periodic message to be sent, supports uni-directional and asymmetric links, and sets up routes based on demand by the source. DSR consists of two phases:

(a) route discovery and;

(b) route maintenance.

Route Discovery

When a source has a data packet to send but does not have any routing information to the destination, the source initiates a route discovery. To establish a route, the source floods a *Route Request* message with a unique request ID. When this request message reaches the destination or a node that has route information to the destination, it sends a *Route Reply* message containing path information back to the source. The ”route cache" maintained at each noderecords routes the node has learned and overheard over time to reduce overhead generated by a route discovery phase.

When a node receives a *Route Request* packet, this message is forwarded only if all of the following conditions are met:

(a) the node is not the target (destination) of the *Route Request* packet,

(b) the node is not listed in source route,

(c) the packet is not a duplicate,

(d) no route information to the target node is available in its route cache.

If all are satisfied, it appends its identification to the source route and broadcasts the packet to its neighbors. If condition (b) or (c) is not met, it simply discards the packet. If a node is the destination of the packet or has route information to the destination, it builds and sends a *Route Reply* to the source, as described above.

Route Maintenance

The main innovation of DSR with respect to bridged LAN routing is in route monitoring and maintenance in the presence of mobility. DSR monitors the validity of existing routes based on the acknowledgments of data packets transmitted to neighboring nodes. This monitoring is achieved by passively listening for the transmission of the neighbor to the next hop or by setting a bit in a packet to request an explicit acknowledgment. When a node fails to receive an acknowledgment, a *Route Error* packet is sent to the original sender to invoke a new route discovery phase. Nodes that receive a *Route Error* message delete any route entry (from their route cache) which uses the broken link. A *Route Error* message is propagated only when a node has a problem sending packets through that link. Although this selective propagation reduces control overhead (if no packets traverse a link), it yields a long delay when a packet needs to go through a new link.

Information Stored in Each Node

Route Cache: Each node stores routing information it has learned and overheard in its route cache. Routing information can be obtained while processing *Route Reply* messages and the source route list of a data packet header. More than one route for each destination can be stored in the cache. When a *Route Error* message is received or overheard, routes that use the broken link specified in the *Route Error* are removed from the route cache.

Route Request Table: Nodes producing a *Route Request* packet store information in the route request table. Recorded information includes the destination node of a *Route Request*, the time when the node last sent a *Route Request* to the destination, and the time the node has to wait until it can send a next *Route Request* to the destination. The purpose of maintaining this table is to restrict frequent *Route Request* transmissions to the same destination.

III. SIMULATION ENVIRONMENT

The simulator for evaluating the routing protocols is implemented within the Global Mobile Simulation (GloMoSim) library [3]. The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation capability provided by PARSEC. The simulation models the network of 30 mobile hosts migrating within a 20 meter x 20 meter space with a transmission radius of five meters. Every node in the network moves in a random fashion, with a static time of five seconds before migrating again. The channel capacity is 2Mb/s. The IEEE 802.11 Distributed Coordination Function (DCF) is used as the medium access control protocol. A free space propagation model with a threshold cutoff has been used in our experiments. In the free space model, the power of a signal attenuates as $1/d^2$ where d is the distance between radios. In the radio model, capture effects are taken into account. If the capture ratio (the minimum ratio of an arriving packet's signal strength relative to those of other colliding packets) is greater than the predefined threshold value, the arriving packet is received while other interfering packets are dropped. A traffic generator was developed to simulate constant bit rate sources. Source nodes and destination nodes were chosen randomly with uniform probabilities. A packet is dropped when no acknowledgment is received after retransmitting it a certain number of times. Simulation runs of 200,000,000,000 simulation ticks (which is 200 seconds of simulation time) were performed multiple times.

Simulation Results

DBF, a traditional table-driven routing scheme used in wired networks, is compared with on-demand ad hoc routing scheme (DSR) in a common multihop mobile wireless network simulation platform.

Parameters of interest are:

(a) control overhead,

(b) data throughput, and

(c) end-to-end packet propagation delay.

Control Message Overhead

Figure 3.1 shows the control overhead incurred by DBF and DSR. DSR, on-demand routing scheme, have considerably less overhead (as high as 75%) than DBF. Sending route updates periodically and triggering updates when the topology changes in order to maintain an up-to-date routing table result in excessive control message overhead, which is unacceptable in a wireless environment with limited bandwidth.

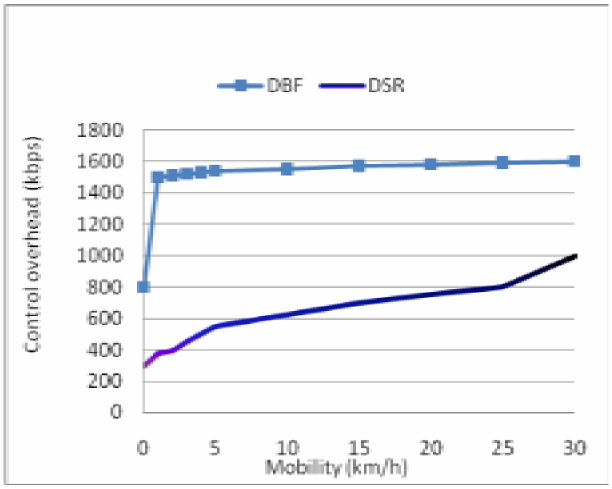

Figure 3.1 Control Overhead with Varying Speed

Data Throughput

Figure 3.2 shows the throughput comparison of DBF and DSR. DBF's poor performance can be attributed to excessive channel usage by route update control messages. Also, as mobility speed increases, more event-triggered updates are generated. However, this is not present in on-demand routing protocol.

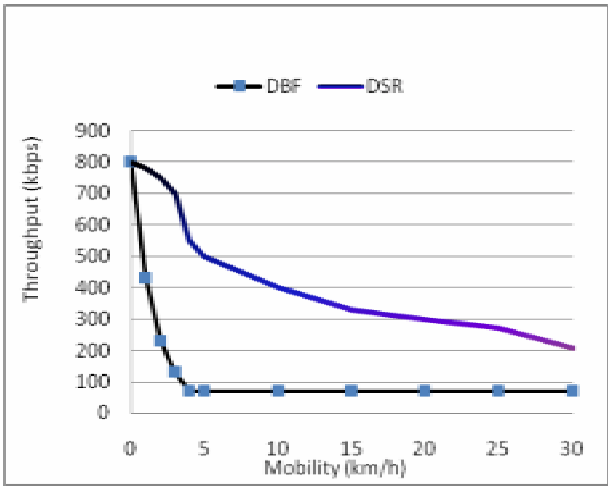

Figure 3.2 Throughput with Varying Speed

End-to-End Delay

Figure 3.3 shows the end-to-end delay of data packets. DBF has a larger delay than on-demand scheme due to high control overhead and thus large queueing delay.

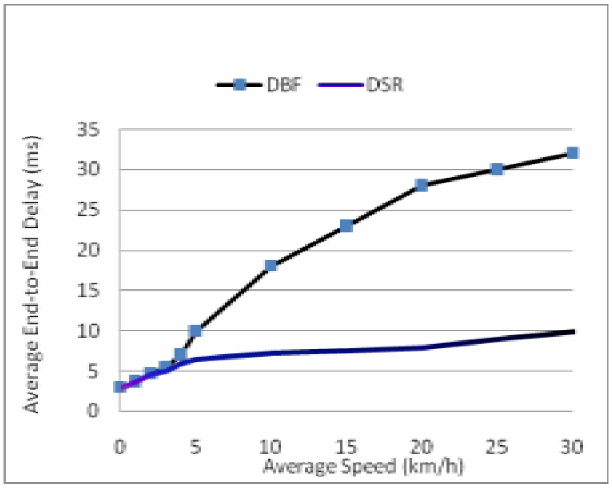

Figure 3.3 Average End-to-End Delay with Varying Speed

Table Storage Overhead

For each route discovered by DSR, a route cache table is kept at the source as well as at each node along the oute. Let R be the average number of active routes a node supports and N the total number of nodes in the network. Assuming a grid-like radio connection topology (consistent with optimal radio power range), the average path length is $\sqrt{N}$. So, the total number of route cache entries for each node is on average R$\sqrt{N}$. The source node of route request packets maintains a node information cache. Having four fields for each destination, the average number of node information cache entries per node is 4R. Hence, the total storage overhead for DSR is $R\sqrt{N}$ + 4R. Note that if there is no active traffic, i.e., R is zero, the storage overhead is zero.

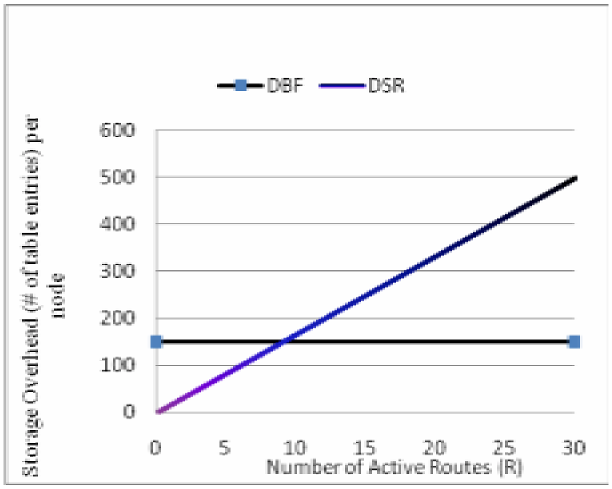

Figure 3.4 Storage overhead (per node) with N = 50, n = 4, and Varing Number of Active Routes (R), where n is the average number of neighbors.

In Distributed Bellman-Ford, the table overhead of each network node is 3N, independent of traffic. (DBF stores destination, distance, and next hop node for each route, thus making it 3N for each node.) This overhead is higher than on-demand routing (DSR) in light traffic but lower in heavy traffic. In Figure 3.4, we show the storage overhead required by each node for varying number of active routes in a network with 50 hosts. We can see that DBF requires more storage overhead than on-demand protocols in light traffic. In DSR, storage overhead is zero if there is zero traffic.

IV CONCLUSION

Many routing protocols for ad hoc mobile wireless networks have been proposed in recent years. In this PAPER, we have reviewed and studied key properties of two distinctive routing protocols. Performance evaluation of these protocols have been conducted via simulation in a common network environment. We have compared the performance of Distributed Bellman-Ford and Dynamic Source Routing. Simulation results reveal that the DBF incurs extensive bandwidth and computation overhead in the presence of mobility, yielding inferior performance when compared to on-demand routing protocol (DSR) in ad hoc networks.

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