Pushing the Limits of Multicast in Ad Hoc Networks

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January 29, 2001

Abstract

This work focuses on the requirements of "better than best effort" (high hop-by-hop delivery guarantee) broadcast in highly dynamic mobile multi-hop ad hoc networks (MANETs). Our work is motivated by mission-critical applications such as disaster relief and military operations. This class of applications is characterized by: (1) high delivery guarantee requirements even in the presence of high mobility, and (2) broadcast-style of communication where all nodes are receivers.

Extensive simulations conducted on two different platforms show that, as node speeds, network traffic load, and number of senders increase, the performance of existing multicast protocols (exemplified by ODMRP and MAODV) degrade in terms of packet delivery and overhead. In contrast, simple flooding, while clearly not a panacea, performs comparatively well and shows promise as a foundation for more specialized protocols for highly dynamic MANETs of the future.

1 Introduction

Mobile multi-hop ad hoc networks, or MANETs, are characterized by the lack of any fixed network infrastructure. All network components of a MANET can be mobile. Moreover, there is no real distinction between a host and a router since all nodes can be sources as well as forwarders of traffic. A number of MANET-oriented multicast routing protocols have been recently proposed. They can be classified as proactive and reactive. The proactive protocols maintain routing state, while the reactive protocols reduce the impact of frequent topology changes by acquiring routes on demand.

One of the main challenges presented by multicast routing in MANETs is the need to achieve robustness in the presence of universal mobility and frequent node outages and failures. We observe that key features of MANETs make them attractive for deployment in critical environments, such as military or civilian emergency operations. Since in almost any critical environment, robustness and high quality of service are very important, multicast routing and packet forwarding algorithms that cannot provide high delivery guarantees may be inadequate for mission-critical, highly dynamic MANETs.

2 Focus

The focus of our work is to probe the need for new protocols that: (1) specifically target broadcast in highly dynamic MANETs and (2) can provide high delivery guarantees. In particular this paper compares the performance of mesh-based and tree-based multicast protocols with plain flooding. The On-Demand Multicast Routing Protocol (ODMRP) [1] was chosen to represent mesh-based protocols . Multicast Ad hoc On-Demand Distance Vector (MAODV) [4] was chosen to represent tree-based protocols. Both protocols belong to the reactive category.

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We have used two simulators (ns) [2], and GloMoSim [5]. to study the reliability of the different protocols under a wide range of mobility conditions, traffic source populations, and network traffic loads. Although we are mainly interested in how multicast protocols perform in broadcast communication, we also evaluate them for different multicast scenarios.

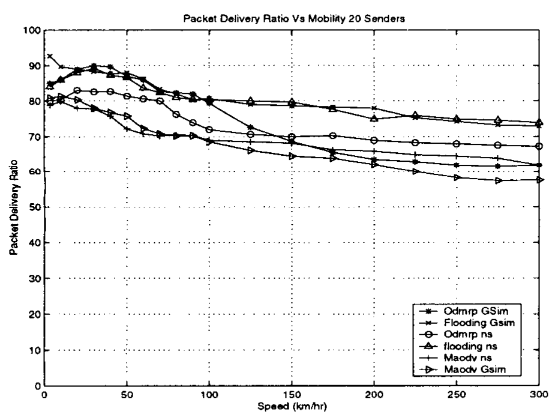
3 Simulation Environment

In our experiments we used GloMoSim 1.1.1 and ns 2.1b6. We tried to make the two simulation environments equivalent to one another by driving both simulators with the same set of parameters. The total simulation time for both simulators was set to 500 seconds. A total of 50 nodes were randomly placed in a 1000x1000 meter field. Each sender generated 100 packets using a 2 Mbit/sec channel with a power range of 225 meters. The mobility model used is a modified version of the random-waypoint model also known as the bouncing ball model. A constant bit rate (CBR) traffic generator was used for both simulators. A more detailed explanation of the simulation environment and parameters can be obtained from an extended version of this paper [3]

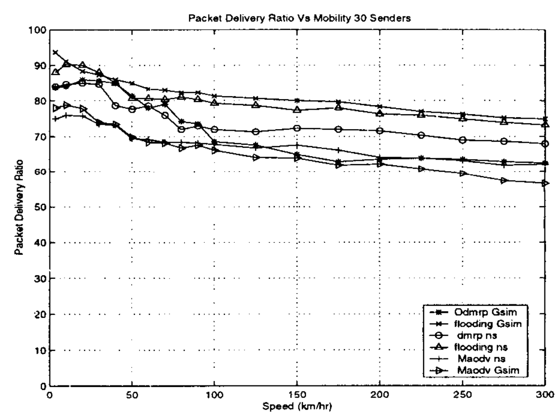
4 Results

4.1 Reliability in broadcast scenarios

We compute packet delivery ratio as the ratio of total number of packets received by the nodes to the total number of packets transmitted times the number of receivers. The graphs in Figure 1 show how protocol reliability varies with mobility (node speed) and the number of traffic sources. The general trend we observe from both simulators is



(a) 20 senders



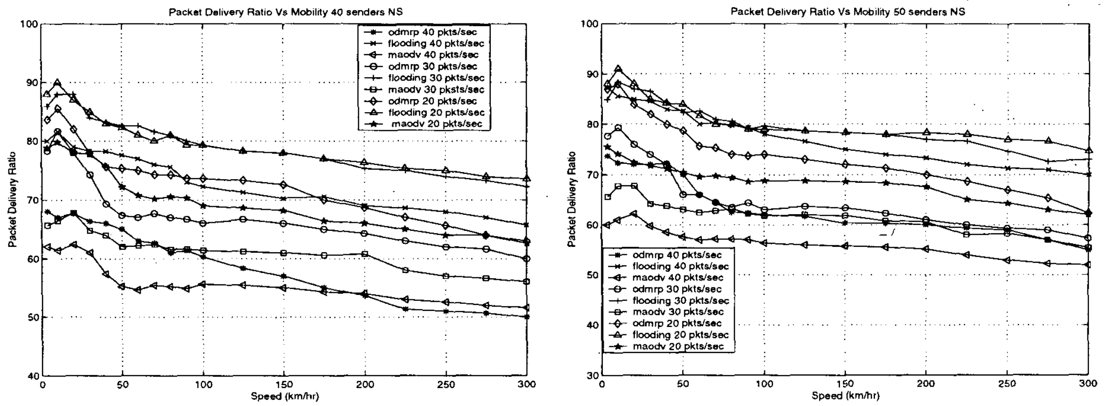
(b) 30 senders

Figure 1: Packet delivery ratio as a function of node speed and number of senders.

that for scenarios with moderate ratios between number of senders and number of receivers, flooding performs better than ODMRP which in turn performs better than MAODV.

The goal of this next set of experiments is to evaluate the behavior of both protocols for different network traffic loads.

We observe that for both 40 and 50 senders and as the traffic load increases flooding maintains higher delivery ratio than ODMRP and MAODV. Take the 50-sender, 40 pkt/sec case: at 0 speed, flooding's delivery ratio is



(a) 40 senders - ns

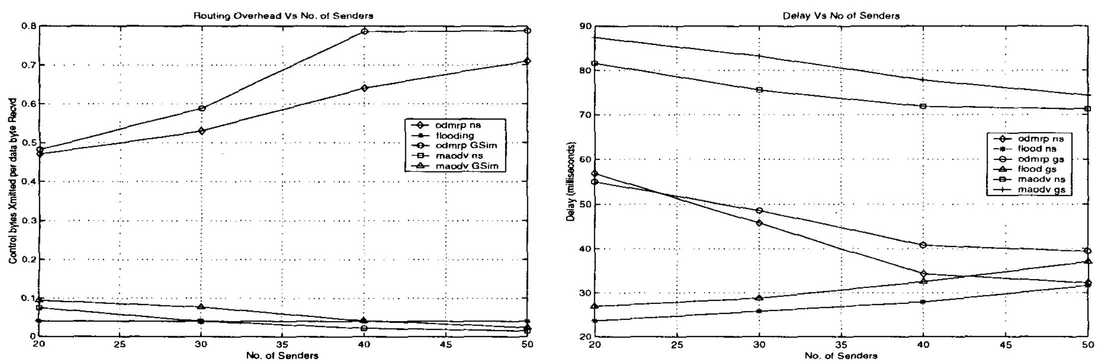
(b) 50 senders - ns

Figure 2: Packet delivery ratio as a function of network traffic load and node speed for 40 and 50 senders.

approximately 85%,ODMRP's is 75% and MAODV's is 60% (referring to results from ns simulations); flooding delivers about 68% of the packets at 300 km/h, while ODMRP 55% and MAODV 52%.

4.2 Overhead and Delay

The graphs plot average routing overhead and average packet delivery delay as a function of the number of senders.



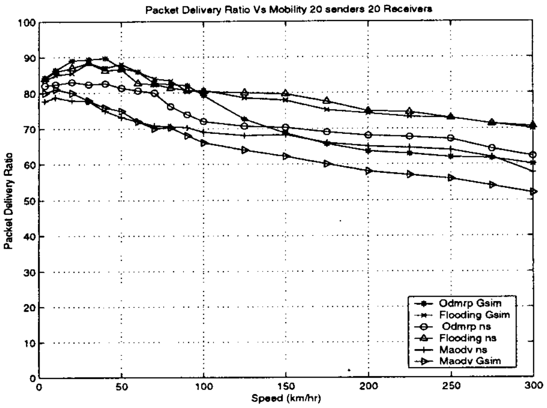
(a) Pure routing overhead

(b) Delay as a function of number of senders

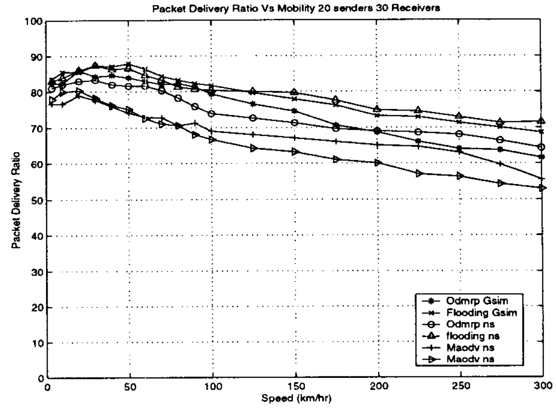
ODMRP's overhead is considerably higher than flooding or MAODV and grows with the number of senders because ODMRP has to periodically flood JOIN DATA packets to maintain the mesh connectivity. Therefore, the more senders there are, the more control and data overhead gets generated. In the case of MAODV, the routing overhead required to maintain the tree is independent of the number of senders. Hence the routing overhead per data byte transmitted is higher for a smaller number of senders and decreases as the number of senders increases.

Flooding provides a lower bound on average delivery delay since it almost always sends packets over the shortest paths to the receivers. We observe that MAODV's delay is higher than ODMRP's due to the collision effect . Note that it stays almost constant with the number of senders.

4.3 Reliability in Multicast Scenarios



(c) 20 senders 20 Receivers



(d) 20 senders 30 Receivers

Figure 3: Packet delivery ratio as a function of node speed.

The graphs in Figure 3 show that packet delivery ratios for flooding in multicast are lower when compared to broadcast (see Figure 1). This is because every unique packet received and forwarded, in broadcast, is counted toward packets succesfully delivered since all nodes are receivers. However, in multicast, every unique packet received and forwarded does not necessarily count as succesfully delivered as the forwarding node may not be a member of the multicast group.

5 Conclusions, Ongoing, and Future Work

In summary, this paper reported on simulation-driven experiments evaluating three approaches to broadcast and multicast communication with an emphasis on high delivery guarantees in highly dynamic mobile ad hoc networks. The results demonstrate that as both network traffic load and numbers of senders increase, multicast protocols (exemplified by ODMRP and MAODV) degrade in terms of delivery ratios and overhead. Whereas, plain flooding performs relatively well and shows promise as a foundation for more specialized protocols for highly dynamic MANETs of the future.

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