Efficient Scalable Group Communication Using Multicast Routing Protocols

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Abstract : In this paper we propose a new multicast protocol for multihop mobile wireless networks. Instead of forming multicast trees, a group of nodes in charge of forwarding multicast packets is designated according to members' requests. A location service for ad hoc networks is a distributed algorithm that allows any source node s to know the location of any destination node t, simply by knowing t's network identifier. A location service has a locality aware lookup algorithm if the cost of locating destination t from source s is proportional to the cost of the minimal cost path between s and t. A location service has a locality aware publish algorithm if the cost of updating the location service due to a node moving from x to y is proportional to the distance between x and y. This paper presents a novel multicast routing protocol for mobile ad hoc wireless networks. The protocol, termed ODMRP (On-Demand Multicast Routing Protocol), is a mesh-based, rather than a conventional tree based, multicast scheme and uses a forwarding group concept. It applies on-demand procedures to dynamically build routes and maintain multicast group membership. ODMRP is well suited for ad hoc wireless networks with mobile hosts where bandwidth is limited, topology changes frequently, and power is constrained. We evaluate ODMRP's scalability and performance via simulation.

Index Terms - **Wireless Network, Multihop, Multicast, Ad hoc, Clustering, FGMP.**

1. INTRODUCTION AND BACKGROUND

In this paper we introduce a novel multicast scheme for a mobile, multihop wireless network with no fixed infrastructure [1, 2]. Various multicast schemes have been proposed for such an environment. One scheme creates a per-source multicast tree for each sender source [3]. Packets are multicast on the tree using Reverse Path Forwarding (RPF) for duplicate detection. We will show that RPF is not very effective in high mobility environments. Another is using a shared tree spanning the members in the multicast group [4, 5]. Data sent to the shared tree are forwarded to all receiver members. For the shared tree multicast, it is necessary to maintain a "core" or Rendezvous Point (RP) for sender and receiver paths to meet. RP mobility may affect multicast efficiency. Some schemes use sets of RPs [6] to direct multicast routing and resource reservation. The mobile RPs tend to increase the overhead of RP selection and thus reduce multicast efficiency.

In this paper we propose a multicast protocol which requires minimal infrastructure (without RP) and is thus resilient to mobility. Yet it achieves good efficiency by exploiting the inherent broadcast property of the wireless medium. In essence, the protocol is a hybrid between flooding and shortest tree multicast. In a static network it does converge to per source multicast. For this reason, we will compare its performance to that of flooding and DVMRP [3], the latter being a popular per source tree implementation.

Multicasting has emerged as one of the most focused areas in the field of networking. As the technology and popularity of the Internet have grown, applications that require multicasting (e.g., video conferencing) are becoming more widespread. Another interesting recent development has been the emergence of dynamically reconfigurable wireless ad hoc networks to interconnect mobile users for applications ranging from disaster recovery to distributed collaborative computing. Multicast plays a key role in ad hoc networks because of the notion of teams and the need to show data/images to hold conferences among them. Protocols used in static networks (e.g.,DVMRP [7], MOSPF [14], CBT [2], and PIM [8]), however, do not perform well in a dynamically changing ad hoc network environment. Multicast tree structures are fragile and must be readjusted continuously as connectivity changes. Furthermore, typical multicast trees usually require a global routing substructure such as link state or distance vector. The frequent exchange of routing vectors or link state tables, triggered by continuous topology changes, yields excessive channel and processing overhead. Limited bandwidth, constrained power, and mobility of network hosts make the multicast protocol design particularly challenging.

To overcome these limitations, we have developed the On-Demand Multicast Routing Protocol (ODMRP). ODMRP applies *on-demand* routing techniques to avoid channel overhead and improve scalability. It uses the concept of *forwarding group* [5], a set of nodes responsible for forwarding multicast data on shortest paths between any member pairs, to build a forwarding *mesh* for each multicast group. By maintaining.

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2. DISTANCE VECTOR MULTICAST ROUTING PROTOCOL (DVMRP) FOR A WIRELESS ENVIRONMENT

In DVMRP, each sender uses flooding to direct the multicast packets to all nodes within a specified range (defined by TTL). Multicast packets are selectively forwarded according to the reverse shortest path forwarding protocol [3]. Non-member leaf nodes and nodes without any downstream members send prune messages upstream to prune off branches to non-member nodes. After timeout, pruned branches become alive again and get flooded with messages. A new receiver member can also send a graft message to upstream nodes in order to speed up the connect process.

There are some problems in the use of DVMRP in mobile wireless networks. One problem is the leaf node detection. In a multi-hop mobile network, all nodes can function as routers; thus, there is no explicit subnet. IGMP is not suitable for this environment. In section 2.1, we explore two schemes to detect the leaf nodes and show their performance via simulation. Another problem is the data flooding overhead. Because upstream nodes may change or be disconnected due to node mobility, it is necessary to re-flood by exploring pruned branches after timeout in order to reestablish the upstream information, reconnect lost members, or allow new members to join. In addition, re-flooding is needed to confirm the existence of the sender source. A sender is declared non-existent after timeout.

(a) (b)

Figure 2: Example of upstream change

2.1 LEAF NODES DETECTION

In DVMRP, leaf routers are responsible for sending prune messages to upstream routers when multicast packets arrive and there is no member on the leaf subnet. For the wire line networks, each router has explicit link information to decide which links are child links for a given source. Multicast packets are forwarded only to child links. However, it is not trivial for a wireless node to decide whether it is a leaf node. For multihop wireless networks, all nodes are routers and there is no explicit link interface information to determine the leaf status. Here we propose two schemes for detecting the leaf nodes for a source. One is using ACK to detect the leaf node. When a node N receives a multicast packet from source Svia RPF , it transmits the packet and all neighbors will hear it.

2.2 ADAPTIVE REVERSE SHORTEST PATH FORWARDING

DVMRP routers set a timer for each pruned-off downstream and upstream link. Multicast packets are refolded to pruned-off downstream when the timer expires. Reflooding is necessary for the following reasons : (1) to pick up new members who do not have source information (i.e., upstream to source), (2) to update per-source tree information, and (3) to refresh source status. A router sends a prune message to its upstream if it is the leaf router and all its down streams are pruned off. When a node receives a multicast packet with source S, it stores (or updates) the upstream link and the timer for S. If a node not on the tree wants to join this group, it can send graft messages directed to the senders of this group. In a mobile environment, it is frequent to find nodes without upstream (new coming nodes, disconnected nodes, etc.). Reflooding is necessary to pick up new members. For a node on the tree, it is possible that the multicast traffic stops due to upstream link change. For example, in figure 2 the multicast tree from source Sto receiver member Ris. When the topology changes from figure 2(a) to figure 2(b), node iwill not accept packets from j but from k(new shortest path), however, there is no traffic coming from k because land kare not forwarding any packets from S(they are pruned off branches). Reflooding will correct this situation establishing the new tree

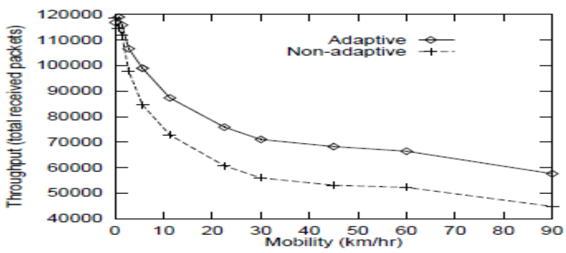

Figure 3: Throughput of adaptive vs. non-adaptive

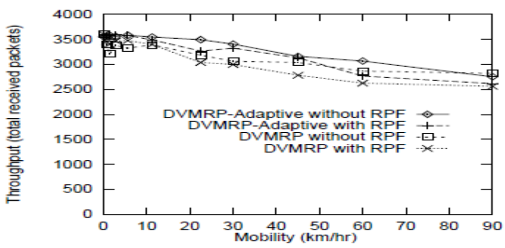

Figure 4: Throughput of DVMRP

Reducing the reflooding overhead is very important for the bandwidth-limited wireless channel.

However, the mobile environment needs reflooding to reconfigure the multicast trees. We propose a variant of DVMRP called "adaptive" DVMRP, which reduces the reflooding frequency in a dynamic changing topology. Adaptive DVMRP monitors the routing information. If the shortest path to the source changes, the node sends a graft message to the new upstream and a prune message to the old upstream. For example in figure 2(b) node idetects the change and sends graft message to k and prune message to j. Reflooding for topology adjustment is no longer required. We still need reflooding however to pick up new members. In addition, status of the senders (live or expired) must be refreshed via reflooding. A scheme similar to "adaptive" DVMRP has been proposed in [7], but it provides only adaptive grafting, not pruning.

Figure 3 shows the improvement of adaptive DVMRP. Table 1 presents the reflooding periods (pruned-off branch timer) used in the experiment

2.3 Reverse path Forwarding limitations

For a mobile environment, RPF is not very efficient. To prove this, we evaluate DVMRP with and without RPF. Without RPF, duplicates are detected by packet id numbers (e.g., source and sequence number). The first packet delivered by flooding is accepted and the corresponding transmitter is marked as the upstream node. Figure 4 shows the throughput results (Type 1, Load B). RPF causes performance degradation in both versions of DVMRP for medium and high mobility.

Table 1: Reflooding period

Mobility (km/hr)	Reflooding period (ms)	
	non-Adaptive	Adaptive
0.02	20000	2000
0.70	4000	2000
1.41	2000	2000
2.81	1000	2000
5.62	800	2000
11.25	700	2000
22.50	600	2000
30.00	500	2000
45.00	400	2000
60.00	300	2000
90.00	200	2000

3. FORWARDING GROUP MULTICAST PROTOCOL (FGMP)

In a wireless broadcast channel, there is no notion of explicit link interface like in a wired point to point channel. Multicast forwarding is based on nodes (routers) which are going to accept multicast packets rather than on links on which multicast packets are forwarded. Traditional multicast protocols based on upstream and downstream links (like CBT [4, 8], PIM [5] and DVMRP) are not suitable here because creating and maintaining upstream and downstream link status in a wireless network is not efficient. The proposed multicast protocol keeps track not of links but of groups of nodes which participate in multicast packets forwarding. To each multicast group Gis associated a forwarding group, FG.

Any node in FGis in charge of forwarding (broadcast) multicast packets of G. That is, when a orwarding node (a node in FG) receives a multicast packet, it will broadcast this packet if it is not a duplicate. All neighbors can hear it, but only neighbors that are in FGwill first determine if it is a duplicate and then broadcast it in turn. Figure 5 shows an example of a multicast group containing three senders and three receivers. Three forwarding nodes take the responsibility to forward multicast packets. This scheme can be viewed as "limited scope" flooding. That is, flooding is contained within a properly selected forwarding set. It is interesting to note that with proper selection of the forwarding group, the FG scheme can emulate any of the existing schemes. For example, to produce global flooding , the must include all nodes in the network. For CBT, the FGis restricted to the nodes on the shared tree except the leaf nodes. In DVMRP, FG includes all the non-leaf nodes on the source trees.

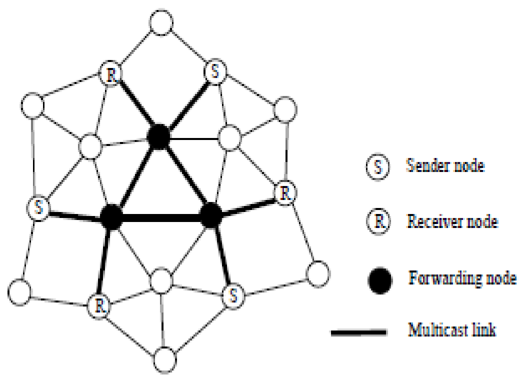

Figure 5: An example of FGMP

Table 2: Format of join request packet

Mcast Group id	Id	Sequence #	TTL

Table 3: Format of member table at the sender

Mcast Group id	
Refresh Timer	
receiver member id	timer

Table 4: Format of forwarding table FW

Mcast Group id	
receiver member id	next hop

4. CONCLUSION

This paper presents LLS, the first location service for mobile ad hoc networks to guarantee both worst case bounds and average case efficiency. Our scheme has inherent fault tolerance both for node failures and for network partitions.

The generalization of our construction results in a geometric location service that is locality aware in any Euclidean metric space. We have proposed ODMRP (On-Demand Multicast Routing Protocol) for a mobile ad hoc wireless network. ODMRP is based on mesh (instead of tree) forwarding. It applies on demand (as opposed to periodic) multicast route construction and membership maintenance.

For future work, we plan to study the impact of new tree construction algorithms, the use of broadcast which does not require RTS/CTS, and exploiting wireless multicast advantage on different data delivery performance metrics, such as delay, forwarding cost, and delivery ratio. We are also interested in evaluating many cast and any cast services using HRPM.

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