Improving the Performance of MANET Routing Protocols using Cross-Layer Feedback

Srinath Perur
K.R. School of Information Technology
IIT Bombay
Powai, Mumbai - 400076
srinath@it.iitb.ac.in

Leena Chandran-Wadia
K.R. School of Information Technology
IIT Bombay
Powai, Mumbai – 400076
leena@it.iitb.ac.in

Sridhar Iyer
K.R. School of Information Technology
IIT Bombay
Powai, Mumbai - 400076
sri@it.iitb.ac.in

***Abstract* – We suggest a simple cross-layer feedback mechanism from the Medium Access Control (MAC) layer to the Address Resolution Protocol (ARP) module which can improve the performance of Mobile Ad hoc Network (MANET) routing protocols. It involves allowing the MAC layer of a mobile node to learn of the IP to MAC address mapping of nodes from broadcast packets that it receives. We show that allowing the MAC layer to create ARP table entries leads to dramatic improvements in route acquisition times using the AODV routing protocol. Our simulations are done using NS-2.**

1. INTRODUCTION

The proliferation of mobile, wireless voice and data communication devices are introducing new and challenging requirements in terms of efficiency and performance. The traditional layered architecture of the networking protocol stack handles the complexity with modularity, at the expense of efficiency. However in wireless networks, efficiency and performance considerations are forcing the adoption of cross-layer design methodology [1, 2] to provide flexible, adaptive and resilient networks.

We believe that information pertaining to the current set of neighbors is an indispensable part of any cross-layer feedback architecture for MANETs. This information is available in broadcast packets that mobile nodes routinely process. We focus on just one of the pieces of information contained in such packets, namely, the mapping between IP and MAC addresses of the sender. Allowing the MAC layer to look into the IP header of broadcast packets, pick up the address mapping, and make entries into the ARP cache constitutes a relatively simplistic use of the cross-layer design methodology. Yet it leads to dramatic improvements in route acquisition times. We illustrate this through simulation using NS-2 [3] and the AODV [4, 5] routing protocol. We expect all routing protocols to show varying degrees of improvement.

II. ARP IN MULTIHOP WIRELESS NETWORKS

The BSD implementation of ARP [6] is designed for wired networks in which the ARP protocol is run largely in LAN environments where the chances of losing ARP requests and replies are small. ARP table entries are made or modified only by ARP reply packets sent in response to ARP query packets. Each node has an ARP buffer which holds at most one packet per destination while the ARP resolution is in progress. If another packet arrives for the same destination before the address is resolved, the earlier packet is dropped from the buffer. ARP is also completely stateless and does not retransmit ARP requests until triggered by a fresh packet. NS-2 implements BSD-ARP.

In wireless networks where ARP packets can easily be lost to collisions, ARP resolution problems can lead to the loss of data packets. In MANETs the problem becomes particularly severe. For instance, the AODV routing protocol uses unicast Route Reply (RREP) packets from the destination to source to create a route. Each hop of this RREP could involve an ARP resolution. Even if a single ARP request or reply is lost, the RREP cannot reach the source. We observed that this event is quite common and affects routing performance significantly. Address resolution is also required very frequently in a MANET since mobility causes frequent changes of a node's neighbors.

III. THE MODIFIED MAC-ARP

We propose a simple scheme where the MAC creates entries in the ARP table upon receiving an IP broadcast. This is accomplished by the MAC constructing a dummy ARP reply and sending it to the ARP module as if it originated at the node sending the broadcast. Since ARP is stateless, it does not reject the gratuitous ARP reply. We call this scheme MAC-ARP. Since broadcasts are very common in MANETs and precede most unicast transmissions, we find that we are able to almost completely avoid using the standard ARP.

IV. RESULTS AND DISCUSSION

We have incorporated the MAC-ARP scheme into the NS-2 simulator. We ran a simple simulation in which one packet was sent along a linear chain of nodes to destinations various hops away. Route acquisition times, defined as the interval between sending a Route Request and receiving a Reply, are plotted in Fig. 1. This controlled experiment was conducted to find the difference in route acquisition times caused by introducing MAC-ARP alone, without allowing it to affect any other aspects of routing.

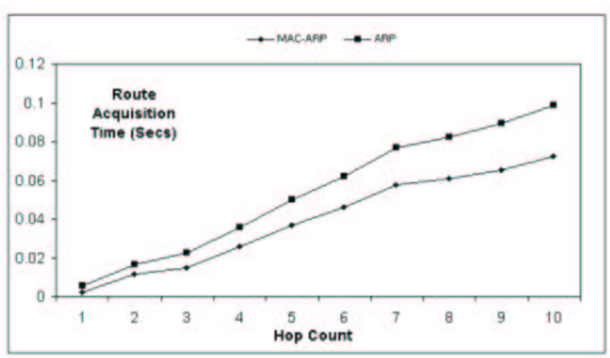

Fig. 1. Route Acquisition Time

TABLE 1

COMPARISION OF ROUTING PERFORMANCE USING ARP AND MAC-ARP

	Pkt. Delivery Fraction	RREQs (Pkts.)	RREPs (Pkts.)	RERRs (Pkts.)	Av. Pkt. Delay (secs)	Rt. Acq. Time(secs)	Total Routing Overhead (bytes)
ARP	0.8874	957.846	41.2	5.088	0.2071	0.0461	47961.2
MAC-ARP	0.8909	904.825	37.5631	4.8642	0.1752	0.0168	45249.21

We also ran a larger simulation to observe the effect of MAC-ARP on other aspects of routing. We considered 30 nodes, each with a transmission range of 250m, moving with a velocity of up to $10ms^{-1}$ modelled by the the random-waypoint model. We used a rectangular simulation area of $360000m^2$ and varied its length and breadth to achieve a variety of path lengths. We also varied the pause times of the nodes to simulate different degrees of mobility. 30 Constant Bit Rate (CBR) connections of 5 seconds each, sending four 512 byte packets per second were formed between random source-destination pairs. Each individual simulation, run for 160 seconds, was averaged over 20 different random seeds. We used the AODV routing protocol running over the IEEE 802.11 MAC [7] first, and then the same MAC modified to implement our MAC-ARP scheme. The averaged results of our simulations are presented in Table 1.

We see slight improvements in all aspects of routing with the use of MAC-ARP, but the reduction of route acquisition time to almost a third of its previous value is the most dramatic. This is since fewer RREPs are lost or delayed owing to ARP. The relatively large absolute value of average packet delay is caused by a few packets which spent large amounts of time in queues when routes could not be found immediately.

V. RELATED WORK

A recently published work [8] also points out the inadequacy of using ARP with MANETs. They propose a solution where address resolution is combined with the routing function. A similar approach is also used in TBRPF [9] where address resolution information is piggybacked on routing packets.

VI. CONCLUSIONS AND FUTURE WORK

We have presented a very simple cross-layer feedback mechanism from MAC to ARP which has wide application in all MANET routing protocols. It makes use of neighbor information which is routinely available at the MAC layer but normally discarded. We have sought to learn only from broadcast packets. One can also learn from overhearing unicast conversations, but then network cards need to function in the promiscuous mode with attendant problems of security and power consumption.

There are several other uses of neighbor information from broadcasts that still remain to be explored. We have shown that a small change at lower layers can have a significant impact on routing. It remains to be seen how else interaction between layers can be exploited to improve performance in wireless ad hoc networks.

VII. REFERENCES

[1] Zygmunt J. Haas, "Design Methodologies for Adaptive and Multimedia Networks," Guest Editorial, *IEEE Communications Magazine*, Vol. 39, No. 11 Nov. 2001, pp 106-107.

[2] Andrea Goldsmith and Stephen B. Wicker, "Energy-Aware Ad hoc Wireless Networks," *IEEE Wireless Communications*, Guest editorial, Vol. 9 No. 4, Aug 2002, pp 6 -7.

[3] Kevin Fall and Kannan Varadhan, editors, "NS notes and documentation." Software available from *http://www.isi.edu/nsnam/ns*

[4] Charles E. Perkins and Elizabeth Royer, "Ad hoc On-Demand Distance Vector Routing," *Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications*, 1999.

[5] Charles E. Perkins, Elizabeth M. Belding-Royer and Samir R. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing," *Internet Draft*, Nov. 2002. Available at *http://www.ietf.org/internet-drafts/draft-ietf-manet-aodv-12.txt*

[6] David C. Plummer, "An Ethernet Address Resolution Protocol," *RFC 826*, November 1982.

[7] IEEE Computer Society LAN MAN Standards Committee: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, *ANSI/IEEE Std. 802.11*, 1999~Ed., IEEE, New York.

[8] Casey Carter, Seung Yi and Robin Kravets, "ARP Considered Harmful: Manycast Transactions in Ad Hoc Networks," *Proceedings of the IEEE Wireless Communications and Networking Conference*, 2003.

[9] Bhargav Bellur and Richard G. Ogier, "A Reliable Efficient Topology Broadcast Protocol for Dynamic Networks," *Proc. of the INFOCOM*, pp. 178-186, 1999.