On the Use of Modular Routers for Implementing Multicast Communications in Hybrid Ad hoc Networks

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Abstract: Current solutions for the specific problem of IP Multicast inter-working between IP access networks and wireless and mobile ad hoc networks are not able to work with standard IP multicast routers. We propose the MMARP protocol which is able to provide a smooth interoperation without an impairment in the overall performance. Modular routers are arousing a great interest, although some people have concerns regarding their performance. We show by comparing a C++ and a Click-based implementation of the MMARP protocol the validity of our proposal as well as the benefits of using modular routers to easily implement ad hoc routing protocols without any reduction in the protocol's performance.

1 Introduction

IP multicast technology provides efficient multipoint communications among a group of nodes. The main benefit of IP Multicast is that the bandwidth consumption for group communications is dramatically reduced, something of particular interest for 'all-IP' and 'beyond 3G' mobile networks where the number of user terminals is high and the applications are typically interactive and consume significant bandwidth. In future mobile and wireless networks in which the network architecture is thought of as an IP core network with a variety of heterogeneous access networks connected to the core ad hoc networks are thought of to play a preponderant role. In fact, the interworking of ad hoc networks and fixed communications infrastructures is one of the hottest topics in the ad hoc networking research community.

The typical intra-domain IP multicast protocols for fixed networks (i.e. IGMPv2[Fe97] for multicast group membership and PIM-SM[EFH+98] for IP multicast routing) are not appropriated for ad hoc networks because they were not designed to cope with the quick and unpredictable link changes in the network topology. In addition, multicast ad hoc routing protocols specifically designed for mobile ad hoc networks such as ODMRP[LSG00] and ADMR[JJ01] are only suitable for isolated ad hoc networks, and they do not provide any mechanism to interoperate with the protocols used in the fixed IP network.

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We propose the Multicast MAnet Routing Protocol (MMARP)[RGSG03] which offer a solutions to these problems by challenging ad hoc nodes with IGMP processing capabilities which allow them to provided efficient ad hoc routing while still being able to interwork with standard IP multicast networks.

There are several proposal of modular routers architectures, like Click[CLI] or Xorp[XOR] which are very interesting in order to reduce the development times as well as to simplify the programming of the protocols by means of reusing existing components. These kind of modular routers have received some critics because of their limited performance in high-speed wired networks. However, we demonstrate that for ad hoc networks, in which the bandwidth requirements are not very high, our implementation of MMARP based on the Click Modular Router architecture can offer as good performance as our implementation based on traditional network programming in C++.

The remainder of the paper is organized as follows: section 2 introduces the MMARP protocol. Section 3 presents some empirical results. Finally, section 4 gives some conclusions and future works.

2 The MMARP Protocol

The MMARP[RGSG03] protocol is especially designed for mobile ad hoc networks (MANETs). It is fully compatible with the standard IP Multicast model and it allows standard IP nodes to take part in multicast communications without requiring any change. Key to this is that MMARP supports the IGMP protocol as a means to interoperate both with access routers and standard IP nodes. The interoperation with access routers is performed by the Multicast Internet Gateways (MIGs) which are the ad hoc nodes situated just one hop away from the fixed network. Every MMARP node may become a MIG at any time. The only difference between a MIG and a normal MMARP node is that the MIG is responsible for notifying the access routers about the groups memberships within the ad hoc fringe. The mechanism allows MMARP to work with any IP multicast routing protocol in the access network and, therefore, it shields the MMARP operation from the protocols performing the intra-domain or inter-domain multicast routing. Figure 1 shows the proposed layered architecture. As it can be noted, by MIGs gathering all membership information and sending IGMP messages to the fixed multicast routers, we achieve a seemless interworking without any impairments in the ad hoc routing performance.

MMARP uses an hybrid approach to build a distribution mesh. Routes among ad hoc nodes are established on-demand, whereas routes towards nodes in the fixed networks are maintained proactively. This offers a good trade-off between efficiency, smooth interworking with the fixed network while still having a good protection against link breakages.

The reactive part consists of a request and reply phase. When an ad hoc node has new data to send, it periodically broadcasts a MMARP_SOURCE message which is flooded within the entire ad hoc network to update the state of intermediate nodes as well as the multicast routes. These messages have an identifier which allows intermediate nodes to detect duplicates and avoid unnecessary retransmissions. When one of these messages arrives at a

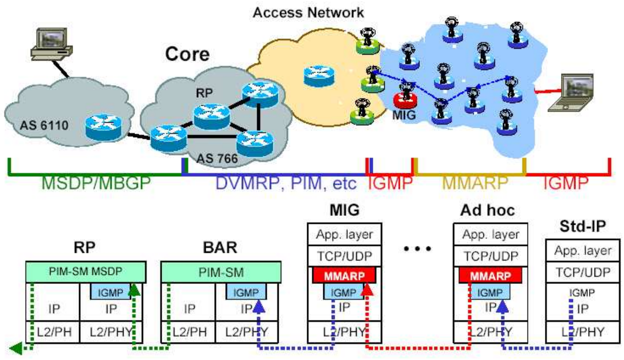


Figure 1: Proposed multicast architecture

receiver, or at a neighbor of a standard IP receiver, it broadcasts a MMARP_JOIN message including the IP address of the selected previous hop towards the source. When an ad hoc node detects its IP address in an MMARP_JOIN message, it recognizes that it is in the path between a source and a destination. It then activates its MF_FLAG (Multicast Forwarder Flag) for the group and rebroadcasts a MMARP_JOIN message back to the source. In this way, a shortest multicast path is created between the source and the destinations. When there are different sources and receivers for the same group, the process results in the creation of a multicast distribution mesh rather than a tree.

The proactive part of the protocol is simply based on the periodic advertisement of the MIGs as default multicast gateways to the fixed network. As the TTL of IGMP messages is fixed at one, the reception of an IGMP Query can be used by ad hoc nodes to detect that they are MIGs and activate its MIG_FLAG. The process of creating the path towards the MIG is similar to the one decribed before. When the MIG receives the MMARP_JOIN message, it then sends an IGMP Report which creates forwarding state in the multicast router towards the ad hoc network.

Once the mesh is established, data packets addressed to a certain multicast group are only propagated by ad hoc nodes which have their MF_FLAG active for that group, after checking that the packet was not sent before.

3 Empirical results

We have set up an indoor 802.11b multicast wired-to-wireless ad hoc network testbed to evaluate the feasibility of our implementation of the MMARP protocol. Our target is to compare our modular implementation (with and without packet priorisation) with a C++ implementation in terms of performance. The testbed consists of nine x86-compatible computers. Five of these computers are acting as ad hoc nodes. These nodes are running Red Hat Linux 7.2 with the 2.4.17 kernel, and they have a Lucent 802.11b PCMCIA card as unique NIC. The nodes acting as wired-to-wireless routers run FreeBSD 4.6. They are equipped with two NICs, one of them being a wireless Lucent WaveLAN PCMCIA card and a 100 Mb/s Ethernet NIC. The wired router in the figure has three 100 Mb/s Ethernet NICs. In addition a Red Hat Linux 7.2 with kernel 2.4.17 will be used as the multicast source in the fixed network. All the WaveLAN NICs are operated in ad hoc mode at the maximum capacity of 2 Mb/s. The topology used in this experiment is shown in figure 2. Nodes in the wired part of the network (including the two access routers) are running the PIM-SM multicast routing protocol. The node's locations were specifically selected so that the topology was the one shown in the figure although there were some inherent randomness in the exact coverage area of the nodes.

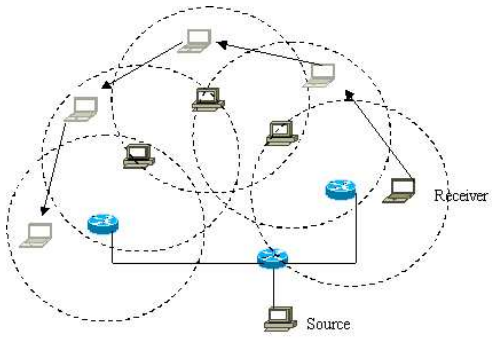
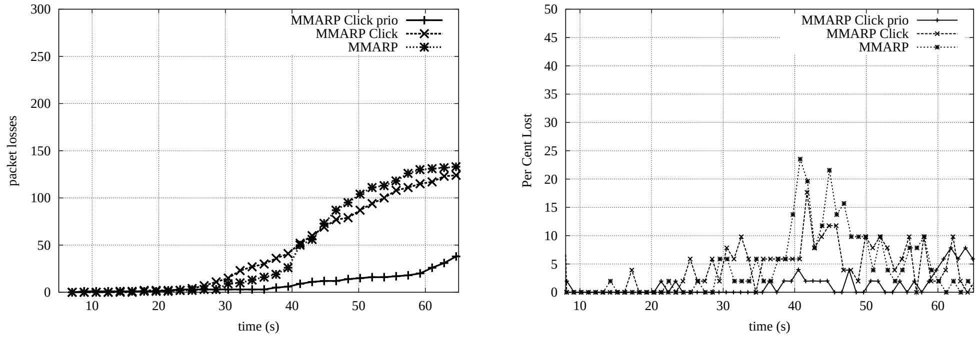


Figure 2: Topology of the experiment

We have performed several experiments using different constant bit data rates at the source. In figure 3 we show the results obtained with 600 Kb/s which is near the maximal throughput of the network, and is the one which would represent the most heavy load for the Click modular router. For lower bandwidths all the three implementations are able to deliver almost 100% of the packets, which is pretty much on the same performance values as other well-known multicast ad hoc routing protocols such as ODMRP. In addition, the results show that most of the packet losses are do to contention and collisions in the wireless links. This contention makes ad hoc nodes loose forwarding state, resulting in packets being dropped. The implementation with priorities, is able to overcome that situation dropping data packets well before control ones. As we can see in the graphs, the implementation using priorities obtains the best results. However, it is also important to mention that even when no priorities are used, the Click implementation is able to deliver as much packets as the C++ implementation. Demonstrating thus, that there are not performance limitations for the Click modular router in these scenarios even when using these limited-power personal computers as ad hoc nodes.

4 Conclusions

We have proposed the MMARP protocol as a solution to obtain a seamless integration of multicast ad hoc networks with fixed IP networks. We have demonstrated that this



(a) Total losses (b) Loss rate

Figure 3: Results of the experiment

protocol performs well even in scenarios with multiple gateways. In addition, we have described our implementation of MMARP using Click. We have shown that our Click-based implementation is able to provide as good performance and the C++ version of our protocol, while still reduces the development times due to the availability of a lot of existing reusable common elements within the Click framework.

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