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Multicast routing and interoperability between wired and wireless ad hoc network

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Abstract

Multicast routing is employed whenever data needs to be delivered from a single source to a group of receivers, in this way, the source can transmit a single flow of data packets which are subsequently delivered to a group of receiver nodes. As a result, multicast routing protocols are extensively used in computer networks, as these techniques allow applications to be able to save bandwidth and reduce the traffic load in the network. In relation to multicast protocols, most of them have been designed for use in wired networks, such as the Internet; similarly, some multicast protocols have been proposed for wireless environments, like wireless ad hoc networks, however they usually deal with the transmission of multicast traffic within the wireless network and do not address those issues related to the interoperability between wired and wireless networks. Nowadays, wireless mobile devices have a large demand of multiple services from the Internet, thus resulting in a need to extend some of the readily available services to wireless network while providing the same level of performance and reliability. This work presents an approach to integrate a wireless ad hoc network with a wired network, while supporting the interoperability of multicast services between the wired network and the wireless ad hoc network. As a result, the multicast traffic generated within the wired network can reach clients located in the wireless ad hoc network.

Keywords: Ad hoc networks; Interoperability; Multicast Protocols; WLAN's

1. Introduction

Due to the growing use of mobile devices, wireless technologies have had a significant development. Common applications for mobile users are video, voice and data, increasing demand for bandwidth.

There are two main types of wireless networks: infrastructure networks and ad hoc networks. In infrastructure networks there is a central coordinator, which is responsible for setting the links between

users of the network and the communication between users is provided through it. In Ad Hoc wireless networks there is no coordinator node, but each node in the network acts as a router. Communications among users are multi-hop.

Infrastructure networks have coverage area delimited by the by the transmission power and the antenna reception gain in the access point. To extend this coverage area, a wireless Ad Hoc can be used. However, it is necessary to tackle with several issues. For example, intercommunication within the mobile ad hoc networks differ from wired networks in the following aspects [1]:

- The wireless channel has variable and unpredictable characteristics.
- The available bandwidth and battery power are limited in mobile devices.
- Computing have limited capacity and limited processing power.
- The mobility of the nodes creates topology changes continuously.
- The wireless medium is a means promiscuous, that is, no matter how specific the receiver node, all nodes within range hear the packages simultaneously.

In recent applications is necessary to merge wireless networks with wired networks. In works such as [2,3,4,5], have extensively studied the integration of these networks using unicast traffic. However for the case of multicast traffic, there are few studies. The multicast approaches are very important in order to save bandwidth, avoiding flood the network with information that not all nodes need, and avoid deliver information to unwished nodes. Multicast operation in hybrid networks are very important issue, because the information can travel across many networks, many architectures and need to be delivered to a group of users efficiently.

For the study of multicast traffic in mobile ad hoc networks have been proposed several mechanisms, one of those protocols is the Multicast operation on Ad-hoc On Demand Distance Vector (MAODV) [6]. In studies like [6,7,8] a comparison of several Ad hoc multicast protocols are made.

Other studies tried to reduce the control traffic in the ad hoc network [9,10,11]. Some other authors deal with problems associated with radio channel conditions [12,13], efficient use of transmission power [14,15], but none propose how to integrate a multicast protocol for wired networks with an ad hoc or infrastructure network, i.e. a mechanism that works for a hybrid network. In this work we integrate multicast mechanism for wired with a mechanism for ad hoc networks.

This paper is organized as follow, a multicast protocol for wired networks is explained in Section 2. In Section 3 we describe a multicast protocol for Ad Hoc network. Section 4 presents the interoperability between both protocols. Experimental results are presented in Section 5. Finally, Section 6 contains the conclusion and presents some future work to do.

2. IP Multicast

IP multicast is a technique for one-to-many and many-to-many real-time communication over an IP infrastructure in a network. It scales to a larger receiver population by not requiring prior knowledge of whom or how many receivers there are. Multicast uses network infrastructure efficiently by requiring the source to send a packet only once, even if it needs to be delivered to a large number of receivers. The nodes in the network take care of replicating the packet to reach multiple receivers such that messages are sent over each link of the network only once. The most common low-level protocol to use multicast

addressing is User Datagram Protocol (UDP). By its nature, UDP is not reliable, messages may be lost or delivered out of order.

An IP multicast group address is used by sources and the receivers to send and receive multicast messages. Sources use the group address as the IP destination address in their data packets. Receivers use this group address to inform the network that they are interested in receiving packets sent to that group. The protocol typically used by receivers to join a group is called the Internet Group Management Protocol (IGMP).

2.1 IGMP: Internet Group Management Protocol

Internet Group management protocol (IGMP), a multicasting protocol in the internet protocols family, is used by IP hosts to report their host group memberships to any immediately neighboring multicast routers. IGMP messages are encapsulated in IP datagrams, with an IP protocol number of 2. IGMP has versions IGMP v1, v2 and v3 [17].

- IGMPv1: Hosts can join multicast groups. There were no leave messages. Routers were using a time-out based mechanism to discover the groups that are of no interest to the members.
- IGMPv2: Leave messages were added to the protocol. Allow group membership termination to be quickly reported to the routing protocol, which is important for high-bandwidth multicast groups and/or subnets with highly volatile group membership.
- IGMPv3: Major revision of the protocol. It allows hosts to specify the list of hosts from which they want to receive traffic from. Traffic from other hosts is blocked inside the network. It also allows hosts to block inside the network packets that come from sources that sent unwanted traffic.

2.2 DVMRP: Distance Vector Multicast Routing Protocol

Distance Vector Multicast Routing Protocol (DVMRP) is an Internet routing protocol that provides an efficient mechanism for connectionless message multicast to a group of hosts across an internetwork. DVMRP is an "interior gateway protocol" (IGP); suitable for use within an autonomous system, but not between different autonomous systems. DVMRP is not currently developed for use in routing non-multicast datagrams, so a router that routes both multicast and unicast datagrams must run two separate routing processes.

DVMRP is developed based upon Routing Information Protocol (RIP). DVMRP combines many of the features of RIP with the Truncated Reverse Path Broadcasting (TRPB) algorithm. In addition, to allow experiments to traverse networks that do not support multicasting, a mechanism called tunneling was developed. The key differences of DVMRP from RIP are: RIP routes and forwards datagrams to a particular destination. The purpose of DVMRP is to keep track of the return paths to the source of multicast datagrams. DVMRP packets are encapsulated in IP datagrams, with an IP protocol number of 2 (IGMP) [18].

2.2.1 Protocol Structure

DVMRP uses the IGMP to exchange routing datagrams. DVMRP datagrams are composed of two portions: a small, fixed length IGMP header, and a stream of tagged data.

4	8	16	24	32 bit
Version	Type	Sub-Type	Checksum	
DVMRP Data stream				

Fig. 1. DVRMP message format

Figure 1 shows the DVRMP message format.
- Version - The current version is 1.
- Type - DVMRP type is 3.
- Sub-type - The subtype is one of:
  1. Response; the message provides routes to some destination(s).
  2. Request; the message requests routes to some destination(s).
  3. Non-membership report; the message provides non-membership report(s).
  4. Non-membership cancellation; the message cancels previous non-membership report(s).
- Checksum -- one's complement of the one's complement sum of the DVMRP message. The checksum must be calculated upon transmission and must be validated on reception of a packet. The checksum of the DVMRP message should be calculated with the checksum field set to zero.

3. Multicast Ad hoc On Demand Distance Vector (MAODV)

MAODV is a multicast extension of Ad hoc On Demand Distance Vector (AODV). In MAODV, all members of a multicast group are formed into a tree (which includes non-member nodes required for the connection of the tree), and the root of the tree is the group leader. Mutlicast data packets are propagated among the tree. The core of the MAODV protocol is about how to form the tree, repair the tree when a link is broken, and how to merge two previously disconnected tree into a new tree.

There are four types of packets in MAODV: Route Request (RREQ), Route Reply (RREP), Multicast Activation (MACT) and Group Hello (GRPH). RREQ and RREP are also packets in AODV. A node broadcasts a RREQ when 1) it is a member node and wants to join the tree, or 2) it is a non-member node and has a data packet targeted to the group.

When a node has received RREQ, it responses with RREP using unicast. Since RREQ is broadcasted, there may be multiple RREPs received by the originating node. The originating node should select one RREP that has the shortest distance to the tree and uncast a MCAT along the path to set up a new branch to the tree.

GRPH is the group hello packet, it is peordically broadcasted by group leader to let the nodes in the tree to update its distance to the group leader. There are a lot of details in the protocol, check the RFCs for detail [19].

4. DVMRP and MAODV interoperability

In this section we presented the interoperability between both protocols DVRMP and MAODV. We described the function of the specialized node that we called Border Router Node. The scenario used has

several kinds of nodes. Two kind of wired nodes: host and routers and two kind of wireless nodes: access points and host nodes, all wireless nodes can route packets.

4.1   Border Router Node

The border router node is a node that acts as a gateway, and lies on the border between the ad hoc network and the wired network. The border router is capable of handling both protocols DVRMP and MAODV, and has the main task of redirecting traffic from the wired to the wireless network, or vice versa.

The border router node doesn't allow Control messages traffic from the wired side go to the wireless side in order to avoid flooding. And it doesn't allow periodically GRPH and other messages from the wireless network spreading to the wired side. Figure 4 show the protocol structure of the border node.

4.2   Interoperability Mechanism

The functioning of DVMRP and MAODV protocols remain unchanged, the border router is what makes the translation, the link between the two protocols. Figure 2 shows the system architecture.

DVMRP is a protocol initiated by the source. The source disseminates information to all nodes in the network and hosts those nodes that are not interested in traffic Prune message sent to the router associated with them. If a router does not have a host in the multicast tree, send a message Prune and prune the tree. If a host node that join the multicast tree sends a message to the router IGMP-J, if this is not part of the tree sends a Graft message to join too. The border router does not broadcast multicast traffic to the wireless network until there is some node in her interest in joining the group.
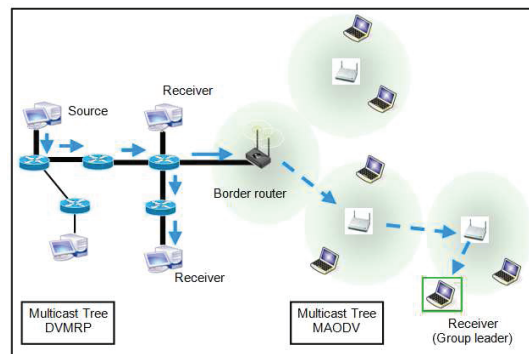

Fig. 2 System Architecture.

MAODV is a protocol initiated by the destination, the group leader (for more information see the RFC) GRPH spreads the message announcing that there is a multicast group. In this work, when the border router receives multicast traffic from the wired network is disconnected from the tree, it has to wait for a node within the ad hoc network is interested in joining the multicast group. A node within the ad hoc network sends a RREQ-J to join the multicast group, but how one does not already exist within the network, this node is configured as a group leader and the group assigned IP address (the IP is the same as in the group DVRMP) and spreads the message GRPH disseminating information of the group. When the border router receives the GRPH message with the correct IP, it sends the message Graft to the wired side to join the tree in the wired network and transmits the

multicast traffic in ad hoc network. When any other node wants to join the group sends a RREQ-J, the nearest neighbor who is a member of the group responds with a RREP.MACT message and joins the group. To leave the group employs a MACT-P with the flag "P" to be pruned.

5. Results

We implement the system architecture on the Network Simulator 2 (NS-2) version 2.26 [20]

5.1   Assumptions and parameters.

   The network architecture is composed of 6 wired nodes, one wired/wireless node (border router), 10 fixed wireless nodes and 40 mobile wireless nodes. Three wired nodes are host and the other three nodes are routers. In the wireless network 10 nodes are wireless routers and 40 mobile users. For wired communications we use IEEE 802.3 @10 Mbps and for wireless IEEE 802.11 @2 Mbps. Table 1 shows the simulation parameters and assumptions.We made for simulations for random mobility at 0 m/s, 1m/s, 2 m/s, 3 m/s.

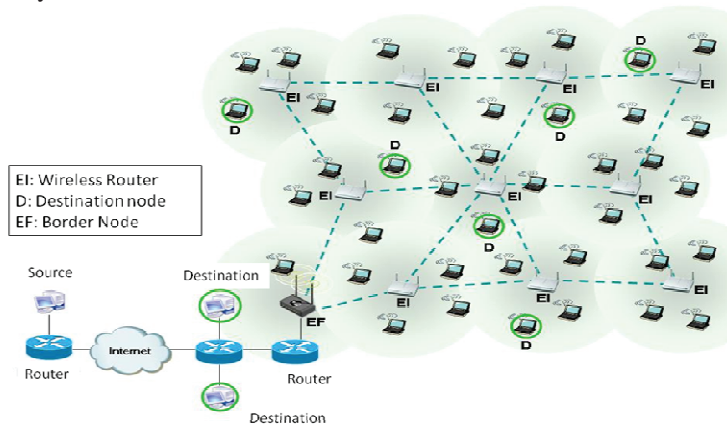   Figure 3 shows the system architecture for the simulation scenario.

Fig. 3. Simulation scenario.

Table 1. Simulation parameters

5.2 Metrics

The metrics evaluate the mechanism are: Packet (PDR) and [20,21].

PDR is

Parameter	value	Parameter	Value
Transport protocol	TCP	Bit Rate	100 kbps
Traffic type	CBR	Fixed wireless nodes range	150 m
Packet size	512 Bytes	Mobile wireless nodes range	40m
Medium access control	CSMA/CA	Transmission mode	DSSS
Radio Channel Model	Two Ray	Simulation Time	2000 s
Max. Bit Rate	2 Mbps	Topology size	400 x400 m

that we used to interoperability performance Data Rate Overload

calculated as:

$$PDR = \frac{\#Packet\ Received}{(\#Packets\ sent)\cdot(\#Receptor\ Nodes)} \tag{1}$$

The Overload can compute as:

$$Overload = \frac{\#Control + Routing\ Messages}{\#Data + Control + Routing\ Messages} X100\% \tag{2}$$

5.3 Results

Figure 4 shows the results of the simulations, we can notice how the PDR decreases with mobility and when the group size grows. Figure 5 shows the System Overload, we can observe that the overload is high when the group is larger and when the user speed increases.
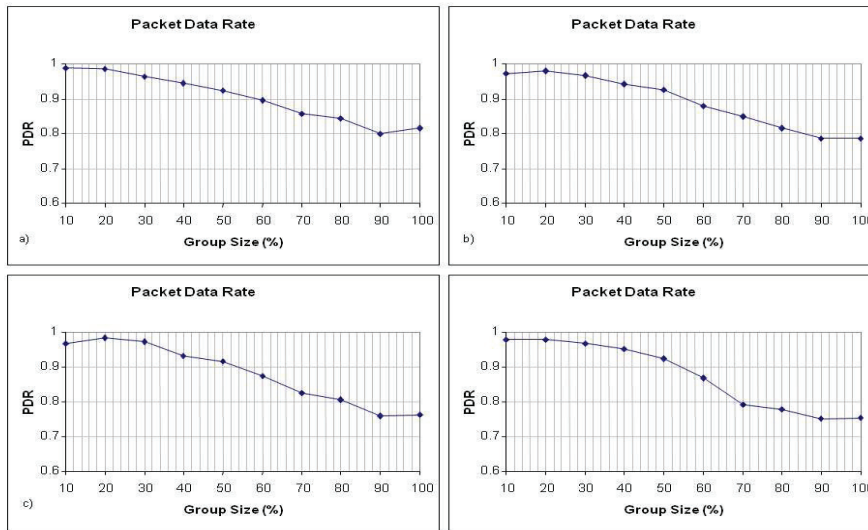

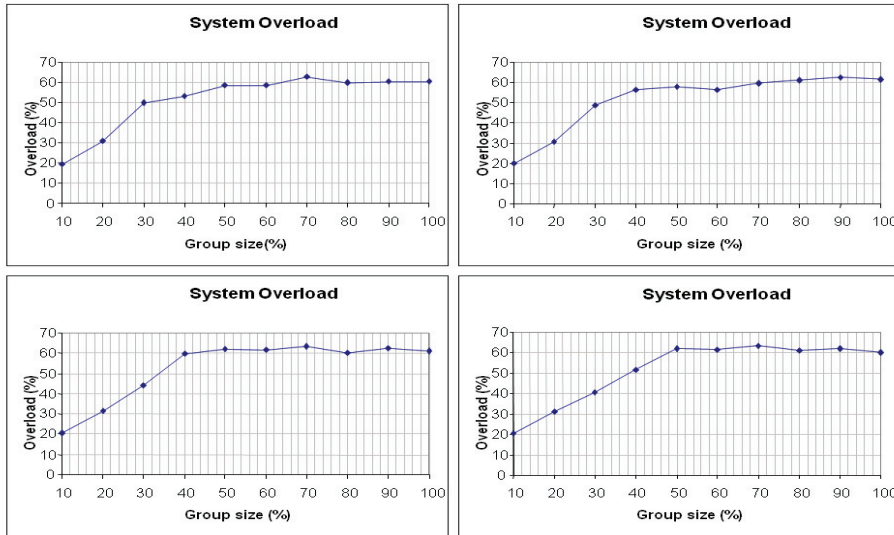Fig. 4. PDR for a) 0m/s b) 1 m/s c) 2 m/s d) 3 m/s

Fig. 5. Overload for a) 0m/s b) 1 m/s c) 2 m/s d) 3 m/s

6. Conclusions and future work

As shown in the graphs, increasing the size of the group and increasing the speed of the nodes, the routing and control messages traffic becomes larger than the data traffic. When the nodes attempt to repair a broken link, they generate many control messages. This is one of the disadvantages of MAODV. In high mobility scenarios this mechanism is no longer a viable option. Another problem is the number of active wireless nodes in the system, high density of nodes can generate many collisions or low throughput due to the sensing time, that's why we can have low PDR and high overload in the system.

The goal in this paper was integrate two multicast mechanisms that work as a single one, merging a wireless network with a wired network, and make possible that multicast traffic generated in the wired network can be delivered to a group of wireless nodes into a wireless Ad-hoc network. The specialized node called Border Router Node integrates both multicast protocols DVMRP and MAODV.

As future work we propose to employ multicast mechanisms more reliable and efficient, based on recent studies, the problem is the implementation of these mechanisms in the NS-2. Another option as future work is the proposal of an adaptive multicast protocol that runs on a hybrid network as proposed in this paper.

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