Proceedings of the IASTED International Conference
PARALLEL AND DISTRIBUTED COMPUTING AND NETWORKS
February 17-19, 2004, Innsbruck, Austria

CORE BASED TREE MULTICAST (M-CBT) APPROACH IN SUPPORTING MOBILITY

Jaipal Singh, Prakash Veeraraghavan and Samar Singh
Applied Computing Research Institute
Department of Computer Science
and Computer Engineering
La Trobe University
Victoria 3086, Australia
email: {j10singh, prakash, samar}@cs.latrobe.edu.au

ABSTRACT
IP multicasting provides a mechanism for faster handoff support than Mobile IP [9] [16]. Coupled with its location independent addressing, multicasting is a viable alternative to support mobility in the Internet. This paper continues research into using IP multicasting in mobility.

Our proposed scheme looks at enabling a mobile node to initiate two way communications with a corresponding node on a shared multicast tree. We use as much of the existing Internet architecture as possible by making the base-station a member of the multicast group. The mobile is not directly connected to the tree but goes through the base-station to send and receive packets.

This paper explains the differences and advantages of our proposed scheme compared with other multicast based mobility schemes and Mobile IP.

KEY WORDS
Wireless Networks, Mobile Computing, Computer Networks, Communications

1 Introduction

Mobility in the Internet is one of the active areas of research which offers great challenges to the research community. Traditional IP does not ofter mobility, since the routing is based on the network prefix of an IP address. If a mobile node moves from one subnet to another subnet having a different network prefix, it will loose its connection. This is because the protocol as well as the routers are not designed to accomodate dynamism.

Mobile IP [14] and Mobile IPv6 [10] were designed to solve the above problem. However, when a mobile node visits a foreign network, it suffers delays due to triangular routing (if route optimisation is not used) and slow binding updates during hand-offs. Another problem is that multicasting support in Mobile IP in not implemented efficiently.

Some multicast based mobility schemes have been proposed to overcome the shortcomings of Mobile IP. Multicast based mobility schemes have shown better handling of handoffs compared to Mobile IP. However, these multicast based schemes have several shortcomings that needs to be addressed before multicast can be adopted for supporting mobility.

In this paper, we propose a multicast based scheme to support mobility. Since we are proposing the use of IPv6, we briefly explain about the workings of Mobile IPv6 in the next section. We then explain the design of our scheme in section 3. Handoff operations are detailed in section 4. A comparison between our scheme and other multicast based mobility schemes is done in section 5.

2 Mobile IP and Mobile IPv6

For mobile IPv6 [10] to work, a mobile node requires two IP addresses, namely its home address and a care-of-address which may be acquired through stateful or stateless autoconfiguration. The care-of-address is the address of the mobile node's current point of attachment in the network. The home address is used to support transparency with transport and higher layer protocols.

Mobile IPv6 can be used in two ways to route packets transparently between a corresponding node and a mobile node. One method uses bidirectional tunneling, where the corresponding node sends a packet to the mobile's home address. The home agent will intercept this packet, encapsulate it and route it to the mobile node's care-of-address. Another method is route optimisation, where the mobile node sends a binding update of its care-of-address to the corresponding node. The corresponding node checks its cached bindings and sends the packet straight to the mobile's care-of-address. The packet uses the mobile node's care-of-address in the destination address field and the mobile's home address is stored in a new destination option header.

Mobile IPv6 solves the problem of mobility within an IPv6 network. However, the main weakness of Mobile IPv6 is in the delay during mobile handoffs. There will also be traffic loss when a mobile node moves to another subnet while the binding update is pending at the corresponding node. To solve this problem, some researchers have suggested using a hierarchical mobility protocol[15].

Another weakness of Mobile IPv6 is its inability to support seamless multicast during handoffs. The mobile node has to rejoin the tree once it has performed a handoff. This will introduce some latency.

3 Our Approach to Mobility

3.1 Assumptions and Design Goals

The proposed architecture assumes that each domain in the internet has one or more multicast routers (mrouters). The mobile's address is a statically defined multicast address that consists of the home domain network address. For this paper, we are using a unicast-prefix-based multicast address [7] that can be globally identified as belonging to a particular domain.

Our proposed scheme intends to use as much of the existing network infrastructure as possible. The only added functionality will be at the base-stations. Our proposal minimises changes required in networks and can be deployed fairly quickly.

This paper will not focus on security and quality of service issues. These two areas will be addressed in future work. This paper will only look at communications between two nodes, ie. between one corresponding node (which can also be a mobile) and one mobile node. Future work will look into private communications between many corresponding nodes and one mobile node.

3.2 Design Overview

In our scheme, a bi-directional multicast tree is used to deliver packets from the corresponding node to a mobile node and vice-versa. We are using the Core Based Tree (CBT) [1] [2] as the multicasting protocol in our research. We are adopting CBT and not PIM-SM since we are fully implementing a shared-tree approach and do not require the option of switching between a shared-tree and a source-based-tree.

The mobile node will only unicast packets under certain situations, namely when sending binding updates to the home designated router and when requesting the corresponding node to join the tree for the first time. When we refer to a mobile node unicasting a packet, we mean that the mobile node will generate an IPv6 packet with its multicast address as the source and the IP address of the corresponding node as the destination. This IPv6 packet will contain a destination option header with the mobile node's multicast address.

When the base-station receives this packet, it will perform a NAT [17] on the packet by replacing the multicast address in the source field with its own IP address. This packet will then be routed to the destination using normal IP routing. Even though the base-station uses its own IP address when sending out packets, it can differentiate any packets it receives based on the multicast address.

3.3 Mobile node Registration

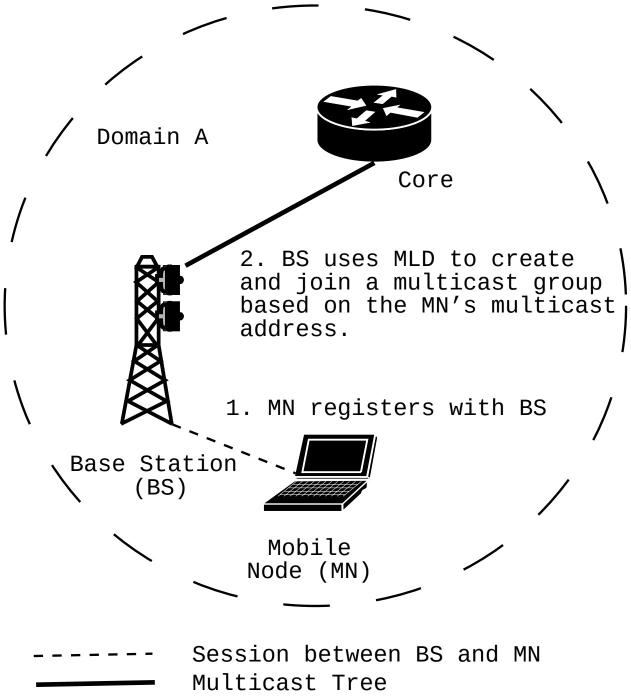

Figure 1. Registering a mobile node in a foreign domain

Whenever a mobile is switched on, the mobile will register with the base-station it gets a strong signal from. The details of how the session is created between the base-station and mobile node using MAC layer connections are not discussed in this paper. The mobile node will send a registration message over a wireless MAC link to the base-station. This process is similar to IP over ethernet [5]. The registration message contains the mobile's unicast-prefix-based multicast IP address and the IP address of the base-station it is attached to. In the case of initial startup, the base-station address will be empty. The base-station address field in the registration packet is very important for ensuring smooth handoff as will be shown in section 4 of this paper.

After receiving the registration request, the base station will create a session with the mobile device and record the multicast address. The base-station will then send a multicast listener discovery (MLD) [6] report message to the designated router and elect a core. For this paper, we are assuming that the first-hop mrouter from the base-station will be elected as the core for the newly created multicast group even though any mrouter in the domain can be elected as the core. The base-station will be the first member of the multicast group. The initial multicast tree will only comprise the core and base station.

Once the tree is created and the base-station starts to receive a MLD group-specific query, the base-station will send a tree completion message to the mobile. The completion message will be a packet containing the base station's

IP address, the mobile's multicast IP address and the core's IP address. Figure 1 briefly outlines the registration process and the initial multicast tree.

After the tree has been created between the core and the base-station, the mobile will send a binding update of the core's IP address to its home designated router.

3.4 Building the Delivery Tree

In order to have two way multicast communication between the corresponding node and mobile node, a multicast tree has to be built between them. Once the tree is built, the packets will be multicast between both the nodes using normal CBT routing protocols.

Our approach requires that the mobile sends packets to the corresponding node through the multicast tree. If we assume that the mobile node is a client, it has to establish a connection with the corresponding node. Since no these two nodes have no existing tree, the mobile will unicast a packet to a corresponding node informing it to join the mobile node's multicast tree.

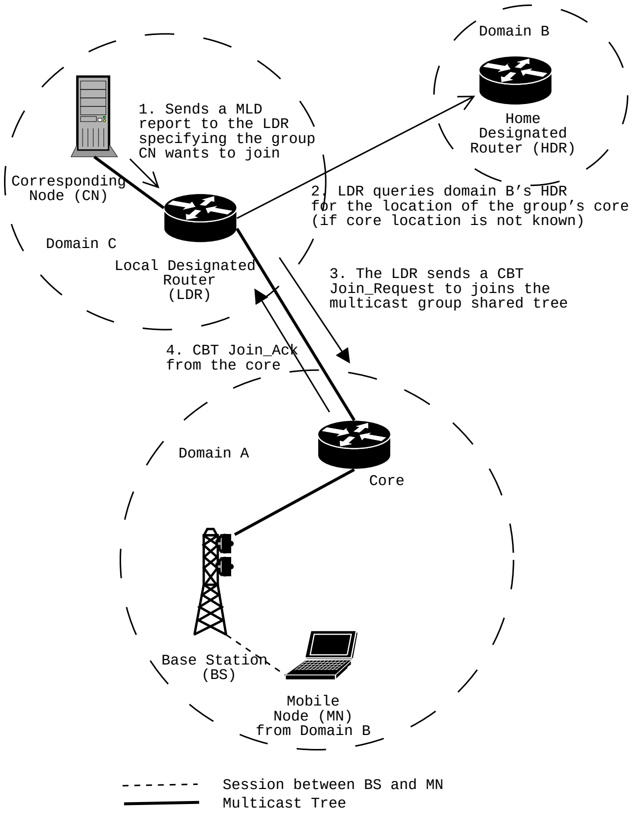

Figure 2. Corresponding node joins the shared tree

The corresponding node can only send packets to the mobile device after joining the multicast tree. The node joins the multicast group as described in section 4.2 of RFC 2201 [1].

If the corresponding node wishes to initiate a session with the mobile node, its designated router will look for the multicast group core address in its routing table. If it can't find the core address, the designated router will then query the mobile's home domain designated router for the address of the core. The corresponding node's designated router will use the mobile's unicast-prefix-based address to find the mobile nodes's domain designated router. Once the corresponding node's router gets the location of the core from the mobile's designated router, it will invoke the tree joining process.

Once the corresponding node receives a join-ack from the core or an on-tree router, the node can multicast the data to the mobile. Figure 2 shows how the corresponding node joins the tree. Note that the multicast tree only links the corresponding node to the base-station and not to the mobile node. The base-station forwards the packet using a link layer connection like IP over ethernet to the mobile node.

4 Handoff

One of the most important aspects of mobile communications is supporting smooth handoffs. A multicast protocol can perform handoffs very smoothly since it supports advance joining to neighbouring base-stations and resource reservation. Once the mobile detects another base-station and is ready to perform a handoff, it registers with the new base-station. The registration message will contain the mobile node's multicast address and the IP of the base-station it is attached to. The new base-station will inform the old base-station that the mobile is going to perform a handoff. The old base-station will send the group core address, mobile node's credentials and any packets it receives for the mobile to the new base-station.

If the new base-station is within the same domain as the core, it will send a MLD report message to join the group. If the new base-station is on another network, it will send a MLD report message to its router and update the router's routing table with the core address supplied by the old base station.

After the new base-station joins the tree, it will inform the old base-station that the handoff process is done. The old base-station will leave the group by sending a MLD done message. All traffic to the mobile will now be received only by the new base-station.

Figure 3 shows how an mobile performs handoff between two base-stations within a domain.

4.1 Loss of Connection

In the event the base-station stops receiving control or data packets from the mobile node, the base-station assumes that the mobile node has lost the connection with it. The base-station will start to cache any packets destined for the mobile and start an expiry timer. This expiry timer is used to indicate the time a soft-timeout occurs. The base-station will flush all cached packets after a soft-timeout. A hard-

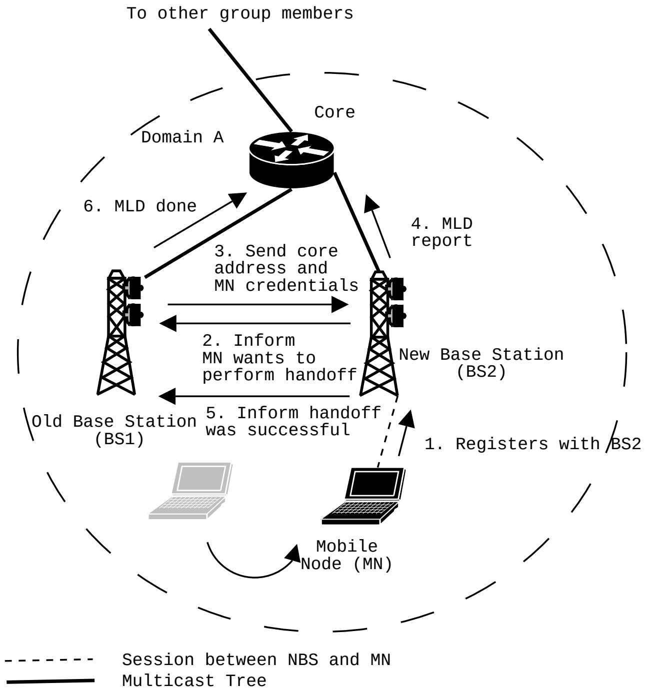

Figure 3. Intra-domain mobile handoff

timeout is three times the duration of a soft-timeout. After a hard-timeout is reached, the whole multicast tree will be torn down.

When the mobile reconnects to a base-station, it will register with the base-station. The reconnection registration message contains the mobile node's multicast address and the IP address of the base-station it was previously attached to.

If the mobile node reconnects to the same base-station before the expiry time, the base-station reestablishes the same session with the mobile node and forwards all the packets it had cached.

If the mobile reconnects to another base-station before the expiry time, the new base-station performs the same process as a regular handoff.

If the mobile does not connect to a base-station before the expiry time (soft-timeout), the old base-station will flush all of the cached packets. If the mobile node joins a base-station after the expiry time but before a hard timeout, the multicast shared tree will be active again. This waiting period is important since the cost of building a multicast tree is high.

After a hard timeout occurs, the base-station will send a MLD done message to leave the group. The core will tear down the shared tree once the group becomes inactive. The base-station address stored in the mobile node will be discarded. If the mobile joins a base-station after that, it has to go through the mobile registration process as described in section 3.3.

5 Comparison with other Multicast Mobility Protocols

Several architectures have been proposed to support macro [13] [9] [4] and micro [8] [12] [16] mobility using multicasting protocols. Since our proposed scheme will only handle macro-mobility at this time, we will compare our scheme with other macro-mobility multicast schemes.

The MSM-IP protocol [13] is a generic architecture for supporting mobility using any sparse-mode multicast protocol (PIM-SM or CBT). A mobile node has a permanent hierarchical multicast address and a care-of-address. MSM-IP uses a location directory protocol that gets the location of a router on the tree from a location server. For the mobile to receive packets, the corresponding node has to join the group's tree. However, communications from the mobile to the corresponding node is done through unicast. MSM-IP also supports resource reservation using RSVP and advance reservation.

Another scheme proposed by Helmy [9] also uses a sparse mode multicast protocol. This scheme uses a source based tree implementation of PIM-SM (PIM-SBT). A router entry is kept for each source (corresponding node) and group (mobile). The mobile node has a permanent multicast address, a care-of-address and its home unicast address. A corresponding node sends packets to the mobiles unicast home address. The home agent intercepts these packets and sends a binding update of the mobile's multicast address to the corresponding node. All the routers along the shortest path from the corresponding node to the mobile node will join the mobile's multicast tree. The corresponding node encapsulates the packet containing the mobile's unicast home address using IP-in-IP encapsulation and sends it through the multicast tree to the mobile. The mobile node decapsulates the received packets before getting the original packet containing its unicast home address. Communication from the mobile node to the sender is done through unicast.

A PIM-SM shared tree (PIM-ShT) scheme by Castelluccia [4] is another approach to using multicast to support macro-mobility. The mobile node has a permanent multicast address and a care-of-address. The mobile uses the care-of-address to join the PIM-ShT. The mobile will create IPv6 packets with its care-of-address as the source address while a new field called the Multicast Source Address (MSA) field in the destination option header contains the mobile's multicast address. For the mobile to receive packets, the corresponding node has to send a multicast packet using the address from the destination option header. This paper also suggests a rendevous point (RP) information distribution algorithm that is similar to what we are proposing. The corresponding node will forward the packet to the mobile's default RP which will forward the packets to the mobile's RP. The default RP will also send a binding update of the RP's location to the corresponding node.

While all of the schemes above uses a sparse-mode multicast protocol, they have some disadvantages that our scheme overcomes. The main advantage of our scheme is reduction of network addresses, two-way multicasting and reduction of routing table entries.

Our scheme overcomes the network address overhead that some of the other schemes require. Our scheme only requires one permanent unicast-prefix based multicast address[7] while the others need two or three addresses per mobile device. The base-station will perform a NAT on the mobile's packet. If a NAT is not allowed, normal IP-in-IP encapsulation can be done. This will save using two or three addresses for one mobile device.

All three of the schemes that we have looked at use multicast to receive packets from a corresponding node to a mobile node. Any communication between the mobile node and a corresponding node is done through normal unicast. Our scheme uses two-way multicast communication. We believe that it is more efficient to use the same multicast tree for the mobile to communicate with the corresponding nodes.

Scheme [9] and [4] uses PIM-SBT and PIM-ShT respectively. Both implementations of PIM-SM requires more routing table entries than CBT [3]. PIM-SBT needs at least n+1 entries where n is the number of senders while PIM-ShT requires at least twice the routing table entries of CBT. PIM-SBT clearly does not scale well while PIM-ShT requires more router overhead compared to CBT.

6 Conclusions And Future Works

We have presented a multicast scheme that supports mobility in the Internet. Our scheme is based on the CBT multicast routing protocol. Our approach makes the base-station a member of the multicast group instead of the mobile node. The mobile node is not directly connected to the tree, but links to the base-station which acts like a NAT to the multicast tree.

Our scheme maintains the benefits of other multicast schemes like location-independent addressing, smooth handoffs and efficient routing. It also improves on some problems faced by other multicast based mobility schemes. The mobile node only requires one multicast address which is used to communicate between itself and the corresponding host. The use of a shared tree makes this scheme scalable as it needs less router states compared to a source-based tree. Our scheme enables two-way multicast communication between the mobile node and corresponding node on the same tree whereas other schemes use multicast for the mobile node to receive packets but unicast to send packets. The benefits of two-way multicast can be seen if the corresponding node is also a mobile device. Communication between two or more mobiles can be done easily on the same multicast tree. Another benefit of two-way multicast communication is better support for one-to-many and many-to-many communication.

Although this paper uses IPv6 as the network protocol, we believe this scheme can be implemented using IPv4. Some of the changes required for this scheme to work in IPv4 is to replace the unicast-prefix multicast address with GLOP [11] addressing for the mobile node and to use IP-in-IP encapsulation rather than NAT on IP packets at the base-station since there is no destination option header in IPv4.

Our scheme requires further work especially in the areas of security, private packet traffic between the mobile nodes and corresponding nodes and quality of service. All of these issues will be addressed in future works along with simulations to show how our scheme compares with Mobile IP and Mobile IPv6.

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