POSITION LEVERAGE SMOOTH HANDOVER ALGORITHM FOR MOBILE IP

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Mobile IP is designed to support uninterrupted connectivity of mobile computers as they roam from place to place. We propose a fast intra-domain and inter-domain handoff scheme using the location of routers to meet the delay and packet loss requirements of real-time services. The scheme achieves an intelligent and dynamic neighborhood discovery and avoids the use of multicast addresses in intra-domain handoff. In addition, it decreases the registration time and distributes home agent data base dynamically in inter-domain handoff depending on how far from the home agent mobile host is. Simulation and implementation results for an interactive voice communication are presented.

1 Introduction

Internet has attachment points at the edges that connect wireless mobile users to the Internet. The primary aim of Mobile IP is to adapt IP to achieve a robust communication between users who change their attachment points[1,2].

A major problem in Mobile IP arises in providing real-time services while achieving certain QoS requirements. The high bandwidth required for real-time services is only be solved through smaller cells. However, small wireless cells cause frequent handoffs.

Frequent handoffs increase latency and loss in the rerouting of packets in handoffs. While a mobile moves from one cell to another, he will not be able to get any message until he makes connection to the new access point and gets confirmed by his home network. Since the packets are forwarded to the old access point during this time period, packet loss will occur in addition to the latency.

Our system achieves fast handoffs by using both hierarchical structure of the network[6] and location devices in the routers. The network is thought to be composed of administrative or geographical domains. Each domain has a hierarchical tree of foreign agents with a domain foreign agent at the top. Each router knows its own position. A special advertisement-messaging scheme informs other routers in the domain of its position. Routers use this position information to send the packets directed to one foreign agent to adjacent foreign agents as well. In addition, we use the position information of domain foreign agents to decide whether to send a registration request to home agent or to the previous domain foreign agent of the mobile host. This brings local home agent functionality to domain foreign agents if a mobile host does not go geographically away from this domain compared to its distance from the home agent.

Organization of our paper is as follows. Section 2 introduces the motivation for our position based scheme with the possible improvements that it brings to the current structure. Section 3 describes the basic architecture of our system. Section 4 presents the performance results of our simulations in Network Simulator (ns2) and our implementation environment. Section 5 concludes the paper and highlights the areas for future work.

2 Motivation

The novelty of our handoff scheme is to provide an adaptive algorithm in the determination of handoff targets, to eliminate the messaging overhead related to forming multicast groups, to prevent potential conflicts related to the usage of multicast addresses and to perform fast handoff among the domains.

All of the previous handoff schemes rely on manual configuration of handoff targets since it is impossible to say anything about the location of access points from their IP address. Our scheme does not assume anything about the network configuration. We only require locatio devices in each access point and implement a simple messaging to propagate this information to the other access points. This messaging overhead can be ignored since it runs only if there is a change in the network configuration or in the times of the day when there is least amount of traffic in the network. Since access points are wired instead of wireless, we do not need to send location information periodically.

Most of the previous handoff [3,4,5] schemes use multicast addresses to send more than one router in intra-domain handoff. This addressing scheme requires a continuous messaging between all routers to learn about new multicast address allocations. Our scheme completely eliminates this messaging overhead. We do not use any multicast address instead we use the hierarchical structure of the access points in the network. Forming this hierarchical structure, as location advertisement messages, does not produce any overhead since it can be updated only if there is a change in the network configuration or in the times of the day when there is least amount of traffic in the network.

Previous handoff schemes [6,7] did not provide much support for interdomain handoff based on the assumption that this kind of handoff is very rare. Our assumption is that the development of power-efficient processors and the increase in the battery lifetime of laptop computers will lead to an increase in the inter-domain usage. Using location devices in this respect decreases the latency considerably.

3 Proposed System

This section describes the intra-domain and inter-domain mechanisms and the extra messaging that our system requires following the overall structure of the network with its elements.

3.1 Structure of the Network

The network is composed of administrative or geographical domains. The structure of each domain is assumed to contain a hierarchy of foreign agents that includes a domain foreign agent at the top. Every FA knows its ancestors and its children in the tree.

Our system is designed according to IPv4 specifications with the following entities:

- `Mobile Host (MH):` A host or router that is portable with wireless network hardware with a constant IP address.
- `Home Agent (HA):` A stationary router on a mobile host home network that keeps the host's current care-of-address and forwards the packets accordingly.
- `Corresponding Host (CH):` Any host on the Internet that sends packets to a mobile host.
- `Domain Foreign Agent(DFA):` A DFA keeps the care-of-address of each MH visiting its domain and forwards the packets to MH. It updates the MH care-of-address in intra-domain handoff and informs either the previous DFA or HA in inter-domain handoff.

  DFA has a *Visitor list* of all the MHs visiting the domain at that time. This list includes the constant IP address of each of these MHs and their current care-of-address. This current care-of-address can either be the care-of-address of a FA inside the domain that MH is connected to at that time or the address of the DFA of another domain if MH has moved to another domain while giving to this DFA a local home agent functionality.

  DFA also has a *Location-FA Table* keeping the location information of each FA inside the domain together with its care-of-address. This will be used in the forwarding of MH packets to multiple FAs to provide fast handoffs.

- `(Normal) Foreign agent(FA)`: A FA keeps the MHs currently connected to this FA and the MHs that recently visited this FA. It forwards the packets either to MH or to other FAs according to its tables.

  A FA has a *Visitor list* containing the MHs currently connected to this FA. It includes the constant IP address of all these MHs. It updates this table according to the responses coming from MHs to each beacon packet that it sends.

  A FA has a *Cache list* keeping all the MHs recently visited this FA. When FA does not receive a response from a MH in visitor list, it puts this entry to the cache list with a specified lifetime. If it does not know the new care-of-address of this MH, it puts an "all ones" entry as the new location of the MH. If it learns the new place of the MH, it puts the new care-of-address of the MH to the table.

  It also has a *Location-FA table* just as the DFA.

3.2 Intra-Domain Module

Our system uses the hierarchical structure in order to eliminate the wasteful trip to HA for each movement of the MH inside the domain. Each domain has one domain foreign agent (DFA), which is the ancestor of all other routers inside this domain.

The communication between the MH and FA is achieved through the wireless network hardware of the MH and one of the radio interfaces of the FA. Each FA broadcasts a beacon packet with a beacon period. When an MH wants to register with an FA, it registers with the DFA and sends the address of the DFA to its HA. Therefore, when an MH moves inside this domain, it does not need to inform HA of its current FA.

Switching from one FA to another can still be a problem inside the domain for real-time services since this kind of services cannot tolerate delay. To solve this problem, we have fast intra-domain module.

The implementation of this module requires the following exchange of messages:

- DFA takes the encapsulated packet coming from HA or CH and decapsulates it.

- DFA examines the destination address and finds from its visitor list the care-of-address of MH.

- DFA finds the adjacent FAs of the MH's FA from the location-IP address table. Then from its routing table, it decides to which of its branches it should send these packets in order to cover all of the adjacent FAs, and sends these packets to these branches by encapsulating with the CoA of MH.
- When the routers at the end of these branches take the packets, they check the location-IP address table to find the adjacent FAs of the MH's current FA according to CoA and decide to which of their branches they should send these packets.
- Adjacent FAs buffer the packets with a specific buffer size in case of a registration.
- Adjacent FAs periodically empty their buffers.

By applying this method at each of the FAs, we achieve the multi-cast forwarding of datagrams without allocating any multi-cast address. By applying this scheme we avoid the extra burden of signaling and push the complexity of signaling to the FAs. This handoff provides minimum delay for the reception of the next packet from the new FA while it may introduce extra traffic in the domain if the MH does not move frequently.

3.3 Inter-Domain Module

The inter-domain handoffs will be needed more and more as the battery-power of laptop computers increases and the world becomes tiled into small wireless cells. Therefore, our system tries to achieve fast handoffs between the domains and gives local home agent functionality to DFA by using geographical information.

As the world is tiled into small cells, macro mobility of a user will be frequent and an intelligent fast inter domain handover scheme will be needed. For instance, suppose a user starts an Internet telephony or real video session with its hand-held computer and connects to an FA in Berkeley campus domain. Then he decides to go to San Francisco. On his way he comes across several domain changes. User will expect an uninterrupted service for these real-time services. Our system tries to make all handoffs transparent to the user during his journey.

The procedure of changing domains without inter-domain fast handoffs upon reception of the registration request from an MH is as follows:

- The MH sending the registration request is not inside the visitor list of the DFA receiving its packet.

- DFA sends registration request to the HA of the MH, takes registration reply from HA, updates its visitor list with the MH entry and sends the registration reply to MH.

The procedure of changing domains with inter-domain fast handoffs upon reception of the registration request from an MH is described as follows (This is the procedure of our system and we assume that the registration request coming from the MH includes the location and IP address of its old local home agent and the IP address and location of its HA):

- The old local home agent DFA entry in the registration request is not the same as the address of the DFA receiving the packet.

- DFA decides whether to become the new local home agent with the global tube algorithm.

- If it decides to become the new local home agent, it sends the registration request to HA and takes the registration reply from HA.

- If it does not decide to become the new local home agent, it sends the registration request to the old local home agent and receives the registration reply from it.

- Then it sends the registration reply to MH by encapsulating it with the care-of-address of the MH, which includes the new local home agent information.

Global Tube Algorithm

The main objective of the global tube algorithm is to eliminate the unnecessarily long handoff times and the traffic created to inform HA when MH changes domains. If the local home agent (DFA) is near the HA, it is better to send the registration request to HA instead of this DFA even if the difference between the two DFAs is small. On the other hand, if the previous DFA is far from the HA, it is better to send the registration request to DFA instead of HA for the same distance between the two DFAs. Therefore, the decision whether to send the registration to old DFA or HA is made as a result of comparing the distance between old DFA and new DFA to an adaptive threshold radius, which decreases as the MH is closer to HA and increases as MH is farther from HA.

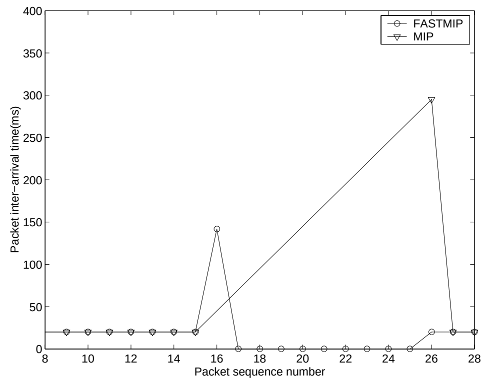

Figure 1. Comparison of Time Intervals of Packets for Intra-Domain Handoff

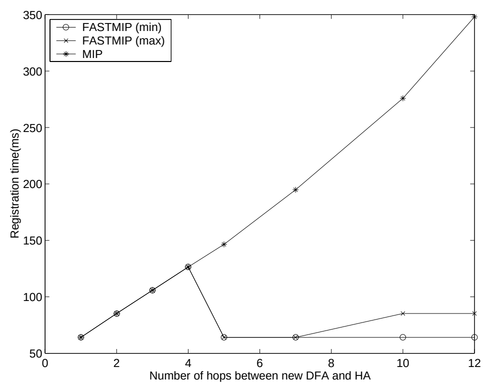

Figure 2. Comparison of Registration Time HA/DFA for Inter-Domain Handoff

4 Performance Evaluation

The performance of our algorithm is examined by simulation and implementation. We performed simulation for intra-domain and inter-domain handoff in Network Simulator (ns2) and implementation for intra-domain handoff in LINUX operating system.

4.1 Simulation of Intra-Domain Handoff

In the intra-domain simulation, the main concern is to observe the registration time. Packets are sent to MH from an audio source with inter-arrival time of 20ms and average packet size of 200 bytes. A good inter-arrival time performance is necessary for real time services. It has been demonstrated that human ear can tolerate approximately 200 ms delay at maximum.

The inter-arrival time performance simulation for Fast Handoff is performed with a 100ms beacon period and a buffer size of 10 in 1Mbps bandwidth and 4 ms wired delay and 1Mbps bandwidth wireless delay. As can be seen from Figure 1, basic Mobile IP handoff does not satisfy the maximum delay requirement while fast Handoff is below 200ms limit.

4.2 Simulation of Inter-Domain Handoff

In this part of the simulation, we compared the inter-domain handoff registration time of the current Mobile IP structure with the maximum and minimum possible registration time in our system by using different HA distances. Here the minimum and maximum registration times are taken to be the registration times for nodes one hop away from the local home agent and for nodes at the boundary of the global tube respectively.

We assume that the distance between DFAs can be used to judge their physical layer distance. The reason for this is that there is a strong relation between the geographical distance and delay for macro movements although we cannot say that IP addresses are distributed geographically in micro movements. We have also assumed that the distance is proportional to the number of hops between two nodes to find approximate number of hops for the node at the boundary of the global tube.

As it can be seen from Figure 2, up to a specific distance, both the basic Mobile IP and our scheme have the same registration time since our scheme chooses HA to make the registration when the distance between HA and MH is very small. As the distance between HA and MH increases, the basic Mobile IP handoff time continues to increase up to 350 ms. whereas the maximum possible registration time of our scheme increases only up to 85ms. This proves for the audio receiver that it is impossible to achieve handoff transparent to user with basic Mobile IP but transparent handoff can be acquired by adjusting beacon period such that the sum of beacon period and registration time is guaranteed to be below 200ms in our scheme.

4.3 Implementation Notes

In this section, we introduce FASTMIP implementation. The implementation is compliant with Mobile IP RFC 2002 [8]. In this implementation[9,10], agents and mobile run the LINUX operating system.

Figure 3 shows the instantaneous throughput during a handoff when the packet size is 200byte, which is an average real-time audio packet size, and inter-sending time is 50ms. This figure shows that basic Mobile IP (MIP) loses all the packets during handoff, which causes an unrecoverable throughput decrease for 3 seconds. These 3 seconds include the time necessary for the detection of the new access point, which is equal to beacon period of access points at maximum, the time necessary for the registration request to reach home agent and for the registration request to reach the access point back. On the other hand, our scheme (FASTMIP) buffers the packets at the prospective access points and send the packets that the mobile missed during the handoff when mobile is connected. The period during which the throughput decreases is around 300ms, which is less than 3 sec in MIP since FASTMIP registration is done only to a specific foreign agent in the local region instead of the home agent in a far away network. In FASTMIP, although the instantaneous throughput decreases during handoff, it is compensated after the handoff by sending back the packets that mobile host has missed. Since this forwarding operation inter-sending time is less than 50ms(they are already in the buffer) the throughput is above the average throughput for about 500ms.

Figure 4 shows the instantaneous throughput during a handoff when the packet size is 200byte and inter-sending time is 20ms. The throughput graph behaviour for Mobile IP is the same as that with 50ms inter-sending time. The reason is that the handoff time 3 sec does not depend on sending rate and the inter-arrival of packets reaches the average value since there is no compensation for packets lost.

The overall throughput graph for different rates, as given in Figure 5, shows that the throughput increases as the sending rate increases and FASTMIP performs better than MIP. The reason for the throughput increase is that more packets are sent overall although the number of packets lost increases as the sending rate increases. FASTMIP performs better than MIP since the number of packets lost is smaller in FASTMIP as we have seen in instantaneous throughput graph.

The number of packets lost depends both on the size of buffer used to store packets for potential handoffs and the sending rate as seen in Figure 6. The number of packets lost is constant for MIP since no buffer is used and increases as the sending rate increases since more packets are sent while mobile

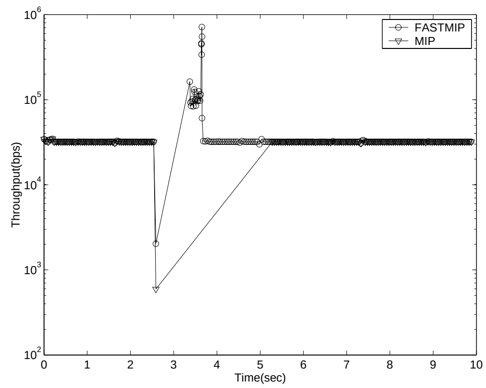

Figure 3. Instantaneous Throughput vs Time packet rate=50ms

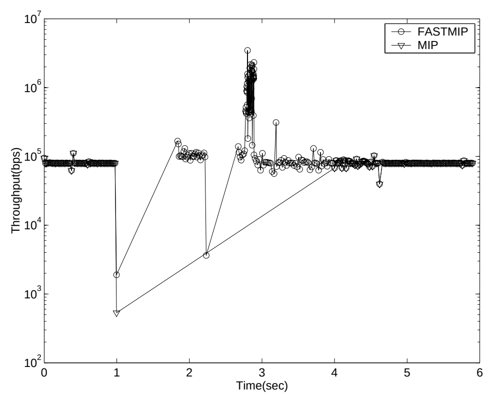

Figure 4. Instantaneous Throughput vs Time packet rate=20ms

is unable to receive during handoff. On the other hand, the number of packets lost decreases as buffer size increases for FASTMIP. This means that the packet loss can be totally eliminated if the buffer size is chosen large enough. Furthermore, this buffer size can be adjustable to the sending rate since the number of packets lost increases as sending rate increases for constant buffer size.

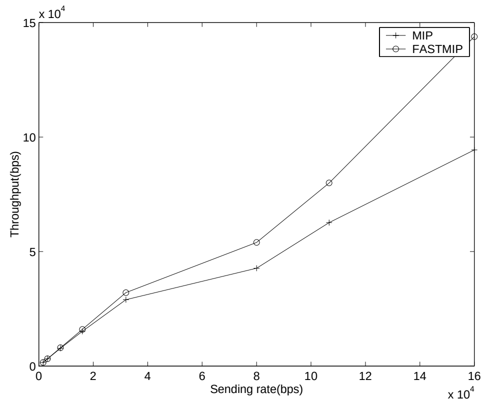

Figure 5. Throughput vs Rate

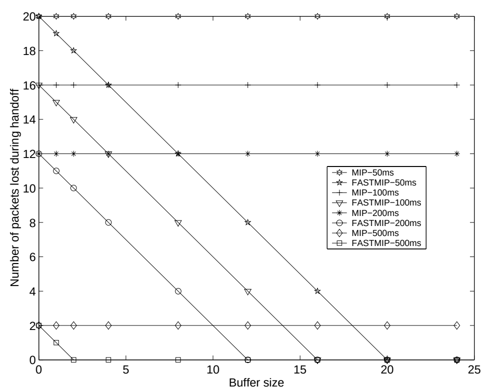

Figure 6. Packet Loss vs Buffer Size

5 Summary and Discussion

In this paper, we have presented an algorithm for doing faster handoffs with less control traffic than previous algorithms in wireless networks. Our scheme uses the hierarchical structure of the network,(i.e, the Internet is a network of domains) and location information of the foreign agents inside every domain of the network. We have achieved an intelligent neighborhood discovery mechanism eliminating the manual configuration of adjacent FAs by these location advertisement messages. Moreover, we have obtained fast handoffs inside the domain by sending the packets to multiple foreign agents without needing any multi-cast address allocation. We have demonstrated that our scheme meets the delay requirement of a real-time audio applications. Furthermore, we have achieved faster handoffs between the domains in contrast to all other systems ignoring inter-domain handoffs. By using local home agent functionality inside the global tube, we avoided the need to register home agent for each domain change.

Our work can be investigated further in various ways. Neighborhood discovery mechanism can be made adaptive to different domain structures and different cell size. Movement detection of the MH by the FA can be investigated in order to decrease bandwidth usage.

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