Service-Differentiated Handoff Protocol (SDHP)

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Abstract

The future mobile Internet will provide various data services with different QoS requirements to roaming users. Due to limited wireless transmission range, handoff is essential and a major determinant of QoS. In this paper, we propose a Service-Differentiated Handoff Protocol (SDHP). Two handoff schemes are implemented: Forwarding and Multicasting. Different schemes will be selected according to the type of ongoing traffic flow. Thus, different requirements on traffic flows can be satisfied and the overall network throughput can be maximized. In addition, our simulation results show that within acceptable QoS limits, SDHP can achieve better performance than single-scheme protocols such as HAWAII-MSF and MMP.

Keywords - Handoff, mobility management, QoS, wireless.

1. Introduction

Recent years have witnessed the explosive growth of wireless networks and the emergence of various new applications. The desire to be connected "any time, any where, in any way" leads to an increasing need for users to receive various data services while moving freely. A handoff protocol is needed to maintain connectivity as users move, while minimizing packet loss and update latency.

The Mobile IP [1] standard is intended to provide mobility support to roaming users. But when the Mobile Node (MN) roams across cells within the same domain, the frequent location update and heavy packet loss will make Mobile IP inefficient. To address this limitation, other protocols have been proposed for intra-domain mobility (micro-mobility), while Mobile IP is used only as an inter-domain mobility (macro-mobility) protocol to support host mobility over wide-area networks.

Micro-mobility issues include packet loss and delay due to handoffs. In this paper, we propose a micro-mobility protocol with QoS support to satisfy different requirements on packet loss or delay by different services. Two handoff schemes, Forwarding and Multicasting are implemented in the protocol. We also adopt a classifier to select the proper handoff scheme according to the traffic type. Our protocol aims to satisfy the service requirements by using different handoff schemes during the handoff process.

We have simulated our protocol using Network Simulator (NS2) [2]. The simulation results show that our protocol performs better than single-scheme protocols in satisfying different service requirements.

The rest of this paper is organized as follows. Section 2 presents related work. Section 3 describes our protocol and a hierarchical mobility management infrastructure. Section 4 reports the performance results of our simulation. Section 5 concludes the paper.

2. Related Work

Mobile IP is a modification to IP that allows hosts to continue to receive data while roaming. In Mobile IP, there is a Home Agent (HA) for each Mobile Node (MN). The intercepted packets destined to MN are tunnelled to MN's current attachment point through HA. The current attachment point is defined by an IP address called Care-of –Address (CoA). The

Care-of-Address is either the address of the Foreign Agent (FA) as the tunnel exit-point, or the co-located address temporarily assigned to one of the MN's interfaces. When an MN enters a new foreign network, the handoff process is triggered by receiving the advertisement message including new CoA from the new FA. The MN's HA is notified of the handoff with a location update message from MN, such that HA will tunnel the packets to MN's new attachment point. However, Mobile IP suffers from long handoff delay and heavy packet loss when an MN is roaming far away from its HA.

A common technique to address this problem is to separate micro-mobility from macro-mobility management. Cellular IP [3] uses specialized domain routers with host-based entries for local mobility and the use of Mobile IP for inter-domain mobility. Thus, location updates can be localized, reducing handoff delay and packet loss. Handoff-Aware Wireless Access Internet Infrastructure (HAWAII) [4] is similar in spirit to Cellular IP, and also uses a macro- and micro-mobility infrastructure. In HAWAII, when an MN enters a new foreign network, the in-flight packets to the old attachment point will be forwarded to the new network using one of the forwarding schemes, Multiple Stream Forwarding (MSF) or Single Stream Forwarding (SSF). Very low packet loss can be achieved through forwarding, but the handoff delay introduced is still bounded by the update latency from the new to the old attachment point, which is unacceptable for some real-time applications such as Voice over IP (VoIP).

Multicast for Mobility Protocol (MMP) [5] uses multicasting to support fast handoff without packet loss. In MMP, packets are multicast to the neighbouring FAs of the current FA when an MN is going to trigger a handoff, such that low handoff latency and packet loss can be guaranteed. However, multicasting will incur heavy packet duplication, and lots of bandwidth and buffers are wasted.

3. Mobility Management with SDHP

3.1 Hierarchical Structure

We propose to adopt a hierarchical architecture as shown in Fig. 1 for mobility management. The mobility agent (MA) will shield all mobility within its domain from other MAs outside this domain. As long as the MN roams within the domain of MA, the location update will end at the MA, such that update latency and packet loss are significantly reduced.

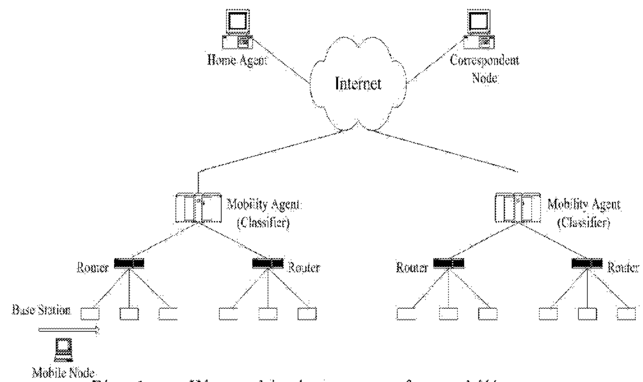

Fig. 1. Hierarchical structure for mobility management.

3.2 Protocol

A. Macro-Mobility

As in HAWAII, Mobile IP is used as the macro-mobility management protocol. When an MN enters a foreign network, it registers with the Mobility Agent (MA), and sends the address of MA as the Care of Address (CoA) to its HA. HA will then tunnel the packets, originally destined to the MN, to the MA.

When the MN moves to a new foreign domain, the new MA will update the location information of the MN at HA, such that HA will set up a tunnel to the new MA.

B. Micro-Mobility

We propose a Service-Differentiated Handoff Protocol (SDHP) for micro-mobility management. In the proposed protocol, a classifier (see Fig. 1) is adopted at MA to classify data traffic into two classes—Minimum Delay and Minimum Loss according to the Traffic Class byte in IPv6 or the application protocol. Two handoff schemes, Forwarding and Multicasting are used. A decision maker at the MA will decide which scheme to use according to the type of traffic class: Forwarding for the Minimum Loss Class and Multicasting for the Minimum Delay Class.

The protocol works as follows. When an MN enters a foreign network, it registers at the MA with the address of the serving Base Station (BS). Besides registering at MN's HA using Mobile IP, the MA will also set up a tunnel to MN's current attachment point. Then, MA creates a Handoff Scheme ID (HSID) for this MH. When a Correspondent Node (CN) sets up a connection with this MN, the classifier will allocate a number as HSID according to the traffic type, then sends this ID to the serving BS.

When the MH is going to leave the range of the current serving BS, it will initiate a pre-handoff process based on physical layer information. In the pre-handoff process, a Handoff Initialization Message will be sent to MA through the old BS. At the MA, the handoff scheme is selected according to the HSID.

If the Multicasting Scheme is selected, the MA will begin multicasting the data packets destined to the MN to the neighbour BSs of the current attachment point. When the MN receives an advertisement message, it will register at the new BS and the buffered packets will be transmitted immediately. At the same time, a registration message will be sent to the MA to change the tunnel exit point and stop multicasting.

If the Forwarding Scheme is selected, the old BS will start to buffer the packet destined to the MN in a circular queue. When the new BS receives the registration message from the MN, it will send a Request Forwarding Message to the old BS besides the registration message to the MA, and then the MA will set up a new tunnel to the new attachment point. When the old BS receives the Request Forwarding Message, it will set up a temporary tunnel to the new BS and forward the buffered packets to the new BS. The tunnel will last a short period of time until it times out, in case there are some in-flight packets on the way.

4. Performance Simulation

In this section, we use Network Simulator (NS2) to simulate the proposed protocol. We want to find out how different handoff protocols affect the performance of the ongoing traffic.

4.1 Simulation Scenario

The simulated topology is shown in Fig. 2. Nodes 2-15 are routers; node 1 is the MA, integrated with the classifier. There are 15 BSs, which are network-layer routers with buffers, and are capable of subscribing to multicast groups. All these nodes are connected by intra-domain wired 1.2Mb/s links to form a tree topology. The inter-domain links between CN, HA, MA and the Internet are of 10Mb/s bandwidth and 40ms delay, including propagation and processing delay. Two mobile users are roaming in the network. One user receives CBR traffic, and the other performs FTP download from CN. CBR traffic is over UDP, with a packet size of 210 bytes and a rate of one packet every 20ms. FTP traffic is over TCP; the packet size is 1400 bytes.

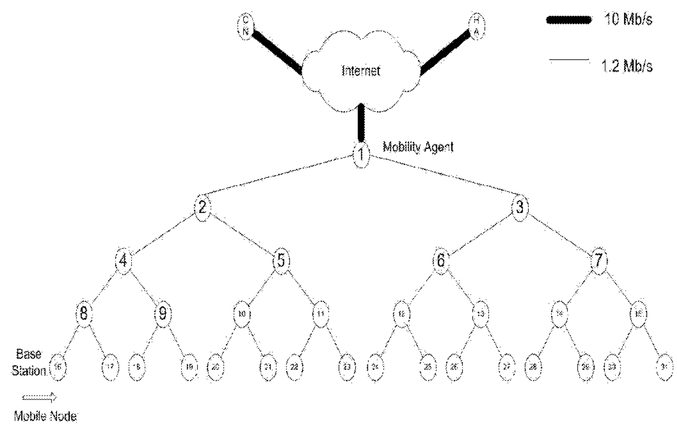

Fig. 2. Network topology simulated.

4.2 Handoff Delay of CBR Traffic

Handoff delay is defined as the time interval between the last packet received from the old BS and the first packet obtained from the new BS. It is a rough indicator on how the ongoing traffic is disrupted by handoff. The objective of the simulation is to compare the handoff delay for CBR traffic using SDHP and HAWAII-MSF. SDHP will select the Multicasting Scheme for CBR traffic, while HAWAII-MSF uses forwarding for any kind of traffic.

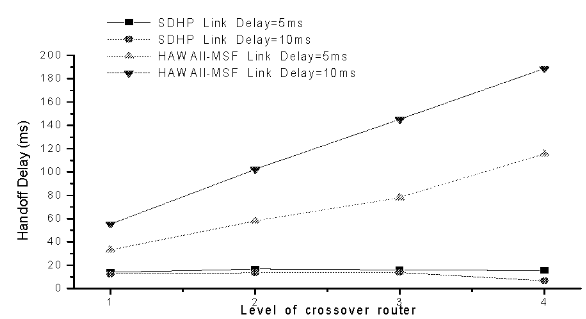

Fig.3. Handoff Delay of SDHP and HAWAII-MSF on CBR traffic with different handoff levels and link delay.

Due to the tree topology adopted in our simulation, the handoff delay of protocols using forwarding will largely depend on the number of hops and the link delay between the old and new BSs. As shown in Fig. 3, the handoff delay of HAWAII-MSF increases roughly linearly with the level of the crossover router. The crossover router refers to the router at the crossover point of the old and new route for the MN. In the simulated topology, routers 8-15 are at level 1; router 1 is at level 4, and so on. From the simulation, we observe that the handoff delay using HAWAII-MSF varies significantly with the parameters introduced; this will adversely affect the performance of real-time services, which have stringent requirements on packet delay.

Compared to HAWAII-MSF, the handoff delay of SDHP remains at less than 20ms irrespective of between which BSs the handoff has taken place. This is because the MN will receive the buffered data packets immediately after it has registered at the new BS. Hence our protocol performs much better than HAWAII-MSF in satisfying the requirement on packet delay during handoff for real-time services.

4.3 Packet Sequence of CBR Traffic

Another factor that affects the performance of real-time services is the sequence of incoming packets. Packets arriving out of order have to be buffered and reordered at the MN until the packets needed are received.

Fig. 4 and 5 show the sequence of incoming packets during Level-1 and Level-4 handoff, respectively. The traffic simulated is CBR traffic; the Multicasting Scheme is used in SDHP, and Forwarding in HAWAII-MSF.

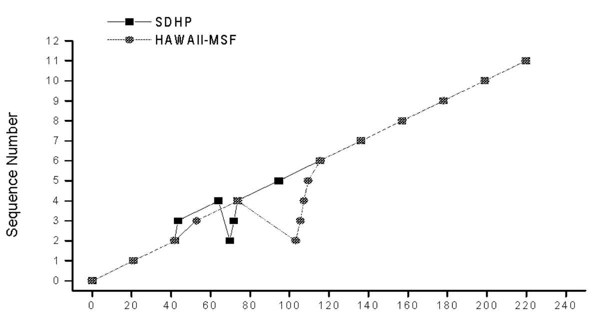

Fig. 4. Packet sequence before, during, and after a handoff (Crossover router lever=1, Buffer size=3)

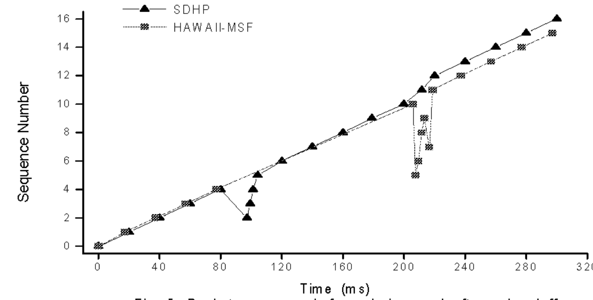

Fig. 5. Packet sequence before, during, and after a handoff (Crossover router lever=4, Buffer size=3)

In Fig. 4, the first packet received from the new BS is the 6th packet in both protocols. We observe that, in SDHP, the first three packets received from the BS are duplicates of the last three received from the old BS. These three packets are multicast to the new BS and buffered there. The result using HAWAII-MSF is similar; the MN receives duplicated packets forwarded from the old BS in order. This does not affect correct operations; the duplicated packets will simply be dropped; no buffer and reordering mechanism are needed.

Fig. 5 shows that SDHP achieves similar result as in Fig. 4. However, in HAWAII-MSF, the sequence number of the first six packets received from the new BS is 9-4-5-7-8-6. This means that the MN has to buffer and reorder these six packets before they can be sent to the application. The severe disorder is caused by long handoff delay during a Level-4 handoff. Hence, compared to HAWAII-MSF, SDHP can achieve more stable performance during any level of handoff.

4.4 Traffic Overload Ratio of FTP download

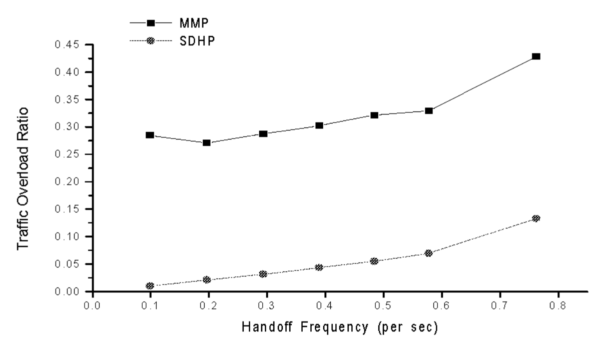

Fig. 6. Traffic Overload Ratio using MMP and SDHP at different handoff frequencies

Fig. 6 shows the overload generated by different protocols during a handoff. We select MMP for comparison, which uses multicasting for any kind of traffic; while for SDHP, the Forwarding Scheme will be selected for FTP traffic. The traffic overload ratio is defined as the number of packets duplicated in the Multicasting Scheme or forwarded in the Forwarding Scheme, divided by the total number of packets received by the MN. We set the size of the buffer at BS as 20, because C.L. Tan et al. [6] suggest that the optimal size of the buffer should be equal to TCP window size to maximize throughput during handoff.

From Fig. 6, we observe that the ratio of MMP is much higher than that of SDHP. The ratios of both protocols increase with the handoff frequency; this is because frequent handoffs will create much more overhead traffic. As FTP traffic has no stringent requirements on packet delay, SDHP performs much better in terms of higher efficiency.

5. Conclusions

In this paper, we propose a handoff protocol with two handoff schemes for different traffic types to satisfy their service requirements. We also present a hierarchical mobility management architecture to provide mobility support for mobile users using Mobile IP and the proposed SDHP. Our simulation result shows that SDHP outperforms single-scheme protocols such as HAWAII-MSF and MMP in satisfying QoS requirement.

Acknowledgement

This research is supported in part by the National Natural Science Foundation of China (NSFC)/Research Grants Council (RGC) of Hong Kong Joint Research Scheme under NSFC Grant No. 60318004, and RGC Grant No. N_HKU 706/03.

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