

Micro Mobile MPLS: A Solution for Micro-Mobility Management in Next Generation Networks

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Abstract

Mobile MPLS is a new scheme that integrates Mobile IP and MPLS protocols to support mobility to MPLS. However, it is optimised for macro-level mobility, and it fails to support micro-mobility efficiently. In this paper, we propose Micro Mobile MPLS that is a practical approach to support local mobility for MPLS. Simulation results show that Micro Mobile MPLS is more efficient, in terms of packet loss and handoff delay, than the other most prominent micro-mobility protocols such as: Cellular IP, Hawaii and Mobile IP Regional Registration. These simulations are based on a generic access network architecture which can therefore be adopted for the Next Generation Networks.

1. Introduction

Mobile IP [1] is the current standard for supporting mobility in IP networks. It provides seamless mobility by hiding the change of IP address when a mobile host moves between IP subnets. However, Mobile IP is not designed to support fast handoff in handoff-intensive environments. It produces a lot of control traffic inside the local domain that increases the handoff delay and the risk of packet losses. Therefore, mobility management issues are solved by separating macro-mobility and micro-mobility. Macro-mobility concerns the management of mobile movements on a large scale between different wide wireless access networks. Micro-mobility, on the other hand, covers the management of local movement inside a particular wireless network, or domain. Several reference models for IP micro-mobility have already been developed, the main proposals being Cellular IP [2], HAWAII [3] and MIP-RR [4].

Recently, multi-protocol label switching (MPLS [5]) is deployed in the Internet backbone to provide Quality of Service (QoS). An architecture integrating MPLS and Mobile IP is proposed in order to enable the MPLS protocol to support mobility [6]. This integration, called Mobile MPLS,

improves the scalability of the Mobile IP data forwarding process [6]. However, recent wireless networks have been implemented based on small-size cells to allow higher system capacity. Micro-cell implementation will increase the handoff rate of the mobile hosts dramatically. So in such an environment, “Conventional” Mobile MPLS is no longer an optimal solution. To overcome this limitation, in this article, we propose a new extension of Mobile MPLS, called Micro Mobile MPLS, in order to support local mobility to MPLS. Then we provide some results via NS-2 simulations of the UDP performance in a generic wireless access IP network. These results show that Micro Mobile MPLS can reduce the packet loss due to handoff and improve the handoff delay when compared with other micro-mobility protocols: Cellular IP, Hawaii and MIP-RR.

The rest of this paper is organized as follows. In Section 2, we briefly review some prominent micro-mobility protocols in IP-based networks. In particular, we describe our new extension of Mobile MPLS, Micro Mobile MPLS, to handle micro-mobility. In section 3, our simulations and the analysis of the results are presented. Section 4 concludes this paper and outlines future work.

2. Micro-mobility in IP networks

Micro-mobility protocols aim to handle local movement of mobile hosts without interaction with the Mobile IP protocol. Some of the most prominent micro-mobility protocols are : Cellular IP, Hawaii and MIP-RR.

2.1. Cellular IP

A Cellular IP [2] network is connected to the Internet via a gateway router. Mobility between gateways is managed by Mobile IP, while mobility within access networks is handled by Cellular IP. A Cellular IP node constitutes the universal component of a Cellular IP network, since it supports routing, paging and a number of handoff techniques.

2.2. HAWAII

The Handoff-Aware Wireless Access Internet Infrastructure protocol [3] uses a separate routing protocol to handle intra-domain mobility. It relies on Mobile IP to provide wide-area inter-domain mobility. When a mobile host moves within a domain, all involved forwarding tables are modified to redirect packets to the mobile's new location. Specialized path setup schemes are employed to install host-route entries in the routing tables of the routers sitting between the mobile host and a Domain Root Router (DRR) to support intra-domain mobility.

2.3. MIP-RR

The Mobile IP Regional Registration protocol [4] uses a different algorithm to handle Mobile IP registration. While the mobile host is moving within a domain, the mobility agent at its home network does not need to be aware of that motion. Once in a foreign network the mobile host performs a regional registration with the Gateway Foreign Agent (GFA) that will be aware of the local mobility but will not mention it to agents outside the domain.

2.4. Overview of Mobile MPLS

Mobile MPLS is a new scheme that integrates Mobile IP [1] and MPLS [5] protocols to support mobility to MPLS. In "conventional" Mobile MPLS [6], when a mobile host (MH) enters a foreign network, it sends a Registration Request message to the Foreign Agent (FA) of this network as defined in Mobile IP [1]. The FA relays this Registration Request message to the Home Agent (HA) of this mobile host by using normal IP routing. When the HA gets the Registration Request message and knows the Care Of Address (COA) of the MH, it sends a label-request message using the Label Distribution Protocol (LDP) [7] to the FA with the COA as Forwarding Equivalence Class (FEC). The FA replies with an LDP label-mapping message to the HA. When this label-mapping message arrives at the HA, the LSP from the HA to the FA is established. Finally, the HA sends a Registration Reply back to the FA along this LSP. If the MH is located in a foreign domain and there is a Correspondent Node (CN) sending some packets to that MH, packets will be intercepted by the HA as described in Mobile IP [1]. However, in the "conventional" Mobile MPLS model, the packets are delivered from the HA to the FA along the LSP by label swapping. The FA receives the packet and looks up its label table. Since it is the egress of the LSP from the HA to the FA, the FA strips off the label and sends the packet to the MH through the IP layer. Finally, MH receives the packet sent by the CN.

2.5. Micro Mobile MPLS

"Conventional" Mobile MPLS is optimised for macro-level mobility [6]. The process of establishing an LSP from the HA to the new FA, as mentioned above, could become very long. If there is a CN sending traffic to the MH during this period of time, there will be a disruption in the traffic flow. In order to reduce the handoff latency, we propose to apply the principles of the earlier work on MIP-RR to a network that employs MPLS. Micro Mobile MPLS can handle local movement of mobile hosts by dynamically changing the association of the IP address with a FEC through special signaling messages. For this purpose, we introduce a new component, which we call Label Edge Router/Gateway (LER/GW), and which is affiliated with each MPLS domain (figure 1). The HA is localised outside the domain. The mobile host performs, as mentioned above, a regional registration with this special gateway instead of the HA of the MH. When a mobile host first arrives in a visited domain, it performs a registration with its HA using the IP address of the LER/GW as its care-of address. Subsequently, when it changes location within the visited domain under the same LER/GW, only a regional registration is required with the LER/GW that will be aware of local mobility but will not mention it to agents outside the domain. When the MH moves to another foreign domain, the usual Mobile IP procedure is used for registration where the LER/GW of the foreign domain is now the FA, responsible for assigning a care-of address and forwarding the packets to/from the MH.

3. Simulation Studies

We use the Network Simulator (NS-2 [8]) as our simulation tool as well MPLS module and IP micro-mobility module CIMS contributed by Gaeil Ahn [9] and Columbia University [10], respectively. We extend the MPLS module to hierarchical address format which is necessary for Micro Mobile MPLS simulation. We performed a series of simulations to study the performance of MPLS-based micro-mobility management on UDP applications and compare it with Cellular IP, Hawaii and MIP-RR protocols.

3.1. Simulation Configuration

In the simulation, we use the handoff delay and the average packet loss per handoff, as handoff performance criteria, to evaluate the handoff performance of Micro Mobile MPLS, Cellular IP, Hawaii and MIP-RR protocols. We define handoff delay as the difference between the time when the mobile host is able to receive the first packet, from a correspondent node, by the new base station and when it was able to receive the last packet by the previous base station.

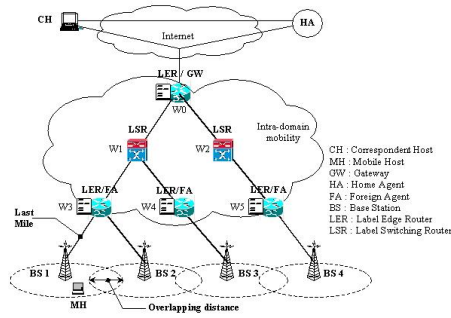


Figure 1. The simulated network topology

The network topology shown in figure 1 and adopted in [11] is used in the simulations. The entry node of the access network is referred to as the Gateway for Micro Mobile MPLS and Cellular IP protocols, as the Domain Root Router for Hawaii protocol or as the Gateway Foreign Agent for MIP-RR protocol. The internal nodes of the Micro Mobile MPLS domain are IP routers that perform MPLS switching. They are called label switching routers (LSRs), while the routers located at the boundaries are usually referred to as label edge routers (LERs). In Cellular IP simulations, the internal nodes correspond to Cellular IP nodes. In Hawaii simulations, all internal nodes are Hawaii-enabled routers, while when simulating MIP-RR they represent mobility-unaware routers with collocated BS/FA. This is a generic access network architecture that can be adopted for the Next Generation Networks. Since we focus on mobility management inside the access network illustrated in figure 1, we assume that packets arrive from a correspondent node without encapsulation. This simplification does not affect observed values.

3.2. Simulation Results

This section discusses the simulation results for handoff performance of Micro Mobile MPLS and the CIMS extension protocols (i.e. Cellular IP, Hawaii and MIP-RR). To examine the handoff performance of the Micro Mobile MPLS scheme, we use UDP traffic, which is directed from the CN to the MH. The encapsulations of UDP datagrams as IP packets sent by the CN are simulated using a constant bit rate source. Therefore packet interval and packet size are constant. We perform simulations by varying the packet interval time and crossover distances (i.e. the number of hops between the crossover node and base station) with a constant rate of about 64kbps (this allows us to simulate voice traffic for digital telephony using a PCM-codec). The crossover distance is 1, 2, or 3 hops when the MH moves between BS1-BS2, BS2-BS3, and BS3-BS4, respectively. The simulation time is fixed to 200 seconds (this allows the

generation of more than 40 independent handoff events). We present simulation results for the basic (hard) handoff performance of each micro-mobility protocol in terms of packet loss per handoff and handoff delay.

i. Handoff delay comparison

To obtain the minimum possible value of handoff delay, we performed a series of simulations by varying the packet interval time of the UDP traffic which is directed from the CN to the MH. By varying the packet interval time, we change the queue occupancy in the “Last Mile” without changing the network load. The aim is to reach the lowest limit, which corresponds to the real value of handoff delay. Figure 2 illustrates the real values of handoff delay for these four micro-mobility schemes obtained with a packet interval time equal to 7ms. From this figure, we can find that the real value of handoff delay is around 6ms for Micro Mobile MPLS and around 13ms for MIP-RR.

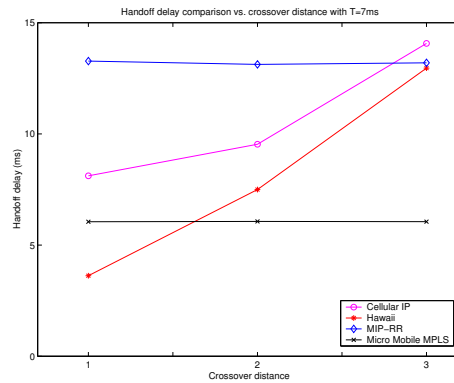


Figure 2. Real values of handoff delay for various micro-mobility schemes

The lower value of Micro Mobile MPLS is the result of having the entire LER/GW data forwarding process executed in the MPLS layer. It implies that no IP routing table search is executed. Since label table search is much faster than longest-bit-matching routing table search, and IP tunneling, required in MIP-RR, needs to search in a routing table, much processing time is saved and handoff performance is much improved. We also can find from this figure that handoff delay of Micro Mobile MPLS and MIP-RR remains almost constant, regardless of the crossover distance. For MIP-RR, the handoff delay is almost equal to the handoff performance in the case of the maximum crossover distance for Hawaii scheme. This result confirms that MIP-RR updates routing only when registration messages reach the GFA in order to set up tunnels between it and the corresponding FA. Micro Mobile MPLS also updates the forwarding table only when registration messages reach the

LER/GW in order to set up LSPs between the LER/GW and the corresponding LER/FA. Therefore, neither of these two protocols can benefit from the fact that a crossover node is topologically close to the BS. In contrast to MIP-RR and Micro Mobile MPLS, handoff delay for Cellular IP and Hawaii is related to the packet delay between the BSs and the crossover node. From figure 2, we can find that when the MH moves between BS1 and BS2, the delay is small. If the crossover distance is larger, the handoff delay increases for each additional hop. The results are a direct consequence of the similarity between Hawaii and Cellular IP schemes, particularly in the way in which the protocols build up the route between a crossover node and the new Base Station.

ii. *Comparison of packet loss per handoff*

Now, we show on figure 3 a comparison of the average amount of packet loss per handoff, when the constant behavior of these four micro-mobility protocols is reached.

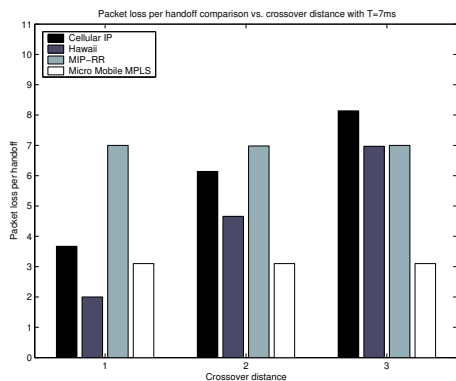


Figure 3. Packet loss per handoff of various micro-mobility schemes

From this figure, we find that Micro Mobile MPLS has the lowest packet loss during handoff when crossover distance is 2 or 3. The reason for this phenomenon is, as seen at the beginning of the discussion, that with Micro Mobile MPLS, the whole forwarding process is done at the MPLS layer. The LER/GW does not need to go up to the IP layer to do the IP tunneling. Since switching is much faster than conventional IP forwarding, the MH receives more packets, during handoff, with Micro Mobile MPLS than with MIP-RR. This implies that, with MIP-RR, the queue in the “Last Mile” is still large, thus resulting in the loss of the remaining packets in the queue when handoff occurs. The old BS does not forward these packets to the new location of the MH since the medium access control (MAC) layer, used in our simulations, does not yet support a packet recovery scheme. This will be integrated into our future work. In addition, we observe from this figure that, for MIP-RR, the packet loss

per handoff is constant and almost equal to the handoff performance in the case of the maximum crossover distance for the Hawaii scheme. The Cellular IP and Hawaii schemes are very similar. The handoff performance increases for each additional hop. The reason was explained earlier.

4. Conclusions

In this paper, we proposed a new extension of Mobile MPLS, called Micro Mobile MPLS, to support local mobility for MPLS. We also performed an analysis of handoff performance for Micro Mobile MPLS, Cellular IP, Hawaii and MIP-RR schemes. Simulation results indicate that our scheme reduces packet loss and handoff delay during handoff compared to the aforesaid IP micro-mobility protocols. As switching is much faster than conventional IP forwarding, the transmission delay and packet processing overhead are reduced. The entire scheme is performed within a hierarchical topology based on next-generation IP networks. Currently, we are analysing the impact, on handoff performance, of using background traffic to overload the simulated network. Also, we are analysing the use of a MAC layer assisted packet recovery scheme to prevent the packet loss due to handoff. Further work includes the study of Micro Mobile MPLS as a micro-mobility solution integrated into the Wireless Metropolitan Area Network (WMAN).

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