Design of MPLS-based micro-mobility management protocol with QoS support

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ABSTRACT

In order to provide seamless wireless Internet service, the basic mobile IP protocol should be enhanced to solve packet loss problem from large registration latency because frequent handoffs occur in cellular networks. In this paper, we suggest a new micro-mobility management protocol based on MPLS while supporting QoS, and evaluate its performance using simulation. We use MPLS label switching technique in cellular access networks to simplify location management and speed up packet transmission. We adopt context transfer procedure to minimize the delay needed to attain prior level of service after handoff. Packet loss can be minimized during handoff by transmitting received packets from old BSLER to new BSLER using a spliced LSP between them. Simulation results show that the proposed MPLS-based micro-mobility management protocol provides a seamless handoff and supports QoS of user traffic.

Index Terms- IP micro-mobility, MPLS, context transfer, QoS

I. INTRODUCTION

The core infrastructure of 4G-communication system is based on the Internet and broadband mobile communication technology, and its service is changing from voice-only to multimedia service including real-time and non real-time traffic. With the increasing demand on wireless Internet, mobile IP protocol has been suggested by IETF to handle IP mobility problems in the Internet [1]. But, basic mobile IP protocol must be enhanced to solve packet loss problem from mobile IP registration latency because frequent handoffs occur in cellular networks. Also, lots of current IP technologies also need to be modified due to characteristics of wireless link. Among them, research and development activities related to QoS issues in the wireless Internet are very important due to the high demand on mobile multimedia services. Also, in cellular networks, the route of the data flow changes very frequently and rapidly, which may cause a significant impact on QoS of real-time applications. Therefore, wireless Internet requires an efficient micro-mobility management protocols with QoS support.

Until now, several protocols have been suggested to provide QoS guarantee in mobile IP network. In [2], Talukdar and Badrinath proposed a new resource reservation protocol to support real-time application of mobile hosts based on the assumption of predictable mobility pattern. This solution has shortcoming that mobility pattern of a user cannot be exactly predicted. Later, Mahmoodian and Haring proposed Mobile RSVP protocol [3] that provides dynamic resource-sharing algorithm to guarantee the service quality of mobile Internet, but this protocol cannot support fast mobile IP registration in cellular networks. Recently, Dinan [4] suggested label switched packet transfer protocol in wireless cellular networks, but it also has lots of shortcoming in the aspects of mobile IP QoS requirements [5].

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For example, it cannot support IP paging, seamless handoff and QoS management. As shown above, an optimal solution providing simplicity, fastness and guaranteed QoS in micro-mobility management network is rare.

In other aspects, some researches about real-time IP handoff protocol have been suggested [6][7]. In Cellular IP [6], location management and handoff support are integrated with routing to reduce IP registration latency. But this protocol cannot support QoS and lossless handoff even if latency can be reduced. And it has complex authentication procedure because every node in access networks should perform authentication for every mobility control message. Low latency MIPv4 handoff protocol using layer 2 handoff notification was suggested in [7], in which layer 3 handoff can be completed before layer 2 handoff is finished. This protocol is good for determining layer 3 handoff timing, but it has to be enhanced to support QoS characteristics and seamless handoff of mobile hosts.

In this paper, we propose a new micro-mobility management protocol based on topology-driven MPLS in access networks. We adopt context transfer procedure during handoff to provide QoS support. We evaluate the performance of the proposed protocol on seamless handoff and QoS support using simulation. Simulation results show that our protocol provides seamless handoff, QoS support, easy authentication and fast handoff. Below, we describe the network architecture, basic operation of suggested protocol, and various simulation results.

Ⅱ. NETWORK ARCHITECTURE

We consider an MPLS-based access network that consists of BSLER (Base-station Label-switched Edge Router) and GLER (Gateway Label-switched Edge Router) such that topology-driven LSPs between them are pre-established as shown in Fig 1. These pre-established LSPs are used for traffic transport between GLER and BSLER. The QoS provisioning of backbone network is not considered in this paper because it can be supported by previously suggested mobile IP QoS protocols [2][3][8][9]. We only focus on access networks to provide micro-mobility management protocol with QoS support in cellular networks.

In our protocol, GLER maintains a RP(Routing Path) cache and a PZ(Paging Zone) cache in order to provide location management function. The former is used to map LSP label towards the BSLER that supports current active mobile hosts, and the latter is for IP paging zone mapping of idle hosts. According to this scheme, no intermediate router in access domain needs to maintain routing or paging information since RP and PZ update message are tunneled through LSP. So, overhead for location maintenance can be reduced. Also, it is not required for intermediate nodes to authenticate routing and paging update information in the messages, so authentication delay can be reduced. A BSLER is connected to several base stations and terminates the label switched paths. Each base station periodically broadcasts beacon signal, which includes BSLER ID, GLER ID and Paging Zone ID.

To support traffic QoS, Differentiated Service model is adopted in access networks. BSLER performs traffic classification, traffic conditioning and marking based on traffic profile of mobile users. The QoS-related information of a mobile node is transferred as context information to new BSLER before layer 2 handoff is finished. Thus, new BSLER can seamlessly support QoS for

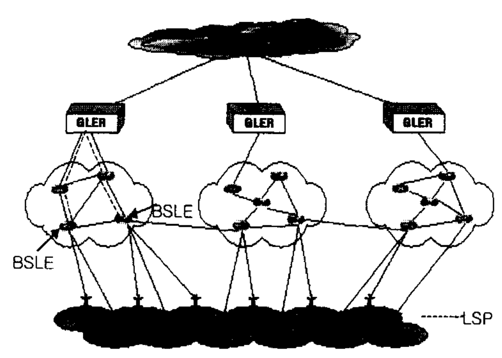


Fig. 1 MPLS-based network architecture for micro-mobility management

incoming active mobile nodes. Also, using MPLS label switching technique, mobile access networks can provide high-speed transmission of data packets and fast rerouting.

Ⅲ. BASIC OPERATION

A. Location Management and Routing

When a mobile host is in active state, the GLER must track its movement from BSLER to BSLER. Active mobile hosts report the current BSLER using *RP update message*. The lifetime of RP cache entry should be refreshed whenever RP update messages or traffic packets toward backbone network are accepted at the GLER. The RP cache entry can be updated whenever mobile host changes location to new BSLER area by using only *RP update message*. So, *RP update message* must include authentication information to protect security attack. If mobile host moves to a new GLER area, it transmits *Registration Request* to its HA according to the basic mobile IP protocol. To do this, mobile host includes Mobile IP Registration control extension in *RP update message*, and GLER extracts Mobile IP *Registration Request* from *RP update message*. At this time, its care-of-address must be set to the IP address of new GLER. The mobile host sends IP packets to GLER along pre-established LSP set up by MPLS protocol. If mobile host is in active state, packets destined to mobile host are delivered to BSLER first according to RP cache entry, and then delivered to mobile host via base station.

Idle mobile host reports its location only when they cross Paging Zone boundary. They compare PZ ID in beacon signal whenever moving to different base station. If new PZ ID is different from old one, they transmit *PZ update message* towards GLER to modify PZ cache entry. If GLER receives a packet for an idle mobile host, it first searches PZ cache and multicasts paging packets to the multicast LSP [10] towards the Paging Zone found in the cache.

B. Handoff

The most important task in real-time handoff network is to minimize the impact of the traffic redirection during a change of packet forwarding path due to handoff. The transfer of context information [11] using link layer handoff notification is most promising technique because layer 3 routing information can be transferred before layer 2 connection with new access point is established. Thus, we adopt context transfer scheme between BSLERs in our suggested algorithm. According to this scheme, layer 2 handoff is notified to old BSLER. If the target base station is connected to new BSLER,

Handoff Request message with context transfer extension is delivered to new BSLER. The issues in how to determine candidate BSLER are not considered in this paper but you can refer [16]. After receiving this message, new BSLER confirms authentication information and sets new service state parameters according to the received context information. Then, it allocates new buffer for incoming packets to mobile hosts, and delivers *Handoff Reply* message to the old BSLER. The detailed handoff procedure is depicted in Fig. 2.

In Fig. 3, we represent a step for handoff procedure (step 1~5). First, when the current BSLER for a mobile node becomes aware that a handoff is about to occur at layer 2, it sends *Handoff Request message* to a new BSLER in order to make the new BSLER reserve buffers for incoming packets from GLER and transfer context information such as QoS parameters.

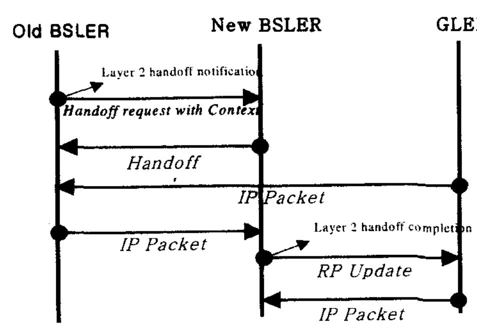


Fig. 2 Handoff procedure

After receiving *Handoff Reply message* from the new BSLER, the old BSLER performs LSP splicing as shown in Fig. 3. All the packets received by the old BSLER are forwarded to the new BSLER through the spliced LSP. This scheme can achieve smooth handoff because it can minimize packet dropping by delivering packets correctly even though they may arrive at the "wrong" BSLER. After the link layer handoff is completed, RP update is sent to the new BSLER and buffered packets in the new BSLER are transmitted to the mobile host.

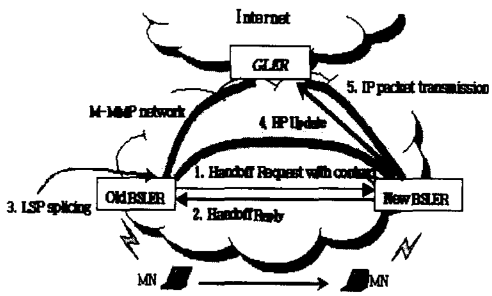


Fig. 3 Network architecture and basic operation

C. QoS Support

We use Differentiated Service model in access networks to provide QoS of user traffic. Traffic conditioning is performed at BSLER based on users traffic profile, and QoS support can be provided using E-LSP or L-LSP. The LSP bandwidth between GLER and BSLER can be allocated according to traffic characteristic or demanded QoS, if necessary. To achieve fast handoff, a context transfer protocol design effort is underway within the IETF. We use context transfer protocol to establish local state for QoS agreements in the new BSLER.

Ⅳ. PERFORMANCE EVALUATION

In this section, we use the network simulator ns-2 [12] to evaluate the performance of the proposed MPLS-based micro-mobility management protocol. We focus on the performance of seamless handoff and QoS support of the protocol. We perform simulation for the network topology as shown in Fig. 4.

First, we show the effect of context transfer during handoff for QoS support. Although there are many possible kinds of traffic for simulation, we select somewhat practical traffic model for the Internet. Recent studies of high-resolution traffic measurements have revealed that packet traffic in the Internet appears to be statistically self-similar [13][14]. Self-similar traffic is characterized by burstiness across a wide range of time scales. Contrary to common beliefs that multiplexing traffic streams tend to produce smoothed-out or less bursty traffic, one gets a more bursty traffic by aggregating self-similar traffic streams.

In our simulation study, we implement a traffic generator of which interarrival time between packets follows a Pareto distribution. This produces a very bursty traffic for a wide range of time, or reveals an approximate self-similar property. A Pareto distribution is characterized by two parameters: location parameter a (> 0) and shape parameter c. A stable Pareto distribution has $0 < c < 2$ and its variance is infinity. The probability density function (pdf) is

$$f(x) = \frac{ca^c}{x^{c+1}}$$

Its mean value is equal to $ca/(c-1)$.

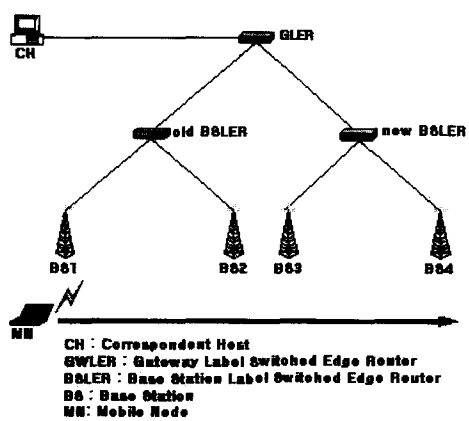
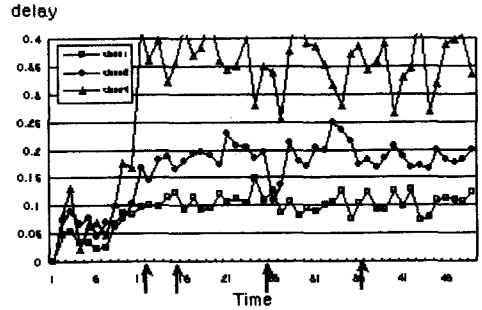


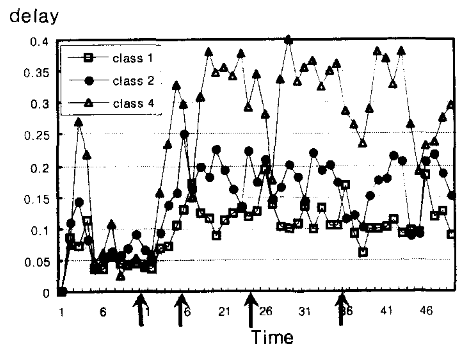
Fig. 4 Network architecture for simulation

We attach Pareto traffic agents to the MN (Mobile Node). The shape parameter of the Pareto traffic is assumed to be 1.7. In order to support QoS in access networks, we adopt a proportional differentiated service that provides predictable and controllable service differentiation. We have chosen a WTP(Waiting Time Priority) scheduler for delay differentiation and LHB(Loss History Buffer) buffer management algorithm for loss differentiation [15]. In the WTP algorithm, each packet in queues is assigned a delay priority which is proportional to waiting time of the packet normalized by delay differentiation parameters. The scheduler selects a packet having the highest delay priority. This algorithm maintains the proportional difference of the delay for each traffic class according to the ratio of delay differentiation parameters. According to LHB, if the buffer is full when a packet arrives, the scheduler looks for the traffic class which has the least relative loss probability normalized by loss differentiation parameters. After that, a packet of the corresponding class is selected in buffers and discarded. Thus, we can maintain the relative difference of the loss probability of each class according to loss differentiation parameters.

Nine traffic sources, one for each class, are attached to MN. There are three delay differentiation classes and three loss differentiation classes in each delay class. Their destinations are attached to CH(Correspondent Host). We simulate an overload traffic condition. We set the relative loss and delay differentiation parameters to 1:2:4. Fig. 5(a) shows delay differentiation for three traffic classes in our proposed protocol that performs context transfer during handoff. One can see that delay is very similar in both cases, but seamless QoS support is only obtained by transferring QoS parameters before layer 2 handoff is completed. In Fig. 5(b), we represent delay differentiation for the same three traffic classes using Cellular IP [6] protocol that cannot get QoS support until QoS parameter negotiation is finished after handoff. One can see the QoS disruption in Fig. 5(b). Arrows in the figures represent handoff instants.



(a) MPLS-based micro-mobility protocol

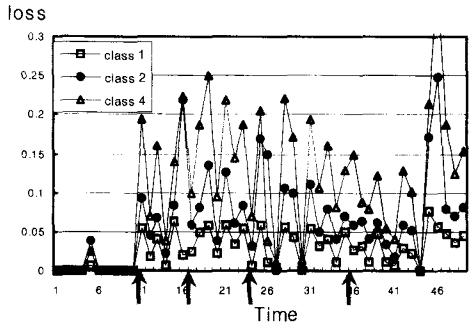


(b) Cellular IP protocol

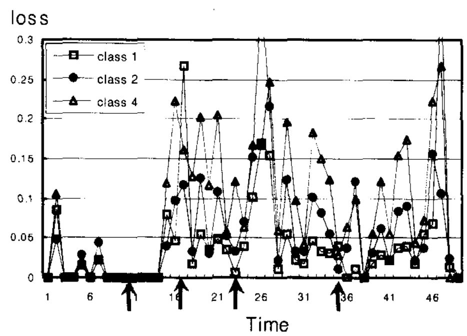
Fig. 5 Delay differentiation performance during IP handoff (Delay differentiation parameter = 1:2:4)

In Fig. 6, we show loss probability differ-entiation for three traffic classes in our proposed and cellular IP protocol. The figures indicate that context during handoff also preserves the loss differentiation property.

Second, we show the effect of seamless handoff provided by LSP splicing in our scheme compared to Cellular IP protocol. Fig. 7. shows throughputs of a TCP connection in Cellular IP and in our suggested protocol. With Cellular IP protocol, TCP plunges into congestion control mode during IP handoff because several packets are lost during handoff until route cache of new path in GLER and new BSLER is settled. Because of this, TCP throughput suddenly decreases to zero during handoff, which occurs at the time 9, 31, 49 and 89 seconds as shown in Fig. 7. However, our protocol maintains TCP throughput by forwarding packets



(a) MPLS-based micro-mobility protocol



(b) Cellular IP protocol

Fig. 6 Loss differentiation performance during IP handoff (Loss differentiation parameter = 1:2:4)

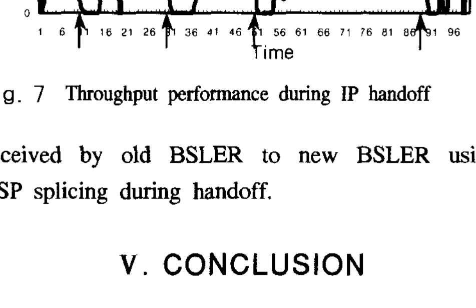


Fig. 7 Throughput performance during IP handoff

received by old BSLER to new BSLER using LSP splicing during handoff.

V. CONCLUSION

In this paper, we propose a new micro-mobility management protocol adopting MPLS protocol in cellular access networks for wireless Internet. MPLS technique in access networks simplifies the location management of mobile nodes, because intermediate nodes in the access network don't need to maintain routing and paging cache table for mobile nodes due to LSP tunneling between GLER and BSLER. Also, due to the same reason, intermediate nodes need not perform authentication procedure for. registration, routing and paging update procedure. As shown in the above simulation, context transfer procedure during handoff maintains QoS level during and after handoff. Therefore, we can conclude that this is a promising micro-mobility management protocol for the future wireless Internet.

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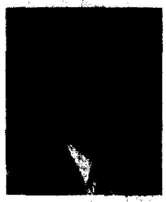

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