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Guaranteed QoS Routing Scheme in MPLS -Wireless Access Networks

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Abstract. With the increasing deployment of mobile network infrastructure and the emergency of real time applications, using Multi Protocol Label Switching (MPLS) capabilities is becoming more and more necessary to satisfy end user requirements in term of Quality of Services. In this paper, we propose a new algorithm that routes efficiently Label Switched Paths (LSP) in mobile MPLS network. The particularity of our work consists of integration both macro and micro mobility management in order to improve the overall performance of the system. We propose first a fast handoff process, which reduces service disruption. We present then new architecture which looks at avoiding triangle routing problem that MPLS inherits from Mobile IP. Finally, we integrate route optimization process which computes efficiently the shortest path by compromising between several Traffic Engineering (TE) objectives, like bandwidth guarantees, load balancing, and minimizing path hop count.

Keywords: MPLS, Mobile networks, handoff, QoS, traffic engineering, routing LSPs.

1. Introduction

As the world is becoming more dependent on wireless and mobile services, the question of the network's ability to handle such growing demand is getting more attention. The Internet Engineering Task Force (IETF) proposes Mobile Internet Protocol (IP) as the principal mechanism in IP-based wireless networks. However, Mobile IP presents several inconveniencies such as large signaling load for frequent registration updates and long handoff latency. Multi-Protocol Label Switching (MPLS) has been developed to overcome the limitation of conventional routing protocols.

MPLS allows the specification of explicit routes through the network, so-called Label Switched Paths (LSPs). Other advantage of MPLS includes service differentiation and traffic engineering. The distinguished advantages of MPLS have inhaled some researches in the literature on the use of this technology in the wireless infrastructure.

[1-3] proposed a mobile MPLS architecture which can be efficient but the proposed scheme is not suitable for intra-domain mobility, called micro-mobility.

To overcome this limitation, a mobile MPLS framework has been proposed by [4] called hierarchical MPLS. This scheme is too complicated and difficult to be applied in real time mobile transmissions.

We propose in this paper a new mobile MPLS architecture that supports both inter and intra Label Edge Router (LER) handoff. Our proposal also takes the advantages to improve MPLS routing paths. In fact, we have first proposed a new scheme able to avoid triangle routing, a problem that MPLS inherits from IP.

Then we have ameliorate our solution by introducing a new computing path algorithm that compromise between several traffic engineering objectives.

The rest of the paper is organized as follows. Section 2 introduces the proposed registration process in Mobile MPLS network. In section 3, we illustrate the two variants of Handoff support: inter LER, and intra LER

Handoff. Section 4 describes the proposed framework that essentially looks at route optimization process.

In this context, our proposal focuses first on how to eliminate triangular routing and then how to provide a sophisticated constrained routing algorithm for Real Time Internet applications. The final section contains our concluding remarks.

2. Registration Process in Mobile PLS Network

Mobile MPLS is based on the same standards that are already defined and applied in mobile IP. But using MPLS instead of IP will improve the Quality of Services (QoS) services which are required nowadays. Figure 1 presents a typical topology[5] for Mobile MPLS network. We use in next paragraph this topology to explain registration process.

When powering, the station Main Host (MH) searches the beacon signals from the surrounding Base Stations (BSs), and selects the one with the strongest signal as its serving BS. The mobile MH knows whether the selected BS is in its home domain or not on the basis on BS's address.

The MH sends a mobile IP registration to the nearest Label Edge Router/Foreign Agent (LER/FA). The latter notes the MH home address in its routing table and then transmits the registration message to the Label Edge Router Gateway (LERG) of its domain. The LER/FA label table (called Label Forwarding Information Base or LFIB) is illustrated in Table 1.

When the LERG gets the registration message, knows the IP address of current LER/FA, it sends the registration message to the Home Agent (HA) of the MH. The LERG uses its IP address to perform the global registration for inter domain mobility. Then, the LERG establishes an LSP between it and the current LER/FA with address LER/FA as Forwarding Equivalent Class (FEC). The LERG Label table is illustrated in Table 2.

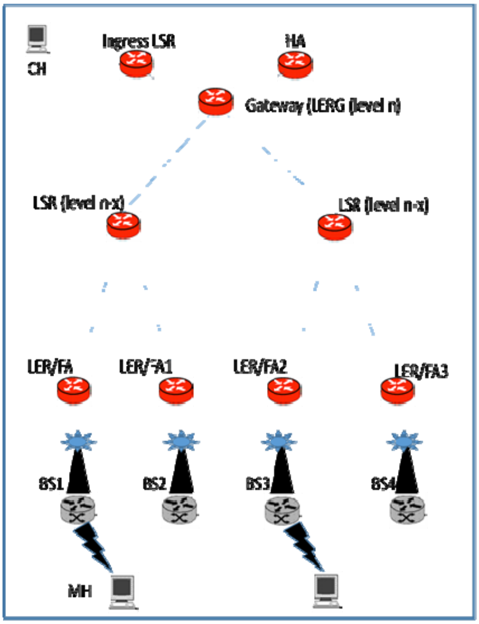

Fig. 1. Network topology.

The Home Agent makes an entry for the LERG in its Label Forwarding Information Base (LFIB), the entry for the LERG is shown in Table III which illustrates the HA label forwarding table. The latter has also an entry for the CH's label switch router (called Ingress LSR in Figure 1). Here Label Distribution Protocol (LDP) can be used to establish the downlink and uplink LSP.

Finally the LERG transmits the Registration reply message, sent from the Ingress LSR from the HA to the MH along the established LSP. The resulting Label table of the LERG after registration is shown in Table IV.

3. Handover Support in Mobile MPLS Network

In the literature, the handover mechanism is classified in Mobile MPLS access network into two types. intra-LER handover and inter-LER handover[2].

When the mobile station is moving, it passes between two BSs. If these BSs are under the same LER/FA, the handover is called inter-LER handover. However, it is called intra-LER in case of the new BS and the old BS are managed by different LER/FAs[6]. We present in the next paragraph how to manage handover requests.

3.1 Intra LER Handover

During a call, the mobile station MH moves between different cellular systems which are controlled by different base stations. The MH transmits a message to the current LER/FA informing through it its movement. The LER/FA, upon receiving the movement signaling message, begins buffering in-flight packets.On the other hand, the mobile station, searching for a new BS, finds one and registers at layer 2 with that BS.

Now, the mobile should verify if it is still under the same network. For this reason, when receiving an advertisement message from the LER/FA it takes advantage of the LER/FA IP address. If it is still under the same subnet, the LER/FA stops buffering and transmit in-flight packets designated to MH toward the new BS. It is important to mention here that no change occurs to LERG Label table after an intra-LER handover since no message has been sent to the LERG. Figure 2 illustrates intra LER handoff in Mobile MPLS network.

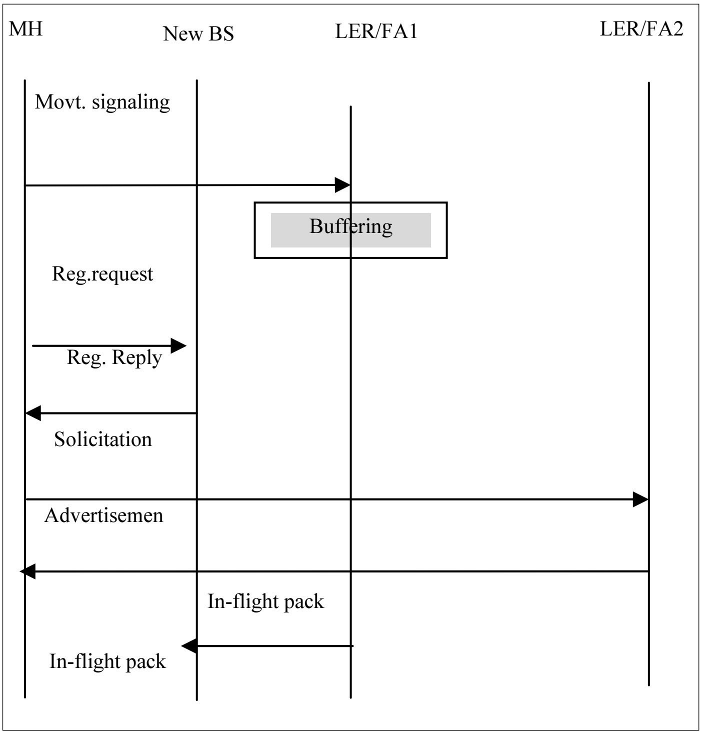

Fig. 2. Intra LER handoff.

3.2 Inter LER Handoff

When the MH moves to a new IP subnet, it first registers to the new Label edge router (called new LER/FA) by sending a registration request message. Then, it conducts the same processes seen in section 2 for registration.

The mobile station should now recuperate all packets that are destined to it and already reach the old LER/FA. For this, it sends to the old LER/FA a message through the new LER/FA informing it by the handover.

When receiving this message, the old LER/FA stops buffering and transmits in-flight packet to the mobile station. Figure 3 illustrates Inter LER handoff in Mobile MPLS.

We illustrate the LERG Label Table in Table 5.

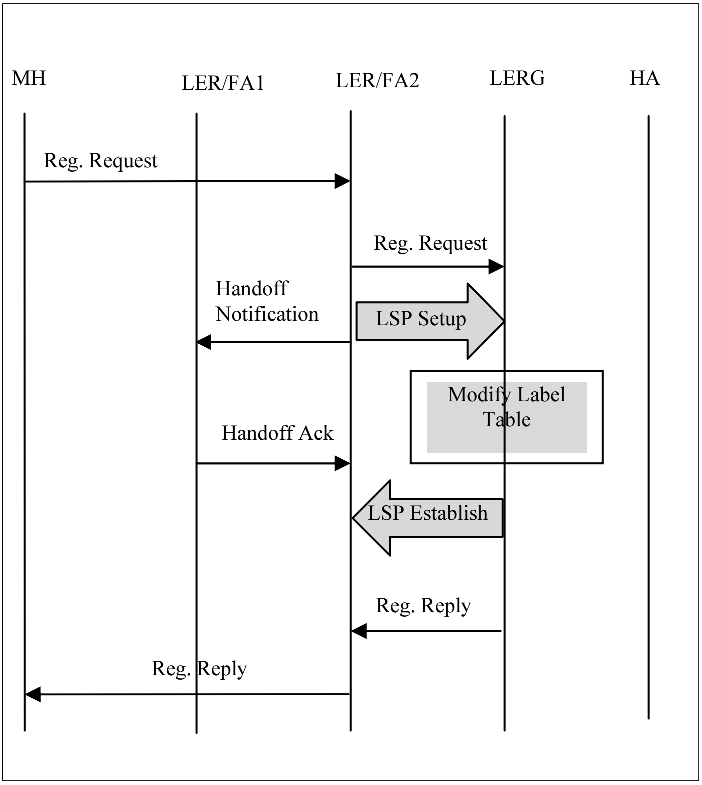

Fig. 3. Inter LER handoff in Mobile MPLS.

Table 1. Label table (LFIB) of LER/FA.

In Port	IN LABEL	Fec	Out Port	Out Label
0	_	@MH	1	1

Table 2. Label table (LFIB) of LERG.

In Port	IN LABEL	Fec	Out Port	Out Label
1	1	@LER/FA	3	3

Table 3. Label table (LFIB) of HA.

In Port	IN LABEL	Fec	Out Port	Out Label
1	3	@LERG	3	9
2	10	@Ingress LSR	2	11

Table 4. Label table (LFIB) of LERG.

In Port	IN LABEL	Fec	Out Port	Out Label
1	1	@LER/FA	3	8
0	11	@MH	3	8

Table 5. Label table (LFIB) of LERG after inter LER handoff.

In Port	IN	Fec	Out Port	Out Label
1	1	@LER/FA	3	8
2	14	@MH	1	15
2	14	@LER/FA2	1	15

4. Route Optimization Process

We are interested in this paper to improve the efficiency of the mobile MPLS network by introducing new mechanism in the routing process. We first discuss how triangle routing is established in mobile MPLS scheme and provide solution to avoid such a problem. Then we propose a new scheme to calculate efficiency the most optimal path to reach destination node.

Let's begin in the next paragraph by explaining our proposed solution for eliminating triangle routing.

4.1 How to Avoid Triangle Routing?

When a mobile station wants to communicate with another one, called here correspondent host (CH), it should obligatory register to its home agent. The latter will be responsible for forwarding data packets to CH following a specific Label Switched Path (LSP). In this way, a triangle route is formed between the source node, the home agent and the destination node. This can affect badly the resource management process and reduce the performance of the entire network. In fact, the data had to follow long path with a number of intermediary nodes to the HA, resulting into a significant delay.

Our proposal consists on the following scheme. When MH moves to a foreign network, it registers to the HA with its new temporary address. The HA keeps this address in its cache. Thereafter, HA will forward this update information to all edge routers in the network. The ingress routers store the binding update between the permanent IP address of the MH and its temporary address in its binding cache and starts a timer. When this timer runs out, that the ingress LSR removes the binding from its cache and send a request to the HA for a new update if cache is available. Thus, every time whenever the HA receives any update from the MH, it will forward this binding update to ingress LSRs so that the movement of MH is transparent to these agents and can provide optimized paths to intended destination.

Our second proposal is to involve QoS constraint based routing with Mobile MPLS architecture. Our goal consists basically of finding a feasible path from source (Ingress LSR) to destination (LER/FA) if one exists, and to select the one that achieves efficient resource utilization if more than one path is available. This will be the topic of the next paragraph.

4.2 Path Computation

Shortest Path First (SPF) routing protocol is the most commonly used protocol in IP/MPLS networks[7]. The core algorithm is based only on the number of hops to compute the shortest path between the ingress and egress router. In despite of its simplicity, SPF protocol presents several inconveniencies. In fact, it generally leads to an inefficient usage of the network infrastructure. It can create bottleneck in some links while other link are severely under-utilized.

Some researchers [4, 8-10] are interested in how to distribute the load in the network to avoid network congestion. However, their proposals selects paths with high number of hops. The trade-off between two or more than two traffic engineering objectives looks to be so difficult to realize. From this fact arises our motivation to compromise between network load balancing and path hop count.

Our problem is a multi-objective optimization problem. Several methods in the literature exist to solve such a problem, like genetic algorithm, but most of them are very complicated and difficult to apply in real time transmission networks. For this reason, we propose to use weighted criteria method. Here, we will form an objective function which will correspond to the traffic engineering metric of the link and we then calculate the shortest path on the basis of this function.

Before defining the objective function form, we need to define some notations. The network is modeled as a graph *G* which is composed of a set of nodes and links between the different nodes. We note *e* a link. Each link in the graph is characterized by a set of parameters: the source node, destination node, bandwidth capacity *C(e)* and residual bandwidth *R(e)*. We formulate in the following expression the proposed link metric *Tem(e)*.

$$Tem(e) = \alpha \frac{R(e)}{C(e)} + 1 \text{ where } \alpha \in [0\ 1] \quad (1)$$

The first term ($Tem(e) = \alpha \frac{R(e)}{C(e)}$)in the expression above will be representative of load balancing objective. However, the second one is for reducing path hop count. The parameter α varies from 0 to 1 depends on the routing objectives of the network. For example, to give the same priority to both load balancing and path hop count, we suggest α to be equal to 1.

5. Pseudo Code of the Route Computation Algorithm

We present in this section the pseudo code of the route computation algorithm. The algorithm will return the path taken by an LSP from the source to the destination minimizing the path objective function. So, we use the well-known Dijkstra scheme and adapt its formulation to our need. Our route computation algorithm is detailed in Figure 4.

Using our proposal, traffic in MIP is conducted via optimal paths that are labeled using MPLS labeling mechanism. This will optimize considerably network resource utilization and guarantee more and nore quality of services.

1 **Route-computation-algorithm procedure(G, request(source, destination, bandwidh required))**
{
2 Calculate the objective function related to each link in the network.
3 Eliminate from the network all links that haven't enough residual bandwidth. Consider in the rest of the algorithm the resulting reduced topology with remaining links and nodes.
4 Use Dijkstra algorithm to compute the shortest path in the network using *Tem(l)* function as a link metric.
5 Route the request from source until destination along that path
}

Fig. 4. Pseudo Code of the Route Computation algorithm.

6. Conclusion

This paper addresses a framework of mobility management and traffic engineering for Mobile MPLS networks, called Global Mobile MPLS (GM-MPLS). The proposed scheme has the advantage to involve two ranges of network mobility, that are micro mobility and macro mobility, to provide excellent solution to the problem of mobility support in wireless environment.

We have presented registration procedure and discussed handoff techniques: inter LER and intra LER handoff. These techniques reduce considerably the number of lost packets due to movement of MH in mobile MPLS network. We have also proposed a new routing scheme to support traffic engineering. The algorithm satisfies meeting QoS requirement of bandwidth, efficient usage of network infrastructure, by providing network load balancing and reducing path length. Thus we can conclude that our solution improves the overall performance of the mobile system.

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مخطط لضمان جودة خدمة توجيه الرسائل في شبكات MPLS اللاسلكية

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المستخلص. تزامنًا مع التطور الكبير الذي تشهده البنية التحتية لشبكة الاتصالات اللاسلكية وانتشار التطبيقات المقيدة بالزمن، استخدام البروتوكول (MPLS) أصبح أكثر فأكثر ضرورة نظرًا لما يجلبه من مزايا متعدد لتلبية متطلبات المستخدم النهائي من حيث جودة الخدمات. في هذا البحث، نقترح خوارزمية جديدة لإنشاء المسارات (LSP) داخل شبكة MPLS النقالة. خصوصية عملنا تكمن في إدارة التنقل الكلي والجزئي على حد سواء من أجل تحسين الأداء العام للنظام. نقترح أولا تقنية تمكن المستخدم من التحول بسلاسة وبسرعة، مما يقلل من انقطاع الخدمة. نقدم في مرحلة ثانية طريقة جديدة لتجنب مشكلة مثلث التوجيه التي يرثها MPLS من بروتوكول الإنترنت IP. وأخيرًا يعرض البحث اقتراح لتحسين المسارات، وذلك بالأخذ بعين الاعتبار جوانب متعددة مثل ضمانات عرض النطاق الترددي، موازنة الحمل بين المسارات وتقليل عدد القفزات بالمسار.