A MOBILE CONNECTION FOR 4G NETWORKS USING MPLS

Johan Theunis(1), **Jan Potemans**(2), **Pieter Leys**(3), **Bart Van den Broeck**(4), **Emmanuel Van Lil**(5), **Antoine Van De Capelle**(6)

(1)***K.U.Leuven, Div. ESAT/TELEMIC, Kasteelpark Arenberg 10,***
B-3001 Leuven - Heverlee, Belgium, Tel:+32/16 32 10 63, Fax:+32/16 32 19 86,
E-mail: johan.theunis@esat.kuleuven.ac.be
(2)***As (1) above, but E-mail: jan.potemans@esat.kuleuven.ac.be***[1]
(3)***As (1) above, but E-mail: pieter.leys@esat.kuleuven.ac.be***
(4)***As (1) above, but E-mail: bart.vandenbroeck@esat.kuleuven.ac.be***
(5)***As (1) above, but E-mail: emmanuel.vanlil@esat.kuleuven.ac.be***
(6)***As (1) above, but E-mail: antoine.vandecapelle@esat.kuleuven.ac.be***

ABSTRACT

Today, two major trends in networking can be observed. First, now that mobile telephony is a fact, also Internet connectivity is moving towards mobile access. Second, real time applications, requiring QoS, are offered to Internet users.

This paper will propose a mechanism for the Internet to accommodate both trends. MPLS will be used to set up mobile connections between communicating nodes. With DiffServ on MPLS, QoS can easily be guaranteed. Using hierarchy, the loss of quality upon hand-off can be reduced, data and signalling traffic can be cut and mobility can be made transparent to the end users.

INTRODUCTION

It is expected that IPv6 [1] will be dominating as layer 3 technology, in the backbone networks as well as in the (wireless) access networks. Conceptually, one can see whole the Internet in the future as an All-IP network. On the other hand MultiProtocol Label Switching (MPLS) [2] will definitely be implemented all over the backbone. K.U.Leuven investigates the migration of MPLS to the access networks as well. In this way, the All-IP Internet will become All-MPLS.

This All-MPLS network has several advantages over the existing architecture. First of all, MPLS can be used to set up some kind of connections by distributing labels across the network. By means of Differentiated Services (DiffServ) [4] and Traffic Engineering (TE), Quality of Service (QoS) can be added to the network and to these MPLS connections. So by introducing MPLS into the access networks, one can guarantee End-to-End QoS to customers attached to the access networks, no matter which technologies are used on layer 1 and layer 2[2]1 This makes the solution independent of whatever the future may bring at these lower layers.

Moreover, in case the access network connects wireless (mobile) customers, such MPLS connections offer additional advantages. Mobility can be addressed better if connections are available: once a connection is established roaming can be supported by rerouting the mobile connection upon hand-off. Using MPLS to set up the mobile connection and to provide for QoS tackles two problems at once: mobility and QoS. These problems will be the key challenges of the future: customers will connect to the Internet through mobile handheld devices and will make use of multimedia applications. These applications need QoS to function properly.

This paper introduces the mobile MPLS connection. Moreover, hierarchy and label stacking are used to improve efficiency and scalability. A mobile MPLS connection without hierarchy can be found in [5]. First a reference future network configuration is described. Afterwards the mobile connection is discussed: the set-up as well as the hand-off of the mobile connection. Then a discussion on QoS and the mobile connection is given. Finally, future work on this research topic is pointed out.

FUTURE NETWORK CONFIGURATION

First of all, a configuration of a future reference network on which the protocol, described in this paper, will be active, is given in Fig. 1. The figure reflects the authors' view on access networks of the fourth generation. The network is hierarchically structured. On the highest level of hierarchy, an IPv6-MPLS backbone resides. Beneath, the access

[1]Jan Potemans is a Research Assistant of the Fund of Scientifi c Research Flanders (FWO Vlaanderen)

[2]If these layers allow QoS: e.g. delay cannot be below certain bounds on a satellite link.

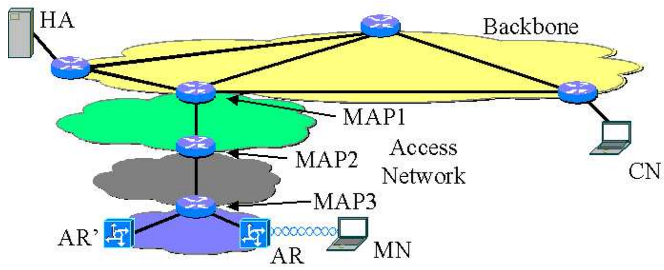

Figure 1: The reference network

network is divided into different levels. Each level is an autonomous system, where Label Switched PAths (LSPs) between ingress router and egress routers exist[3].

Because this topology is similar to the one in the Hierarchical Mobile IP concept (HMIP) [3], the same terminology is used. Each ingress router of an autonomous system is a Mobility Anchor Point (MAP). The lowest MAPs, connecting the Mobile Nodes (MNs) to the access network, are called Access Routers (ARs). The node the MN is communicating with is called the Corresponding Node (CN). At the home location of the MN, a Home Agent (HA) is present.

THE MOBILE CONNECTION

In this section, the mobile connection itself will be commented. Three topics will be discussed: first the registration of the MN, afterwards the set-up of the connection and finally the hand-off of the connection.

Registering a Mobile Node

As in Hierarchical Mobile IP [3], MAPs send *MAP Discovery messages* towards underlying MAPs and ARs. These messages are propagated down the hierarchy along with the necessary options, until they reach the MNs. Using these messages and their options, the MN starts registering itself to several MAPs it received a message from. The MN has to register itself to at least one *stable* MAP[4]. Each of the MAPs a MN registers to, sets up an LSP to and from the MN[5]. These LSPs will serve as the last part of the mobile connection. Apart from registering at MAPs, the MN also registers at least one stable MAP at its HA.

As the MN moves and changes its point of attachment to the access network, it needs to register itself again with some MAPs. However, normally the MN stays registered at the stable MAPs; it just has to update its current location.

Setting up a Mobile Connection

Actually, the mobile connection is a hierarchical MPLS LSP between CN and MN. The messages sent and their options will not be discussed into detail, this is beyond the scope and page limit of this paper. In a first part, the CN will initiate the connection. In a second part, the MN is the initiator.

From CN to MN

The set of messages necessary to set-up the connection in case the topology of the network is as in Fig. 1, are given in Fig. 2. The difference between part (a) and part (b) is explained below.

The CN has no other information about the MN than its home location IP address (i.e. at HA). The CN sends a connection request message (`cr`) to the HA. At the HA it is registered that the MN is connected to a stable MAP, in this case MAP 1. The HA forwards the `cr` to MAP 1. At MAP 1, the MN is registered. In case a direct LSP from MAP 1 to MN is set up at the registration of the MN, MAP 1 forwards the message directly to the MN (this is part (a) of Fig. 2).

[3]For reasons of clarity, only one egress router per autonomous system is drawn in Fig. 1.

[4]A stable MAP: because of the mobility of the MN, the MN will change its point of attachment to the Internet frequently. However, MAPs can be distinguished at a higher hierarchical level that will remain legitimate MAPs for the MN, even if the MN moves over a large distance. In other words: the MN will remain connected to a stable MAP for a long time. In order to determine a stable MAP, statistics can be stored at the AR.

[5]Questions may arise about the scalability of this approach: will the label space be big enough at higher levels in the hierarchy? However, if a MAP runs short on labels, it won't send MAP Discovery messages anymore (at least none that will arrive at the MNs).

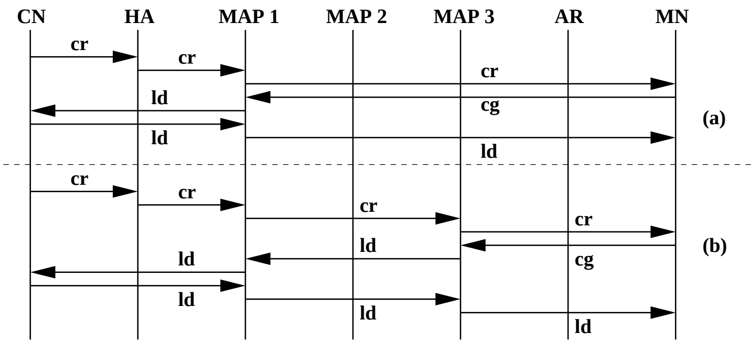

Figure 2: Setting up the Mobile Connection from CN to MN

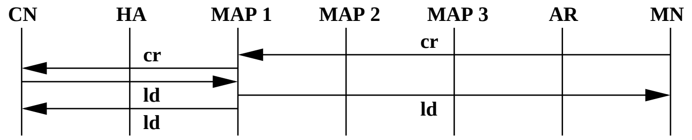

Figure 3: Setting up the Mobile Connection from MN to CN

The MN accepts the connection and sends a connection granted message (`cg`) to MAP 1. MAP 1 starts distributing labels (`ld`) towards the CN. An LSP from CN to MAP 1 is set up. Additionally, MAP 1 distributes to CN the proper incoming label for the LSP from MAP 1 to MN. As a result of the `ld` arriving at the CN, CN stores a label stack (*L1, L2, ..., Ln, L_MN*). This label stack is pushed on packets destined for MN. In the MPLS network, all but the bottom label (*L_MN*) are used to reach MAP 1 from CN. At MAP 1, all remaining labels except *L_MN* are popped. *L_MN* informs MAP 1 that the arriving packets are destined for MN, so MAP 1 puts them in the direct LSP to MN.

Now we have a one-way connection from CN to MN, going through MAP 1. CN now starts distributing labels to MAP 1 (`ld`). MAP 1 forwards these labels to MN. As a result, MN now also has a label stack (*L_MAP1, L1', ..., Ln'*). This label stack is pushed on the packets of MN destined for CN. The top label brings the packets to MAP 1, the others are used to switch the packets across the MPLS network from MAP 1 to CN. The connection is now active in both directions.

In case there isn't a direct LSP from MAP 1 to MN (part (b) of Fig. 2), the protocol looks slightly different. If, for example, the MN is registered at MAP 1 along with the IP address of MAP 3, MAP 1 simply forwards the `cr` to MAP 3. MAP 3 now has the same functionality as MAP 1 in case (a). As a result from the `ld` messages in case (b), CN pushes a label stack (*L1, L2, ..., Ln, L_MAP3, L_MN*) on packets destined for MN. Labels *L1, L2, ..., Ln* are used to guide the packets across the MPLS network to MAP 1. At MAP 1, the packets are forwarded to MAP 3 according to *L_MAP3*, where they are switched to MN because of *L_MN*. Actually, now the mobile connection is hierarchically split up into one extra part. This can be useful if the access network itself is rather large. Of course, even more hierarchical levels can be introduced in the mobile connection.

From MN to CN

The message flow is similar to the CN-to-MN case and is given in Fig. 3. Because of the analogy and the page limitation of this paper, the flow is not explained.

Handing off a Mobile Connection

In this section, an overview of the messages flowing upon hand-off is given. The process is illustrated in Fig. 4. When the MN changes its point of attachment (e.g. from AR to AR' in Fig. 1), is has to update the information stored at the MAPs which it is registered to. Therefore, MN will send a registration update message (`ru`) to its MAPs, in this case MAP 1. MAP 1 will initiate the set-up of new LSPs from and to MN (`ld`). As soon as those LSPs are active, they will be plugged into the mobile connection, replacing the old local part of the connection. The part from MAP 1 to CN can be maintained.

Several temporal solutions exist that cope with the loss of connection between the beginning of the hand-off and the

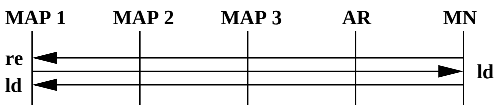

Figure 4: Handing off the Mobile Connection

activation of the new LSPs, such as tunneling from old AR to new AR, multicasting, sending synchronisation packets, etc.

It is important to notice that neither the CN, nor the HA needs to be informed about the movements of the MN. This means that local changes have only local impact and cause only local traffic. This reduces latency, packet loss and jitter upon hand-off.

QOS AND THE MOBILE CONNECTION

Because of the hierarchy in the mobile connection, the part between MAP and CN can be maintained. Only for the local part QoS needs to be guaranteed again. However, this is very straightforward. Indeed, one of the reasons to use MPLS for the mobile connection is the easy integration of DiffServ in MPLS. The Experimental (EXP) field in the MPLS shim header can be used to store the DiffServ CodePoint (DSCP), giving some packets a higher priority and thus enabling QoS. Another possible solution is to assign a separate MPLS label to each traffic class[6].

The interaction of MPLS and DiffServ leads to an End-to-End QoS solution for the mobile connection, at least if MPLS is implemented End-to-End (from CN to MN, which is assumed in this paper). In case the MPLS network does not reach the end users, the egress Label Switching Routers (LSRs) must have additional functionalities and QoS needs to be guaranteed at Layer 2 between these LSRs and the end users.

FUTURE WORK

This research is far from complete. Apart from a more elaborate description of the reference network and the message flows of the protocol, extensive analysis, simulation and testbed implementations[7] are required to tune the protocol.

CONCLUSION

In this paper a mobile MPLS connection, providing End-to-End QoS by means of DiffServ, was introduced. This connection can be used to replace or upgrade existing mobility management protocols lacking proper QoS support (Mobile IP [6], Hierarchical Mobile IP, Cellular IP) in IP networks.

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[6] In other words: create a different LSP for each traffi c class

[7] For simulations, K.U.Leuven uses OPNET. Testbed implementations are done on the Telemic Networking Lab, donated by Cisco.