Integration of Hierarchical Mobile IP into an MPLS-based UTRAN*

O. Horvath, A. Janz, O. Drobnik

Architektur und Betrieb Verteilter Systeme,
Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany
email: {horvath,janz,drobnik}@tm.informatik.uni-frankfurt.de

Abstract: The UMTS specification (Release 5), a third-generation mobile system, proposes an all-IP network architecture. In the near future, UMTS will offer a variety of services to users. Some of these services, e.g. real-time services, require a certain guaranteed quality of service. Multi Protocol Label Switching (MPLS) is a technology providing means to control data flows in IP networks. MPLS has been developed with respect to wired networks. In this paper, we propose the integration of MPLS and Hierarchical Mobile IP as a mobility solution for UMTS Access Networks together with an approach to support efficient handover of mobile nodes.

1 Introduction

The shift towards an IP-based UMTS infrastructure introduced several enhancements to IP technologies. There is a need to meet the demands of different types of service, e.g. real time services. The already huge number of mobile users is expected to increase steadily. Therefore, scalability is an important issue.

The UMTS network architecture [ET01] consists of three domains: Core Network Domain (CN), UMTS Access Network Domain (UTRAN) and User Equipment Domain (UED). The UED comprises the Mobile Nodes (MN). The UTRAN provides functions that are needed for MN to access the CN. The CN supports tasks such as management of user location information and telecommunication services. An IP-based UTRAN enhanced by Multi Protocol Label Switching (MPLS) [Ro01] supports UMTS requirements regarding the different classes of Quality of Service (QoS). MPLS is a technology combining the simplicity of IP routing with high speed switching. MPLS forwarding is significantly faster than conventional IP forwarding. It provides small state maintenance and high scalability. Using the extended Reservation Protocol (RSVP-TE) over MPLS allows Traffic Engineering (TE) on the network [Aw01]. Technologies like Open Shortest Path First are useful for an MPLS-based domain to dynamically provide the needed routing information, hence ensuring a fail-safe network [Ro01]. The mobility of the MN can be seen at

*This work was done within the framework of the 'IPonAir' project which is partly funded by the German Ministry of Education and Research (BMBF). See also http://www.iponair.de

two different levels: inter-domain mobility (macro-mobility) and intra-domain mobility (micro-mobility). Mobile IP [Pe02] is the current standard for macro-mobility in IP-based networks. In [Re01] an integration of MPLS and Mobile is proposed, which enhances the routing performance over an IP network with Mobile IP.

Several competing protocols for micro-mobility exist. After evaluating the protocols Hand-off-Aware Wireless Access Internet Infrastructure (HAWAII), Cellular IP (CIP) and Hierarchical Mobile IP (HMIP) we chose HMIP. HMIP is an extension to the Mobile IPv4 protocol to support micro-mobility, where Foreign Agents (FA) are hierarchically organized in a tree-like structure. In contrast to other micro-mobility solutions, HMIP uses tunneling mechanisms which offer a promising approach to combine HMIP tunnels with MPLS tunnels to obtain a coherent solution. Dynamics - HUT Mobile IP (HUT MIP) is an implementation of HMIP [Fo99]. We extend HUT MIP with RSVP-TE tunnels as an additional tunneling mechanism.

The next section contains details about the integration of MPLS and HMIP. A basic handover algorithm is proposed in section 3.

2 Integration of MPLS and HMIP

In HMIP, the FAs act as routers for MNs. Moreover, only the FAs "know" about the MNs' locations. The network defined by the FAs can be seen as a logical network upon the physical network. Due to the UTRAN's hierarchical structure, the logical network is structured as a tree with FAs as vertices. This structure minimizes the amount of signaling as the Home Agent (HA) is not involved in local handovers in case of micro-mobility. The connections between FAs are accomplished by two directed LSPs.

2.1 Types of FAs

An MPLS-based UTRAN needs several types of FAs. The Highest Foreign Agent (HFA) is the root of the logical network tree and should reside on the gateway router between UTRAN and CN. It forwards the traffic between the MN and the HA.

The Lowest Foreign Agents (LFA) are placed on all network nodes connected to the Access Points (APs) (similar to the Radio Network Controller of UTRAN [ET01]). LFAs control the traffic from and to the APs. They are the only FAs sending agent advertisements to the MNs. The LFAs handle registration requests and forward data packets from the MNs through LSP tunnels to intermediate FAs or the HFA. LFAs reside on MPLS label edge routers [Ro01]. Data and signal traffic is forwarded to the MNs via IP.

The Intermediate Foreign Agents (IFA) are the nodes between the LFAs and the HFA. They ensure the local handover handling. The IFAs forward signaling traffic from their upper and lower FAs (IFAs, LFAs, HFA).

Each IFA and the HFA know the IP address and the appropriate port number of the lower and upper FA. During initialization or in case of a network failure leading to LSP loss, an FA has to create an upper and a lower LSP tunnel for each QoS class.

Figure 1 shows the signaling process for a registration request of HUT MIP. The Switching FA (SFA) is the cross-over point between the old and the new path.

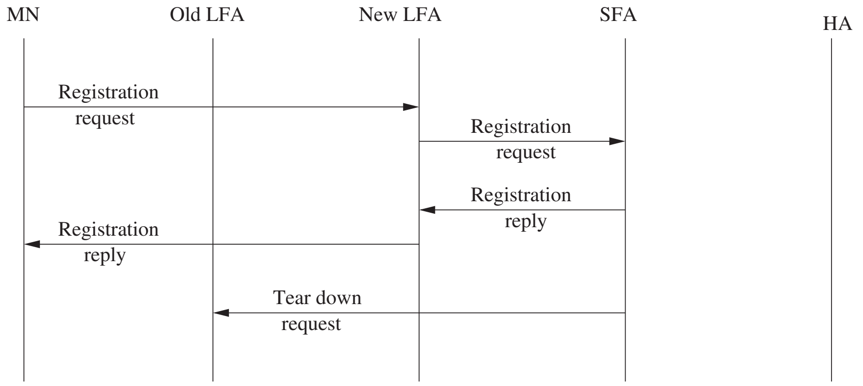

Figure 1: *Registration request of HUT MIP*

2.2 LSP tunnels

The HUT MIP IP-based tunneling mechanism works in the following way: at each hierarchical level data packets are fully encapsulated/decapsulated. Simply replacing IP-based tunnels with LSPs is inefficient because each node with an FA along the path from an MN to the HFA and vice versa will act as ingress and egress for the LSPs which are oriented upward and downward.

Label switching along the path (generally consisting of several LSPs) from the leafs to the root of the logical network tree offers a better solution. In [Ro01] it is proposed to tunnel traffic through an MPLS domain by means of label stacking. However, we do not propose this since the use of label stacking for mobility would lead to a single label at the HFA and a stack of many labels (as high as the number of hierarchy levels) at all hops to the LFA. This means that the signaling overhead increases along with the number of hops to the MN. Additionally, the bandwidth of the links decreases towards the MN. Both effects accumulate to a typical slow-link problem on the last hop (LFA), leading to QoS degradation.

To take advantage of LSP tunnels directed towards the root of the HMIP tree, reverse tunneling of Mobile IP [Mo98] is used. Data from an MN to the HFA is forwarded along the following path of FAs: LFA, IFA, ..., IFA , HFA (figure 2). An LFA node acts as the ingress for the upstream LSPs. The MN designates the LFA as its default router. The LFA detects packets sent by the MN and assures they are dispatched to the appropriate upstream LSP. The FAs are responsible for setting the IPv4 TOS field to the appropriate value concerning the QoS class. Dispatching the packets to the upstream LSPs is done by applying the mapping functions provided by the MPLS support of differentiated services [Le02].

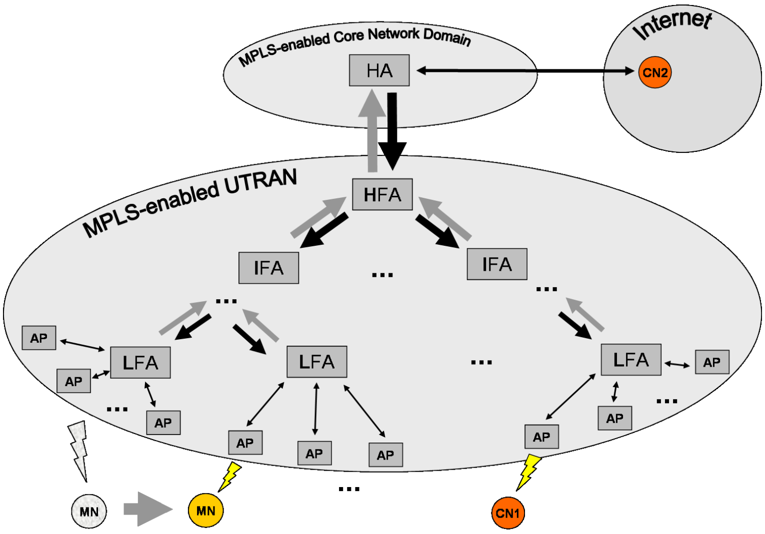

Figure 2: *MPLS-based UTRAN*

3 Basic handover algorithm within an MPLS-enabled HMIP

The following algorithm describes the necessary steps during the handover of an MN between two APs.

The MN moves from the old AP to the new one. At first, a connection to the new AP is established on the link layer in order to receive LFA advertisements. The MN replies with a registration request to an LFA advertisement.

If the new AP is connected to the same LFA as before, the LFA assigns a new care-of-address to the MN and updates its routing table. Now the MN is able to send/receive data packets to/from correspondent nodes (figure 2: CN1 and CN2) because the FEC-to-NHLFE (Forwarding Equivalency Class to Next-Hop Label Forward Entry) mapping remains the same [Ro01]. The handover is complete.

In case the new AP is connected to a different LFA, the new LFA does not have an entry for this MN. The LFA therefore adds the MN's IP address to its routing table and forwards the registration request to the next higher FA. The registration request is forwarded along the hierarchy until it reaches an FA which already knows the MN (worst-case: HFA).

The FA (IFA or HFA) with a routing data base entry for the MN is the SFA, the cross-over point between the old and the new path (figure 2: IFA). The FA sends a registration reply downwards to the MN. In parallel, the downstream LSPs along the path to the new LFA are reevaluated with respect to bandwidth requirements and, if necessary, (re)reservations with new values are made by RSVP-TE. The LFA sends the registration reply to the MN. LFA and MN update their routing tables. The handover is complete.

4 Conclusion

An IP-based UTRAN architecture has been developed with micro-mobility support. The approach is based on the integration of MPLS, HMIP, and RSVP-TE. A basic handover algorithm has been introduced which keeps the signaling overhead at a low level. At present we implement a prototype of this architecture. The next steps are to evaluate its performance and to focus on the development of improved handover procedures.

References

[Aw01] Awduche, Daniel O. et al.: RSVP-TE: Extensions of RSVP for LSP Tunnels. *Network Working Group*. Dec. 2001. RFC 3209.

[ET01] ETSI: *Universal Mobile Telecommunications System (UMTS): UTRAN Overall Description, Techical Specification 125.401*. 2001. http://www.etsi.org.

[Fo99] Forsberg, Dan et al.: Distributing Mobility Agents Hierarchically under Frequent Location Updates. *Mobile Multimedia Communications*. Jan. 1999.

[Le02] Le Faucheur, F. et al.: Multi-Protocol Label Switching (MPLS) Support of Differentiated Services. *Network Working Group*. May 2002. RFC 3270.

[Mo98] Montenegro, G.: Reverse Tunneling for Mobile IP. *Network Working Group*. May 1998.

[Pe02] Perkins, C.: IP Mobility Support for IPv4. *Network Working Group*. Aug. 2002. RFC 3344.

[Re01] Ren, Z. et al.: Integration of Mobile IP and Multi-Protocol Label Switching. *IEEE International Conference on Communications (ICC'2001)*. June 2001.

[Ro01] Rose, E. et al.: Multiprotocol Label Switching Architecture. *Network Working Group*. Jan. 2001.