A Seamless Vertical Handover Approach

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***Abstract*— Wireless network devices are equipped with multiple access technologies like UMTS and Wireless LAN. The handover between the technologies has been widely studied in literature. Several of these research papers build their handover mechanisms on top of existing protocols like Mobile IP. The protocols however, operate on the network layer and only react on link layer changes. Consequently, a seamless vertical handover between Wireless LAN and UMTS cannot be provided. In this paper, we introduce a vertical handover protocol based on a tight-coupled network architecture. With this architecture, it is possible to perform the handover on the link layer and thus, reducing the handover delays. The protocol is implemented in a simulation environment and the results reveal that a seamless vertical handover can be performed, with blackout times of only a few milliseconds.**

***Index Terms*— Vertical Handover, Wireless LAN, UMTS**

I. Introduction

Future mobile networks will most likely be based on a packet-switched architecture with a diversity of access technologies. With such an architecture, the 3G mobile networks can easily be extended by other IP based wireless access technologies like *Wireless Local Area Network* (Wireless LAN) or *Worldwide interoperability for Microwave Access* (WiMAX). The design and purpose of these various wireless networks are completely different. However, exactly their diversity of characteristics complement one another which makes the integration attractive. On the one hand, we already have the ongoing *Universal Mobile Telecommunications System* (UMTS) as a representative of 3G cellular networks which provides wide-area coverage with high mobility and a comparatively low bandwidth. On the other hand, several technologies like Wireless LAN provide a lower coverage area but offer a high bandwidth. Combining these technologies creates a ubiquitous wireless network with local hotspots to supply the user with high speed services.

Several approaches have been published [1], [2], [3] showing how to combine Wireless LAN and UMTS and how to perform a handover between these technologies. Almost every approach is based on Mobile IP and its extensions. However, simulations have shown [4] that the handover performance with Mobile IP [5] is really low even when performing a handover within one technology. The low performance results from the operation on the network layer. Mobile IP sends out messages periodically to look for connection changes. Only if three consecutive messages are lost, a handover will be performed. The consequence are handover delays of several seconds. To reduce the handover delays, we propose a handover protocol using a tight-coupled architecture, where the Wireless LAN Access Points are integrated into the UMTS network architecture.

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II. Handover from Wireless LAN to UMTS

In this section, we describe the handover protocol from Wireless LAN to UMTS only. However, the full paper accounts for both directions. Figure 1 shows the underlying tight-coupled network architecture. The Wireless LAN Access Point is an integral part of the UMTS network, directly connected to the *Serving GPRS Support Node* (SGSN) and thus represents an alternative radio access network to the existing cellular one. The *Mobile Equipment* (ME) itself is equipped with two interfaces, a Wireless LAN interface and a UMTS interface, which are connected to each other and the network layer by a handover module.

Whenever the ME moves out of the coverage area of a Wireless LAN cell, indicated by measurement reports to the SGSN, the vertical handover is initiated. The detailed process is shown in Figure 2. On the top of the figure, the involved entities are shown. The green arrows indicate transmissions using Wireless LAN and the blue ones are UMTS transmissions. To keep it simple, only the important steps are shown and minor aspects to the vertical handover, like intercommunication and tunnel management between the SGSN and the *Gateway GPRS Support Node* (GGSN), are suppressed in this figure although they are implemented in the simulation. The vertical handover process is split into three parts, the connection establishment, the handover procedure, and the connection release.

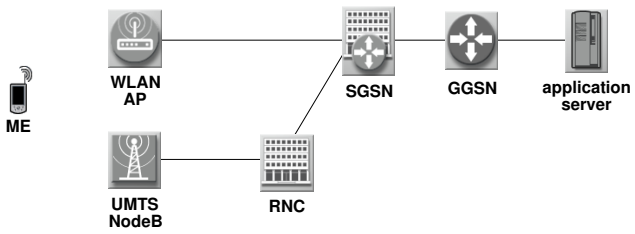

Fig. 1. The tight-coupled network architecture

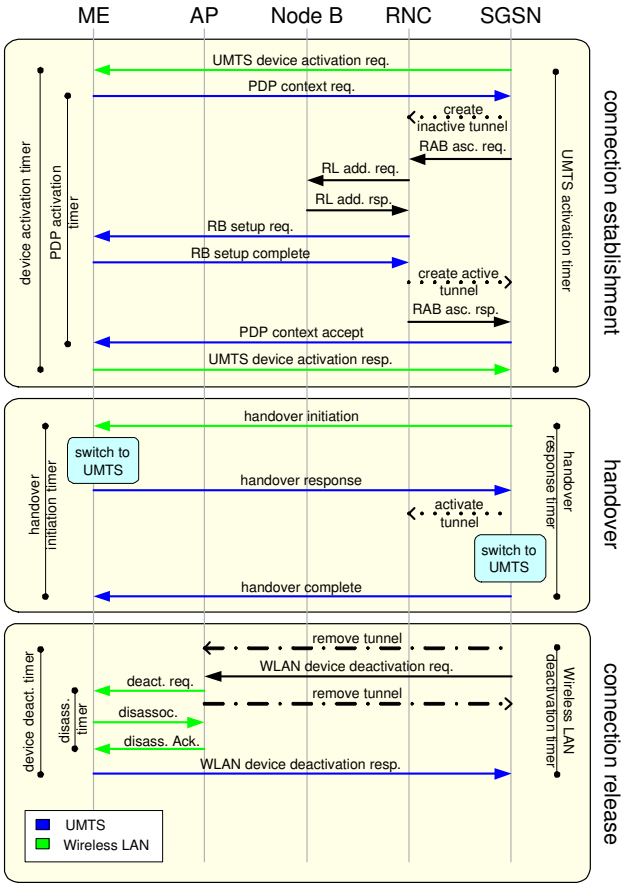

Fig. 2. Protocol for a Wireless LAN to UMTS handover

The process is initiated by sending a UMTS device activation request from the SGSN to the mobile equipment using the existing Wireless LAN connection. In return, the ME sends a *Packet Data Protocol* (PDP) context request for every quality of service class used in Wireless LAN over the UMTS shared channel back to the SGSN. This is followed by the *Radio Access Bearer* (RAB) setup and the creation of a tunnel between the RNC and the SGSN. When all quality of service classes are active, the mobile equipment is connected to both networks and transmits a positive UMTS device activation response to the SGSN.

After the successful connection establishment, the SGSN initiates the vertical handover itself, the switching of the networks. First, the ME switches to UMTS and indicates the change of devices to the SGSN with a handover response message. Then, the SGSN activates the IP-over-IP tunnel to the RNC and updates its address of the ME so that all traffic is forwarded to RNC which is responsible for the ME. Finally, to complete the vertical handover process, the old connection to Wireless LAN is deallocated to save resources. Therefore, the tunnel between the SGSN and the Access Point is released and the ME disassociates to the Access Point.

III. Simulation Results

The handover protocol for both directions, from Wireless LAN to UMTS and UMTS to Wireless LAN, has been implemented and evaluated using the OPNET Modeler [6]. The mean handover delays from 40 simulation runs are plotted in Figure 3. The total handover delay, indicated by the dark blue bars, is less than 750 ms for both directions and by far shorter than the Mobile IP delay. However, included in this delay are the connection establishment and the connection release during which packets can be transmitted normally. The period with no connection at all is marked with orange and lasts less than 100 ms.

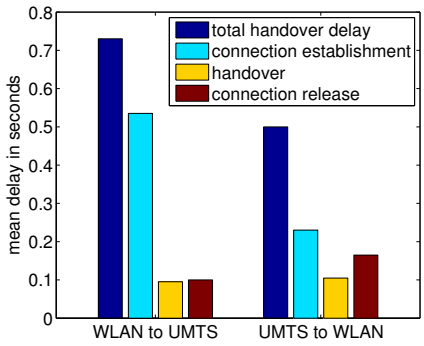

Fig. 3. Mean handover delays

The figure further reveals that the connection establishment takes most of the time, especially for the Wireless LAN to UMTS handover. This results from the complex radio access bearer and tunnel setup. Unfortunately, this delay cannot be reduced and will always be around half a second for the UMTS connection setup and 230 ms for the Wireless LAN connection establishment. However, the handover delay itself, which is less than 100 ms, can be decreased which will be shown in the full paper.

IV. Conclusion

In this paper, we introduced a seamless vertical handover protocol using a tight-coupled network architecture, where the Wireless LAN Access Points are integrated into the UMTS network. Simulations of the proposed protocol revealed that the complete handover can be performed within 750 ms and the blackout time with no connection lasts only 100 ms.

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