User-Controlled Handover in Wireless LANs

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Abstract

This paper adresses the optimization of handovers in a Wireless LAN/Mobile IP/QoS environment by giving control over the link layer handover process to the mobile node. This is done by transfering parts of the hardware's functionality to a management software residing on the mobile node. The required handover thresholds have been determined by analyzing the wireless LAN hardware. The implemented concepts allows a service user (in our case the mobile client of a bandwidth broker) to decide about when to conduct a handover and to which access point to connect to. The experience made shows that more powerful drivers would fully enable our concept.

1 Introduction

While the wireless LAN technology spreads more widely, available Mobile IP implementations do not yet handle handovers satisfactorily. The design of Mobile IPv4 is restricted by the abilities of IPv4 and leaves a lot of room for improvements. Especially the reduction of the handover latency is a topic widely discussed. And although IPv6 provides better prerequisites (in terms of flexibility and extensibility) for the implementation of a mobility support protocol, Mobile IPv6 still has some flaws.

One of the major concerns is, that while the wireless LAN technology and Mobile IP operate at different layers, there is no definition for the inter layer communication between link and network layer. In practice, this is reflected in the Mobile IP implementations that are just following the behavior of the wireless LAN hardware. Of course, this leads to delays or unwanted and unpredictable results. But especially for applications relying on QoS, the well timed transfer of network management information (i.e. flow descriptors) to the new point of attachment is very important. This can only be guaranteed, if control over the link layer handover process is provided to these applications.

1.1 Related work

Only few of the proposed solutions implement inter layer communication, most of them define rather complex extensions to the mobility support in IPv4 and IPv6. The paper [1] addresses three issues in Mobile IPv4: triangle routing, out-of-date location information and frequent handovers. The proposed solution implements route optimization, a buffering mechanism and hierarchical FA management. In [2], methods to minimize the latency caused by the Mobile IPv4 registration process, are proposed. The design includes pre- and post-registration mechanisms as well as link layer triggers. With [3] handovers are performed based on available resources. The maintenance of the old reservation until the successful completion of the new one aims to provide a constant QoS level. The Internet Draft [4] attempts to reduce latency of the Mobile IPv6 registration process. Several new messages have been defined as well as the usage of link layer triggers. Unfortunately, when used in a proposal, link layer triggers are not specified in detail. Also, most solutions add additional administrative overhead or put short high peak load on the wireless network, which still is short of bandwidth.

1.2 Proposed approach

The need to rely on link layer information to allow certain means of synchronization between the handover processes of the link and the network layer is understood. The most obvious parameters that influence the wireless LAN hardware's behavior are indicators of the signal quality. These quality parameters are usually provided by the driver of the wireless LAN hardware and can be gathered easily.

This leads to the main idea to continuously monitor the signal quality and, upon exceeding or falling below certain thresholds, alert concerned applications. Additionally, we need to ensure that the time (when to conduct the handover) and the destination (to which access point to connect to) of the handover are under control of the mobile node.

The first is achieved by delaying the handover until the reconfiguration is completed, the latter by keeping the association with the currently chosen access point. Therefore, we can effectively handle delays caused by the reconfiguration of the network's QoS attributes as well as prevent interruptions in the current handover process.

With these abilities, a mobile node can control the handover process and perform fast handovers. By taking over control, a mobile node is also responsible to conduct the handover by itself. Therefore, parts of the hardware's functionality need to be transfered to the implementation of our concept.

Our implementation requires access to the wireless LAN hardware, a specification of the thresholds (Section 2) as well as a communication interface to other programs (Section 4).

2 Link layer handover statistics

The resulting first step was to determine and validate the Signal-to-Noise Ratio thresholds used by wireless PCMCIA cards to initiate a layer 2 handover.

As no standard thresholds have been prescribed each manufacturer uses its own values. Our test equipment consists of two access points (APs) (Lucent WavePOINT-II V3.83) and a Laptop acting as the mobile node (MN), all using WaveLAN cards (Lucent WaveLAN/IEEE Turbo, Firmware 7.52). The AP Manager [5] provides a limited control over the threshold values to be used. Three length values (large, medium or small) in the *Distance between APs* field describe the AP density (low, medium or high) of the wireless network. Table 1 lists typical threshold values depending on the AP density (taken from Lucent's Technical Bulletin 023/B [6]). Lucent calls the threshold, which initiates a layer 2 handover the Cell Search threshold.

In accordance with the available AP density settings three series of measurements have been carried out, each consisting of 20 runs. The signal's quality parameters have been gathered at 300 ms intervals. Starting one meter before the first AP the MN moved in front of the second AP and from there - following the same path - back to the starting point. With a speed of approximately 3 km/h the distance of 50 meters was covered in about 60 seconds. A sample run for the low density setting is shown in Figure 1. The handovers take place at 19 and 50 seconds. The figure also contains some of the thresholds listed in Table 1. Depending on the configured density of APs in the wireless network we measured the corresponding thresholds (Low = 10.5 dB, Medium = 23.5 dB, High = 30.5 dB).

Threshold	AP Density		
	Low	Med.	High
Carrier Detect [dBm]	-95	-90	-85
Defer [dBm]	-95	-85	-75
Cell Search [dB]	10	23	30
Out of Range [dB]	2	7	12
Delta SNR [dB]	6	7	8

Table 1: WaveLAN/IEEE thresholds

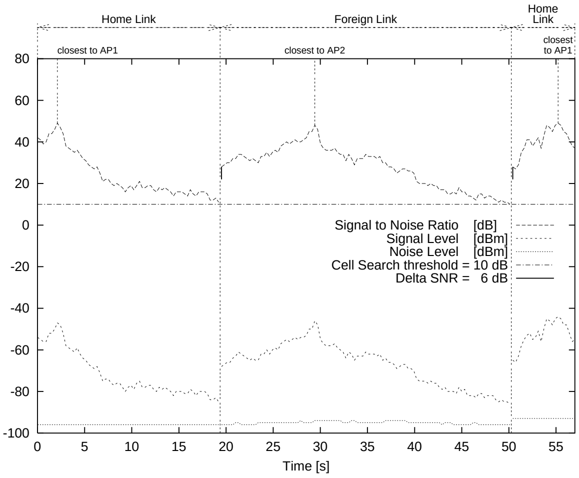

Figure 1: Signal to noise ratio when roaming with low AP density

These obtained results could be verified with the help of the Technical Bulletin [6] mentioned above and have therefore been used in our implementation of the mobile-controlled handover concept.

3 Mobile-controlled handover

In our scenario, a Differentiated Services architecture is used to provide QoS to mobile nodes. The network management unit is the bandwidth broker. The necessary administrative communication between the bandwidth broker and the mobile nodes is realized by a mobile client of the bandwidth broker, which runs on each mobile node. The management tasks of the bandwidth broker include the provisioning of the network resources to mobile nodes and the maintenance of the mobile node's reservations. However, in a wireless network mobile nodes frequently change their location, so their flow descriptors need to be updated constantly. Additionaly, the network resources are subject to constant changes, often causing recalculations of existing reservations. Therefore, the bandwidth broker always needs to know where the mobile nodes are and when they are about to move to a new point of attachment, a so called handover. This requires control mechanisms for each mobile node.

The underlying concept assumes that a change of location always directly affects the signal quality. Thus, observing these values gives information about the MNs movements. Moreover, a scan for surrounding APs reveals potential new association targets for the MN. These possible targets will be advertised to concerned entities (e.g. bandwidth broker) in due time, so they can take appropriate actions.

Unfortunately, the firmware of the wireless LAN card could not be forced to stay associated with a certain AP, which led to the decision to introduce a one-to-one relation between APs and ESSIDs instead of using a common ESSID for all APs. But the wireless LAN hardware drivers under Linux were unable to provide the signal's quality parameters from APs using an ESSID different from the MN's current ESSID. Therefore, the switching of ESSIDs to gather the signal quality from all APs had to be applied.

These encountered restrictions led to incisive consequences. Each AP needs to be assigned a unique wireless cell name (i.e. ESSID) and the program must be informed in advance about it's surrounding APs by transferring their ESSIDs. Nevertheless, the following feature of IEEE 802.11 compliant hardware is very useful. The assignment of a specific ESSID to the MN will only allow the association with an AP using the very same ESSID.

Due to the predefined one-to-one relation between ESSIDs and APs, we force the MN to stay with the chosen AP and not switch to a - eventually appearing - more dominant, but currently unwanted AP. Also, the successive switching of ESSIDs on the MN forces the handover and allows the gathering of the signal's quality parameters for each of the ESSIDs.

As this solution works on the link layer level, it does not interfere with Mobile IP, which operates at the network-layer. In fact, this concept supports the fast handover process, by providing means of control over and synchronization with the handover procedure.

The operational design is based on a program which provides services to entities in need for them. This allows other programs (service users) to directly supervise the handover process and immediately obtain the results.

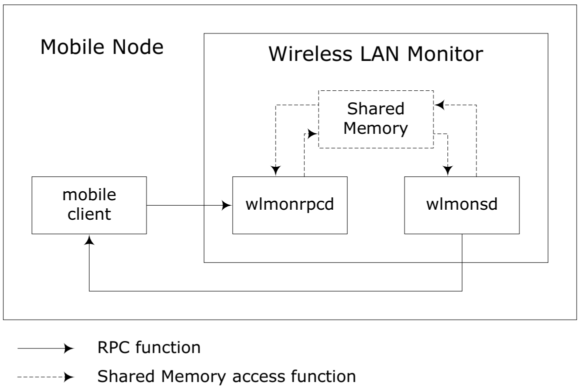

Figure 2: Interaction of the Wireless LAN Monitor components

The service user sends a list of available wireless cells (i.e. ESSIDs) to the service program. The service program itself resides on the MN and constantly monitors the signal quality of its current wireless link. It reacts upon a change of these values (e.g. falling below a threshold) and alerts the affected service user. The service user in turn orders the search for potential new links. The service program queries the surrounding APs by their provided ESSIDs and sends the results to the service user. Next the service user can dispose the change to the new location with a certain delay. Having performed the change, the service program informs the service user about the results. It then continues to monitor the link quality, waiting for the next threshold shortfall to occur. The service user can send a new list of wireless cells to the service program at any time to adjust to a changing environment.

4 Implementation and application

The implementation allowed us to test and analyze our developed concept in a true application scenario. The handover control mechanisms are used by the mobile client of a bandwidth broker, in order to allow the updating of the network configuration in due time.

The programming work of this proposal is released under the name Wireless LAN Monitor. The implementation was done in C++ under Linux, using the C++ Standard Library. The Wireless Tools [7] have been used as a reference for the wireless LAN hardware access functionality.

The Wireless LAN Monitor has been split into two daemons called *wlmonrpcd* and *wlmonsd*. The first provides the data transmission from the bandwidth

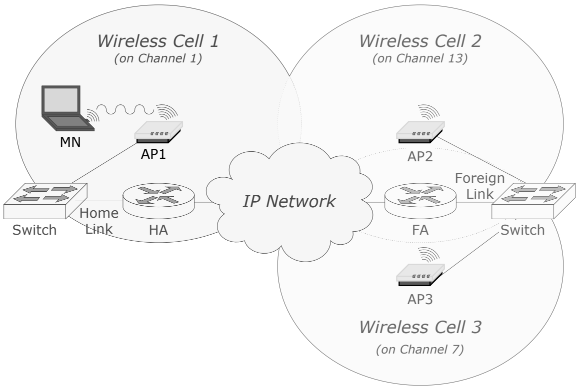

Figure 3: Test environment

broker's mobile client to the Wireless LAN Monitor, the latter is responsible for the data transmission to the bandwidth broker's mobile client and for monitoring the signal's quality parameters of the mobile node, where all three programs are running on (see Figure 2).

To exchange data between the two daemons the shared memory concept is used. To synchronize the shared memory access of the wlmonsd and the wlmonrpcd the first character in the shared memory field has been turned into a status flag. The communication between the Wireless LAN Monitor's components and the bandwidth broker's mobile client has been realized via remote procedure calls (RPCs).

A specifically designed test environment has been built up in the lab to study the Wireless LAN Monitor's functionality in practice. Figure 3 shows the test scenario.

During the Wireless LAN Monitor's operation it became apparent, that either the WaveLAN driver or the Linux kernel needed some time to reflect the change of the ESSID and update the singal's quality parameters to the actual values. Therefore, a configurable parameter, which states the delay between the change of ESSIDs, has been introduced. Currently it is set to $200\,\mathrm{ms}$.

5 Summary

The concept provides the necessary instruments to monitor and control the handover process without adding new extensions to the already existing Mobile IP standard. Instead it uses already existing features, namely the quality parameters of the wireless link and the wireless LAN hardware's specification.

Nevertheless, the usage of the SNR as parameter that is common to all wireless LAN hardware, makes it a rather flexible design. Although the adjustment of the thresholds to the hardware vendor's specific values remains, this task could be avoided by using relatively high thresholds (adding 5 dB to the Cell Search thresholds used herein, see Table 1). This would increase the amount of handovers on a reasonably planned AP installation only little and offer a more universal area of application.

The implemented communication interface permits other applications (i.e. service users) to take over the handover process control. Including this functionality, the concept can be seen as integral part of a fast handover solution. Giving the service user the possibility to delay the handover, enables him to execute all necessary network management functions for a fast handover. Furthermore, other entities, which do not reside on the mobile node itself, can take advantage of the provided handover control. An example would be a smooth handover procedure which involves buffering mechanisms at the mobile node's current point of attachment.

In its current state the Wireless LAN Monitor enables fast handovers, but can be easily extended to support smooth handovers at the same time, thereby allowing seamless handovers.

6 Conclusion

Most of the Mobile IP extensions can be divided into two categories: either they aim to support fast or smooth handovers. Today, no proposal exists that implements both, fast and smooth handovers (i.e. seamless handover) at the same time. An effort into this direction led to the foundation of the SeaMoby Working Group [8]. One of the group's goals is the definition of a common signaling protocol which allows the transfer of authentication, authorization and accounting (AAA) information between IP nodes. The SeaMoby working group's work is still in it's early stages.

It is clear that the problems (e.g. lack in hardware documentation) encountered during the specification and implementation phase led to some incisive restrictions. The most troublesome certainly is the very slow scan process (recognizing the new ESSID can take up to 200 ms) and the need of information about the surrounding network topology in advance.

Recently, a modified (through reverse engineering) version [9] of Lucent's WaveLAN driver for Linux has been published. This driver allows the gathering of the signal quality from all APs in range at the same time via the active scanning function of the wireless LAN hardware. This would enable the original concept and lead to much faster response times. It is to say, that the author of the modified driver choose to define its own API instead of integrating his work into the already existing and established drivers, making the compatibility and future of his work uncertain.

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