Improving Video Quality for Handover between Legacy MIPv4 Overlay Networks

Claudio de Castro Monteiro
Federal Institute of Education of Tocantins
Computing Science Departament
Network Group
Av. NS-10 c LO-5 Tocantins Brazil
Email: ccm.monteiro@ieee.org

Paulo Roberto de Lira Gondim
University of Brasilia
Electrical Engineering Department
Wireless Networking Group
Campus Universitário Darcy Ribeiro, Brasilia
Email: pgondim@unb.br

***Abstract*—In this paper, we introduce a novel specialized MIP implementation (S-MIP) to reduce native MIP latency into a scenario in which Wireless Local Network (WLAN) and 3G networks are integrated through user multimode terminal. This solution attempts to preserve the quality of the streaming video during each handover and recover the user video session damaged by high delays caused by MIP. The performance of our solution was evaluated using a testbed implementation into a real scenario and the results were better when compared to solutions based on traditional approaches.**

***Index Terms*—QoS; Wireless; Network; Integration; MIP**

I. Introduction

In the past few years, the demand for high performance services for mobile 3G connections has increased exponentially. Although cellular networks can have high transmission rates, the cost for mounting or adapting the necessary infrastructure is very high. In contrast, WLAN infrastructure has been developed in various countries and offers data rates that are much higher than 3G networks at lower deployment and maintenance costs.

These two networks, therefore, complement each other and, if properly integrated, can provide the user with the appropriate conditions to access services, regardless of the access network being used. The integration of these networks has been the subject of several studies in recent years. In general, these studies can be divided into three main areas according to their chosen solution, namely, those that use systems of coupling, those that advocate mobility management and those that include direct applications of IMS (IP Multimedia Subsystem) [1] [2] and MIH (Media Independent Handover) [3] [4] standards.

The focus of this paper is to demonstrate the possibility of reduce the MIP latency in the integration of mobile wireless networks. As a case of study, we consider the integration of WLAN and 3G networks, using an architecture without coupling with MIP protocol [5] to help mobile users in order to ensure continuity of the sessions involving video reception with good quality.

The effectiveness of our proposal is demonstrated through experiments conducted in real environment with a WLAN network [6], over which we have total manage control, and a 3G network from a local carrier in Brazil, over which we have no manage control.

This environment considers multimode mobile terminals containing two network interfaces (i.e., WLAN and 3G). In addition, an access point based on Linux was implemented to generate the WLAN coverage. An implemented MIP Home Agent (HA) is at the core of a WLAN, while a MIP Foreign Agent (FA) is implemented and available on the Internet. Thus, we show that the measured delay during the handover between the mobile WLAN and 3G is reduced by 20% compared to a native implementation of MIP.

This paper is organized as follows: Section 2 shows a background about scenarios used for integrating WLAN and 3G networks using MIP. Section 3 presents the main related works, discussing solutions for heterogeneous network integration problem with mobility management based on MIP. Section 4 presents our proposal, including details of S-MIP implementation. Section 5 details testbed and methodology used in the work. Session 6 presents the results and discussion about S-MIP and Session 7 presents the conclusion of this work.

II. Background

Cellular networks are currently able to provide better mobility to their users without offering high bandwidth for data applications. In contrast, WLANs are known for their relatively high bandwidth but limited mobility. Ubiquitous data services and high data transmission rates across heterogeneous networks can be achieved by using WLAN as a complementary technology to cellular data networks. Today there is great need for efficient mechanisms to enable interworking between WLANs and cellular data networks [2].

These interworking mechanisms could provide authentication, billing, roaming, mobility and terminal mobility services [7]. Some integration architectures have been proposed by researchers in previous studies. In general, these architectures can be categorised as tightly-coupled, loosely-coupled and peer-to-peer architectures [8].

In a tightly-coupled architecture, WLAN networks are connected to the core of a 3G cellular network through a gateway known as the Serving GPRS Support Node (SGSN) [9]. The data and UMTS signaling are transported over the WLAN to the cellular network's core through that gateway. Thus, the

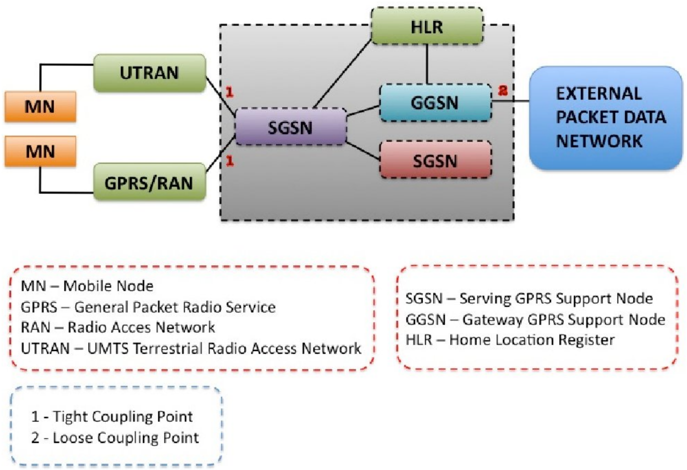

Figure 1. Coupling Architectures

Basic Service Set (BSS) of the WLAN serve as another area of coverage for the cellular network, extending that network to better serve the user. In a loosely-coupled architecture, only signalling between the mobile device is transported over WLAN, while data flows are forwarded directly to the IP network.

Although considered a new architecture, peer-to-peer architecture can also be understood as an extension of the loosely-coupled architecture. It treats the two networks as peers, and gateways are used for integrating this networks [10].

There are also hybrid coupled schems that are able to differentiate the path followed by data and signalling according to traffic type. For example, in [11], a tightly-coupled architecture is used for real-time traffic, and a loosely-coupled architecture is used for other types of traffic. In the loosely and peer-to-peer coupled schemes, the use of mobile IP (MIP) has been commonly considered as a mechanism for mobility management [5].

III. Related Works

A proposal of a handover study in mobile IP networks and mobile IP protocol extensions for handover latency minimization was given in [12], indicating that native mobile IP has a very high handover latency. The authors proposes a reduction in MIP signaling messages and use discrete event simulation for comparing alternatives.

A scheme for reducing the handover latency of mobile IP into infrastructure mode WLANs is presented in [13], reducing the handover. The proposal attempts to resolve the mobility intra-WLAN measuring the signal strengths of multiple access points working in the infrastructure mode. It accelerates the detection of link-layer handover by replaying cached foreign agent advertisements. The proposal is transparent to the mobile IP software installed on mobile and wired nodes. The authors demonstrate the efficiency of the proposed method, with a mechanism of bandwidth guarantee in 802.11e-based standard wireless LAN. This implementation does not predict a mobile node's handover, leaving this to the IAPP mechanism. It proposes an acceleration of handover detection.

In [14], an analytical model of handover latency for FMIPv6 and HMIPv6, using WLANs as access networks, was presented. This model considers factors of both link and network layers that influence the mobile IP handover delay. The results show an improved performance in MIPv6, which helps in the handover process. However, the solution requires that the clients support MIPv6.

A framework is proposed in [15], for multimedia delivery and adaptation in mobile environments. A concept of a Personal Address (PA) is introduced in this work, which is a global network address used by user for her ubiquitous identification in a network. The proposed address network layer problems, and provide the mobile with move functionality across networks and devices, allowing the seamless delivery media. The authors claim that the location's transparency sponsored by the PA allows the user to receive multimedia data independent of the IP network. However, the solution presented used a mobile IP and did not show how it impacted the transmission multimedia session continuity, influenced by the implementation of the entities that manage the PAs.

Some studies [16] [3] [4] [17] were also analyzed. They all have solutions for reducing the latency of a vertical handover, using models drawn from a Markov chain, combined with implementations of the MIH Weighted Markov Chain (WMC) and various algorithms to perform all phases of the handover, always seeking to optimize them to detect the best available network, find the ideal time and perform the handover, ensuring quality of service to the user. All it consider a scenario where the re-IP conection is not necessary, so MIP handover delay is not considered.

Other approaches evaluate the impacts in video quality caused by handovers in WLAN/3G integrated networks have been treated to some extent. In any works [18], [1], [19], [20], [21], [22], [23], [2], [24], [25], issues about standards, couple architecture and frameworks for video delivery in heterogeneous wireless networks use are address. Therefore, the MIP latency reduction still is a relevant problem not treat for this works.

IV. Proposal

Our proposal consists of a new opensource MIP implementation, named S-MIP, using the GNU Linux Operating System and Openvpn Software tools. For the sake of evaluating the quality of video streaming, we used a PC-based video server as Correspondent Node (CN).

The MIP signaling involved in the operation of the protocol is presented in figure 2, where the differents times (t_1 to t_8) related to messages flow is shaw.

We can express the MIP latency by:

$$MIP_L = \sum_{i=1}^{8} t_i$$

where t_1 and t_2 are times of IP association and are not considered in MIP latency handover, as well as the time t_3,

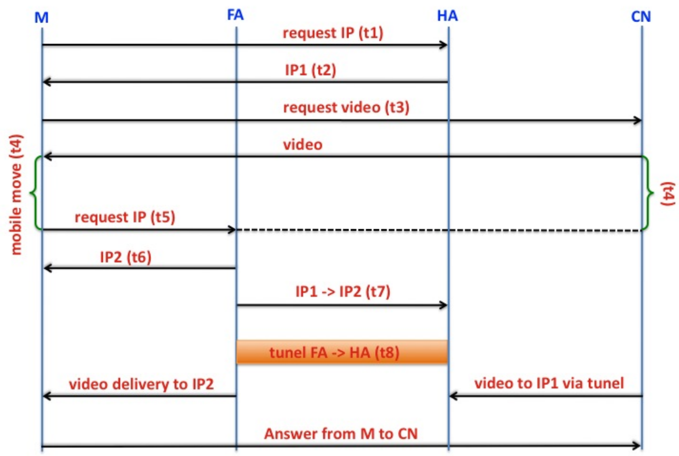

Figure 2. MIP Signaling

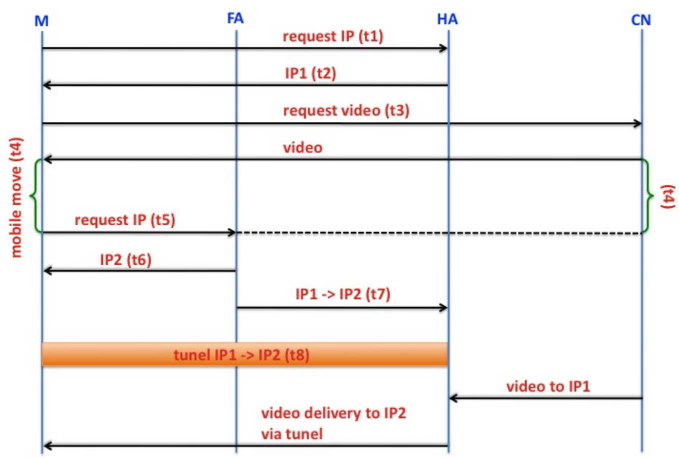

Figure 3. S-MIP Signaling

related to delay involved in the video request to the CN. During t_4 occurs the movement of the mobile, while t_5 and t_6 are similar to t_1 and t_2, involving FA in this case. During t_7, the new address is informed by the FA to HA.

The default MIP signaling considers a tunneling between FA and HA after the register of new IP of the mobile at FA. Thus, all traffic addressed to the mobile is handed to the HA, which forwards it to the FA, using the tunnel. Moreover, all mobile originated traffic is routed to the CN directly, characterizing the triangular routing.

To reduce the delay caused by this signaling at handover, we decided to implement a HA and a FA based on raw sockets and to restrict MIP signalling to recording the new IP address in the FA and the registration of the new address in the HA according to a message sent by the FA. After that, the HA adds a new route to reach the mobile device, using it for the establishment of an IP tunnel with the help of openvpn software.

In our solution, after the registration of the mobile in the FA, its proper IP association and due registration of its new IP address in the HA, a tunnel is established directly between the HA and the new IP address of the mobile in the foreign network (figure 3). thus reducing the time t_8 and video propagation delay between the CN and the mobile in its new location, considering that home IP address of the mobile is configured with a IP address alias in active interface of mobile.

All signaling between the HA and FA is done using UDP sockets containing only the necessary information for the realization of records between those entities.

The algorithms used for the implementation of HA and FA in S-MIP, are presented below, as well as the client portion of S-MIP.

Listing 1. Algorithm HA Implementation

```
...
main(int argc, char *argv[])
{
        ...
        if(-1!=bind(sock,(struct sockaddr *)&me,
            sizeof(me)))
        while(1)
        {
                len=recvfrom(sock,ip_new_cli,sizeof(
                    ip_new_cli),0,(struct sockaddr
                    *)&from,&adl);
                len=recvfrom(sock,ip_old_cli,sizeof(
                    ip_old_cli),0,(struct sockaddr
                    *)&from,&adl);
                exec("openvpn 'echo ip_new_cli >> /
                    etc/openvpn/tunel.conf'");
                system("route add -host 'ip_new_cli'
                     gw 'ip_fa');
        }
        close(sock);
}
```

Listing 2. Algorithm FA Implementation

```
main(int argc, char *argv[])
{
        if(-1!=bind(sock,(struct sockaddr *)&me,
            sizeof(me)))
        while(1)
        {
                len=recvfrom(sock,ip_new_cli,sizeof(
                    ip_new_cli),0,(struct sockaddr
                    *)&from,&adl);
                len=recvfrom(sock,ip_old_cli,sizeof(
                    ip_old_cli),0,(struct sockaddr
                    *)&from,&adl);
                sendto(sock,ip_new_cli,sizeof(
                    ip_new_cli),0,(struct sockaddr
                    *)&target,sizeof(target_fa));
                sendto(sock,ip_old_cli,sizeof(
                    ip_old_cli),0,(struct sockaddr
                    *)&target,sizeof(target_fa));
                fclose(fp);
        }
        close(sock);
}
```

Listing 3. Algorithm CLIENT Implementation

```
main(int argc, char *argv[])
{
    for(;;)
    {
        int sock=socket(AF_INET,SOCK_DGRAM,0);
        ip_wlan0=sysctl(ip.wlan0);
        ip_ppp0=sysctl(ip.ppp0);
        if(def_route_wlan0==1)
        {
                ip_wlan0=sysctl(ip.wlan0);
                sendto(sock,ip_wlan0,sizeof(ip_wlan0
                    ),0,(struct sockaddr *)&target,
                    sizeof(target));
        if(def_route_ppp0==1)
        {
                ip_ppp0=sysctl(ip.ppp0);
                sendto(sock,ip_ppp0,sizeof(ip_ppp0)
                    ,0,(struct sockaddr *)&target,
                    sizeof(target));
        }
        close(sock);
    }
}
```

V. Methodology

To compare the S-MIP and MIP Linux native alternatives, we considered a scenario in which 3G and WLAN networks operate without integration, but are overlayed. We used multimode clients (netbooks) with WLAN Atheros card and HUAWEI Mobile Broadband (E1756). The HA was mounted at AP, while FA at netbook, linked to an ethernet network with routable IP. All handovers were done throught default route changes at mobile multimode terminals.

Initialy, 200 unicasts of foreman video were sent, as request for mobile device. When the video stream reached frame 200, we changed default route from WLAN interface to 3G (PPP) interface of the mobile device, forcing the client portion of the MIP implementation to identify this change and start the MIP HA and FA procedures. So, the client implementation notifies the FA of the new IP address and triggers the registration process between the FA, the HA and the mobile device, as described in the specification of the MIP. The same procedure was done for S-MIP.

Since the terminals has stablish connections in the two networks, we consider, for all experiments, the handover only at the network layer, i.e. the time spent during handover in the lower layers is disregarded. The handover, in our scenario, is triggered by simply changing the default route of the mobile.

VI. Results

In the section, handover latency and video quality was evaluated, considering standard MIP and S-MIP implemantations.

A. MIP Linux Native Implementation

The results show a delay around 5 seconds (when considered the times t_5, t_6, t_7 and t_8) during handover, when using MIP Linux native implementation. In addition, this implementation presented difficulties in establishing the tunnel between the HA and the mobile device as well as some additional delay in the necessary registration between the mobile device and the FA and between the FA and the HA. For non-real-time applications, this result is satisfactory, but it is not satisfactory for real-time applications.

B. S-MIP Implementation

This implementation was more efficient than that available natively on Linux; it reduced the delay around 20% as shown in Figure 4. However, three seconds is still a long delay for video session connections to be maintained.

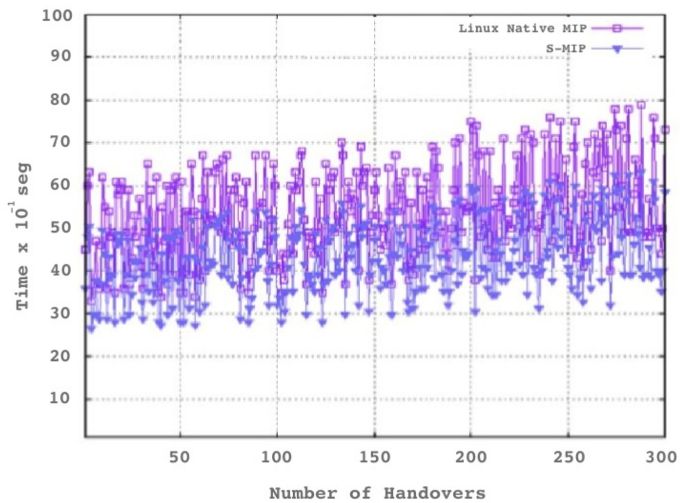

Figure 4. Delay I-MIP x Delay Linux Native MIP

C. Video Quality Impacts

Using a modified version of MIP, a significative improvement in the video quality after vertical handovers was verified, considering objectives metrics of video quality.

Due to the time spent to re-establish the IP connection, the video stream is quite impaired. Thus, the higher layer protocols attempt to recover these streams when possible. The protocol used to transport the video was the UDP encapsulated in RTSP. For this reason, the videos were interrupted during the handover, but recovered after IP re-connection.

The average of PSNR measured in experiments reflect directly in the user video perception as showed in figures 5 and 6. We can see in figure 7, that with S-MIP, the PSNR improved around 15%,

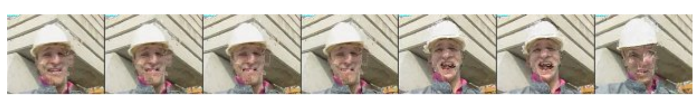

Figure 5. Video quality after handover in MIP native

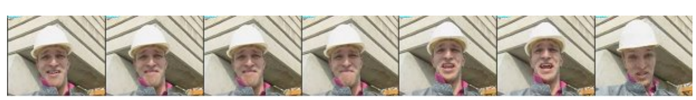

Figure 6. Video quality after handover in S-MIP

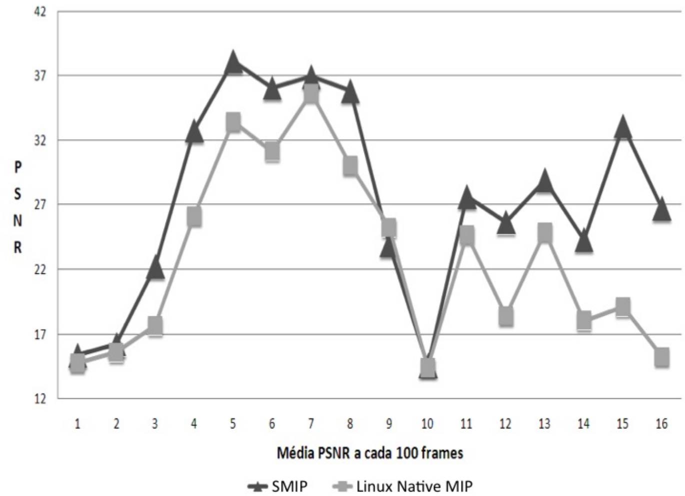

Figure 7. PSNR MIP Native x PSNR S-MIP

VII. CONCLUSION

This study provided evidence supporting our hypothesis. It is possible to reduce the delay caused by the implementation of the MIP, which was achieved with the MIP implementation presented.

Our main goal was to reduce the delay caused by vertical handovers, as well as to minimise its impacts on video streams. Using only the techniques of mobility management, some studies have proposed solutions that reduce handover latency in different layers of the OSI model. Although we also successfully reduced latency in layer 3, the reduction was not sufficient to maintain the continuity of video sessions after a vertical handover.

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