A Solution for Seamless Video Delivery in WLAN/3G Networks

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***Abstract*—In this paper, we introduce a Session Proxy (SP) into a scenario in which wireless local network (WLAN) and 3th generation of networks cellular (3G networks) are integrated using peer-to-peer architecture, with mobile IP (MIP) as the mobility manager. This solution tries to preserve the quality of the streaming video upon each handover, recovering the user video session damaged by the high delay caused by MIP.**

Keywords-Video, 3G, WLAN, Handover, Proxy

I. INTRODUCTION

Currently, the demand for high performance services offered for mobile 3G connections has increased. In order to meet this demand, cellular providers have deployed 3G networks using the Universal Mobile Telecommunication System (UMTS) [4] and the Code Division Multiple Access 2000 (CDMA2000) [7].

However, due to the high cost of deployment and low transmission rates, cellular providers have not been successful in attracting customers.

Although cellular networks can have high transmission rates, the cost for mounting or adapting the necessary infrastructure is very high. On the other hand, the infrastructure of WLAN has been deployed in various countries and offers data rates much higher than 3G networks, with 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 networks 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: those who use systems of engagement, those with mobility management and those with direct applications of IMS (IP Multimedia Subsystem) standards and MIH (Media Independent Handover).

The focus of this paper is to demonstrate the possibility of integration between WLAN and 3G using an architecture without coupling, with the peer-to-peer protocol MIP as the mobility manager and a proxy session to ensure continuity of the connection sessions for the user in order to maintain quality when receiving video streams.

The effectiveness of our proposal is shown through experiments conducted in real life with a WLAN network, over which we have total managerial control, and a 3G network from a local carrier in Brazil, over which we have no management control. The technical difficulty of access to the local cellular operator has motivated us to create this solution, which, in principle, is not dependent on the resource deployment of any hardware or software in the core of mobile carriers.

This environment has a multi-mode mobile terminal, containing two network interfaces (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 40% as compared to results in the literature, and we propose that this integration uses MIP.

However, this reduction of delay is not sufficient for sessions that are connecting video stream applications to have continuity.

Therefore, we insert a proxy session at the core of a WLAN that is able to cache the video frame after receiving the unit, signalling the start of a handover and delivering the frames to the mobile once the handover is completed, using a tunnel made between the SP and the mobile and duly recording between the FA and the HA.

The article is divided as follows: In Section II, we present some related works. In Section III, we present our proposal including the algorithms used to implement the SP. In Section IV, we present the testbed used to test and validate the proposed solution. In Section V, we present the conclusions of the work.

II. RELATED WORKS

The problem of reduced video quality caused by the handover in WLAN/3G integrated networks has been treated to some extent.

However, this problem has been divided into two parts: one part studies ways to integrate WLANs with 3G networks in order to reduce delays in the exchange of control messages between the two networks, in an attempt to make the user feel as though he is working with a single network; and the other part studies methods to maintain a video session when a handover process occurs, by adapting the transmission.

We analyze works that address solutions for this problem, focusing on these two categories.

In [1], the authors present a scheme for dynamic negotiation of QoS parameters between access points. The paper introduces a concept of BAG (Bandwidth Aggregation), which allows the user to dynamically

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negotiate, using the access points involved, the path to be used to request a service.

Thus, users can move between access points, keeping the best service condition possible. Despite showing the efficiency of the solution, the authors only considered the bandwidth dependence of the QoS parameters, without emphasizing the reflections in the delay, jitter and packet loss that the solution generates. However, the proposal shown for QoS negotiation allocates the resources after the handover.

Nothing is reported about the handover period, still leaving open questions that are very important with regard to streaming video.

The work presented in [2] proposes a comparative study of video-encoding tools and storage techniques used for the delivery of video on demand to users on a next generation network.

The paper analyzes the performance of these tools and techniques in a tightly coupled environment using the IP Multimedia Subsystem (IMS) connected to a live operator network.

All results are presented at the Quality of Experience (QoE) parameter level and indicate that some of these techniques can be used to help solve the problem treated in this paper.

However, the techniques and tools were evaluated in a tightly coupled environment, where it was assumed that the cellular operator had control over the technical solution.

This is not the case with our situation, since we are proposing a structure in which the cellular operator does not need to have control over the solution and does not have to install any hardware or software components in the core.

In [3], the authors presented and compared three strategies for checking the quality of user experience for the reception of video streams.

Although the authors presented three strategies, the paper focused more on the results of a hybrid strategy, called Pseudo Subjective Quality Assessment (PSQA), which, according to the authors, presents advantages over the traditional PSNR.

This work demonstrates the applicability of the objective QoE metric, known as PSNR, which does not have temporal characteristics of the delays inherent in the transmission of video streams over the network, but the excessive loss of frames only.

This has led us to choose PSNR over the PSQA, whereas we measure the quality of perception of the user in the continuing video session after the vertical handover of the mobile.

Some studies found in the literature present coupling architectures for 3G-WLAN interworking. One of these studies is shown in [4], where the authors propose a loosely coupled architecture called SHARE.

In this proposal, each AP has a WLAN card to connect to a 3G network, which is used for the AP and can be connected simultaneously to the cell WLAN and cellular 3G.

The result is that 3G base stations can share their control channels with the APs, facilitating the detection of available APs in the region for mobiles, without, according to the authors, generating the characteristic delay of discovery networks in the handover process.

The proposal of the paper is good, and we found that the delay caused by network discovery activity in the handover process is small enough, considering the cost of inserting a 3G connection hardware into each AP and software procedures into both APs and 3G base stations.

Thus, although the solution of the authors has inspired us, we consider a scenario in which 3G networks and WLAN are overlapping and in which the mobile already has both 3G and WLAN interfaces available and is connected to each network, so that there is no need to detect the available networks.

In addition, we are concerned with reducing the handover latency at the level of reconnection IP, which is mandatory after the handover process and is decisive in solving our main problem.

In [5], a framework was presented to assist with admission control and resource reservation in next generation mobile networks.

The proposal presents a distributed call admission control with resource reservation, using the position information of the mobile to predict the movement of the user, determining the acceptance of the connection requests that can be made to that cell, which is based on the probability of movement of the user and the resources required by the connection.

However, this solution requires the use of a Global Position System (GPS) for each base station to find the location of the mobile and provide its movement in order to determine whether that cell has the resources required by the mobile.

This solution has a high cost and requires hardware and software elements to be installed into the 3G network core, with regard to admission control based on resource reservation.

Nothing is needed to maintain continuity of the session of the mobile connection after the handover, since we can predict the movement and allocate resources to be used after the handover of the mobile, but if a session is already open, the handover latency can be decisive for continuity of the session.

In an attempt to maintain multimedia services during a vertical handover between WLAN and 3G, we find in [6] an assessment of the support mobility mechanisms proposed by IEEE 802.21.

The authors presented the results of application studies of these mechanisms to assist with the handover in both directions, using an implementation of an MIH Link Going Down event for IEEE 802.11 networks.

The authors validated their results using a simulated environment with the NS-2 software. In the proposal, it is unclear how the multimedia session connection will be maintained, since the Link Going Down event informs the mobile that the link is suffering a fading.

Thus, other actions should be taken from this point forward to ensure the sessions, depending on the multimedia traffic type.

In our study, although MIH could have been implemented into the mobile and WLAN core, we chose to implement (only in the mobile) software elements that verify the operation of the device interfaces.

If there is any change in the active interface (the one used as the standard output), here represented by being powered

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off, the hard handover process is then characterized, and all other procedures related to re-establishing the IP connection and caching the video frames are started.

A framework for interworking between a WLAN and the UMTS network is presented in [7]. This proposal uses the IP multimedia subsystem suggested by the 3GPP for mediating network coupling in order to manage real-time sessions.

The work uses the IMS in order to provide for a user from a cellular network and QoS (Quality of Service) features available in a WLAN, while also providing a common and unified platform for control session user connection.

This architecture provides service control for a mobility terminal in an environment of heterogeneous wireless networks. The work validates the proposed model to ensure continuity of services during and after the handover by simulation.

The work ensured that a better continuity of service was possible. The model does not explain how to characterize the traffic during the simulation and focused only on the coupling of the WLAN and 3G networks using IMS, assuming that the operation of IMS elements can reduce the latency caused by the exchange of messages during the handover.

When proposing an unified architecture with mediation by the IMS, the handover is to be transparent to the user with the viewpoint of exchanging signalling messages.

The solution is interesting but requires that significant changes be made to the core of the networks involved, which may be difficult in a real scenario.

Our solution uses an architecture without coupling and therefore does not require that changes be made to the core 3G network, while requiring only some simple implementations in the core WLAN network.

The authors in [8] proposed a practical design of a proxy agent – SPONGE (Stream Pooler Over a Network Graded Environment) - localized between the wireless user equipment and the streaming video to facilitate the adaptation of delivering video stream service by wireless networks.

The architecture proposes the storage of a video, encoded at different qualities, permitting the user equipment to receive videos according to the characteristics of their network.

The authors focused their contribution to ensuring the video delivery, considering the conditions of the network QoS and the quality of the streams stored. The results did not lead to a guarantee of video stream delivery during or after the handover of the user.

Our work, despite having a similar direction, presents a Session Proxy (SP) without considering multiple video qualities with the aim of adapting the delivery.

The SP is presented as an alternative to associating a connection session of a mobile with a central element, designed to lead the intermediate cache frames of video transmission during the vertical handover of the mobile, in an attempt to deliver them in the same sequence after the handover.

The work of a SP is supported by our strategy for MIP implementation, which contributes to the reduction of handover latency in the re-establishment of IP connections.

A proposal of a handover study in mobile IP networks and mobile IP protocol extensions for handover latency minimization was given in [9], indicating that native mobile IP has a very high handover latency, and the proposal improved the performance of handover latency by 15%. Our proposal reduces this latency by 40%.

In [10], a proxy-based multimedia scheme is proposed for control Real Time Streaming Protocol (RTSP) to support fast signalling in the home network. The testbed implementation showed that the proposed scheme improved performance as compared with the RTSP in terms of the latency time, but it did not resolve the RTSP session continuity problem. The proposal reduced latency time, but the loss rate was large enough that the RTSP session could not continue.

A framework is proposed in [11] for multimedia delivery and adaptation in mobile environments. This work introduced the concept of a Personal Address (PA), which is a network address associated with the user instead of a network interface.

The proposed framework works at the network layer, and it moves the PA among networks and devices to deliver media in a seamless and transparent way.

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.

All of the related works studied attempt to resolve problems in wireless network integration for service delivery.

In special cases, solutions have been reported for the integration and interoperation between WLAN and 3G networks in order to ensure the video delivery to users of these networks.

The problems discussed include the handover. Many studies have adopted ways to reduce the handover latency using MIH, IMS protocols, mobility, coupled architectures, algorithms for network discovery, or even an integrated set of techniques.

Our work attempts to solve the problem in two stages. First, we suggest an architecture without engagement and the implementation of a MIP to manage the mobility of the user, considering an architecture in which no change is required in the core 3G network.

In the second stage, we suggest a session proxy, implemented into this architecture, that is able to provide the user with session continuity after the video handover, which is granted only with the MIP.

In general, video stream sessions have a synchronization time that does not support the handover latency. The studies found in the literature handle problems with enlace retransmission techniques, with different frame types that deliver only the necessary or usual application technologies of mobile IP.

Thus, our solution is based on a set that uses a mobile IP and a session proxy (SP). The proposal attempts to resolve the session continuity problem after handover, ensuring the

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receiver quality (PSNR – Peak Signal Noise Ratio) of the video transmitted.

III. Proposal

In our proposal, we suggest inserting two components in the WLAN core operator: a MIP HA implementation and a Session Proxy (SP).

In addition, a MIP FA implementation is proposed for working through the Internet, in order to register the Care of Address (CoA) of the mobile. In Figure 1, these components and their links can be seen.

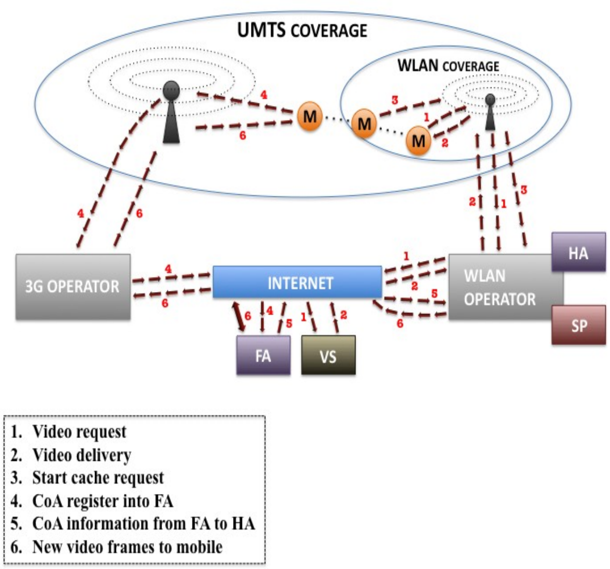

Figure 1. Proposed Architecture

The main idea is to maintain the continuity of the user video session after handover. To accomplish this, we set up a testbed containing native Linux MIP implementation only, as shown in Figure 2.

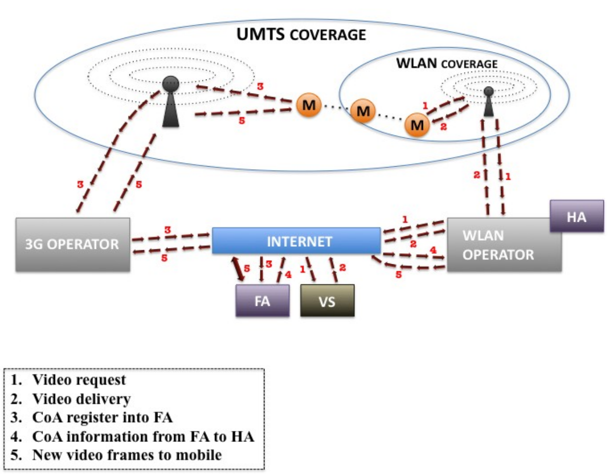

Figure 2. Proposed Architecture with MIP implementation only

A. *MIP utilization and implementation*

We considered 200 unicasts of video highway, requested by the mobile. When the video stream reaches frame 400, we turn off the WLAN interface of the mobile, make the client portion of the Linux MIP native implementation identify the fact and change the default route of the mobile to the 3G network gateway, telling the FA the new IP and triggering the registration process between the FA, the HA and the mobile, described in the specification MIP.

The results, as expected, showed a high delay during handover, reaching an average of 5 seconds, whereas this implementation presented difficulties in establishing the tunnel between the HA and the mobile, plus some additional delay in the necessary registration between the mobile and the FA and between the FA and the HA. For non-real-time applications, this result is satisfactory, but not for real-time applications.

To try to reduce the delay caused by the MIP handover, we decided to implement a HA and a FA, based on raw sockets, and to restrict the MIP signalling to recording the new IP address in the FA and the registration of the new address in the HA, made by the FA.

After that, the HA adds a new route to reach the mobile, using it for the establishment of an IP tunnel, with the help of openvpn software.

This implementation was more efficient than that available natively on Linux; it reduced the delay by 40%, as shown in Figure 3. However, 3 seconds is still a long delay for video session connections to be maintained.

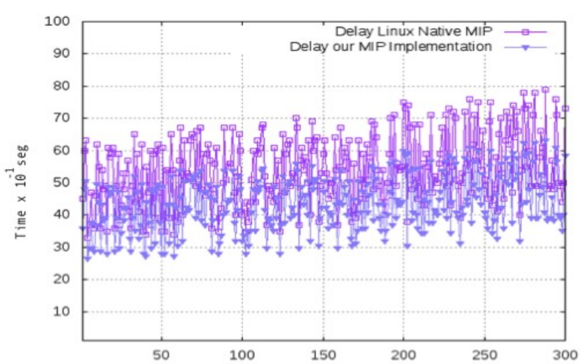

Figure 3. Native MIP vs proposed MIP delay

We observed that the objective QoE (Quality of Experience) metric, known as the PSNR, does not suffer a direct influence of the delay in receiving frames, rather an excessive loss of frames at the reception of the video, which can cause a significant reduction in the PSNR values obtained, as shown in Figure 4.

Thus, the loss of the video session during the reception generates, from the viewpoint of the player, an excessive loss of frames, directly affecting the PSNR of the received video.

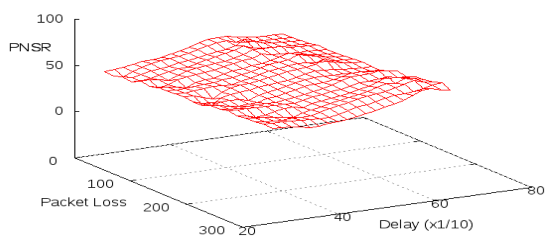

Figure 4. PSNR vs Frame Delay and Loss

B. Session Proxy

To address the problem of a continuous session during the transmission of video streams, we included a software entity in the proposed architecture, called a Session Proxy (SP) [12], as shown in Figure 1.

The SP ensures the continuity of the session even after long periods of link discontinuity. Although the SP can use the prediction of a handover of the mobile, through the thresholds defined after the extensive experiments detailed and displayed in Table 1 [12], for simplicity, we assume that the handover will be determined by the number of frames received from the video, using a setting of 200 frames; a hard handover will occur if the active interface of the mobile is turned off.

Before that, upon receiving frame 150, the mobile informs the SP that it is about to start the handover and that it should start the cache frames.

Thus, the mobile requests an open session RTSP with the video server. This request will be received by the SP, registered with the structure shown in Table 1 and then forwarded to the video server, according to the algorithm shown below.

```
receive_socket(socket, RTSP_request);
registered_session(session_ID, RTSP, IP_MAC, 0);
open_socket(socket1, IP_server);
send_socket(socket1, RTSP_request);
receive_socket(socket1, RTSP_response);
send_socket(socket, RTSP_response);

while(Session_ID <> 0)
{
        receive_socket(socket, RTSP_packets);
        receive_socket(socket2, status, MAC_AP);
        if(status==1)
        {
                FrameID=frame_ID;
                start_cache(Session_ID);
        }
        if(status<>1)
        {
                send_socket(socket1, RTSP_packets);
        }
        sendcache_socket(socket1, RTSP_packets);
}
```

The video server then opens an RTSP session with the SP, which will begin to receive the frames and transfer them to the AP, which delivers it to the mobile node. This process will continue until the mobile receives video frame 100, indicating that the SP should start the frame cache.

At this point, the SP-cached frames are transmitted to the mobile, using the data structure shown in Table 2. When the mobile receives frame 150, the hard handover will start.

When the mobile receives video frame 100 and informs the SP, it records the identifier of the last frame received in the session registration cache and continues with the video server session open, receiving frames, inserting in the cache and transmitting to the mobile.

When the active interface of the mobile is switched off, the MIP is employed in order to achieve the necessary records for rebuilding the user's IP connection, as described in the previous section.

This informs the SP that it must start the transmission of frames in its cache following the last frame that was received by the mobile, now using the new path created by our MIP implementation.

TABLE I. SESSION REGISTRATION CACHE STRUCTURE

Session ID	Service ID	IP association	Frame ID

With the use of a SP, we continue to deliver the video after the handover of the mobile, without the loss of frames influencing the quality of the video received. The display shown to the user stops for 2.23 seconds, with the next frame playing after the last frame received.

In Figure 5, can see the PSNR of the video received with and without the use of a SP. Note that when we use the SP, the values do not have variations that could impair the quality of the video received. This is not so when we do not use this software component, demonstrating the efficiency of the proposed mechanism.

With a SP, the mobile receives frames after the handover, from the last frame received before the handover, without affecting the quality of perception of the user.

Moreover, without the SP after the handover, the mobile no longer receives the remaining frames of the video, which, after a certain number of frames not received, reduces the PSNR of the received video. In practice, the user realizes that the session connection has been interrupted and that the video has stopped being displayed.

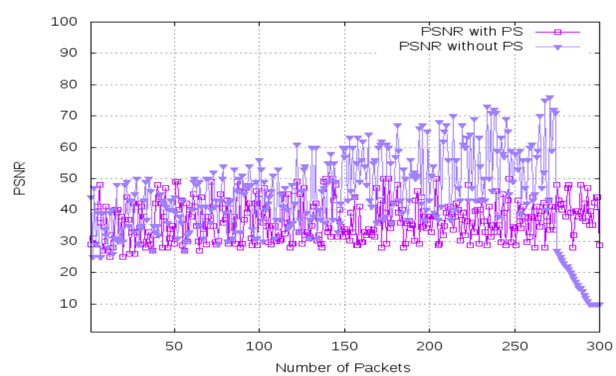

Figure 5. PSNR video with and without SP

C. Mobility Considerations

For testing purposes, we first considered the user mobility of WLAN → 3G. However, as we are not considering a soft handover, the methodology used to study the behaviour of the proposed architecture in the case of the user mobility of 3G → WLAN was exactly the same, and the results have similar values, since the components that are involved are the latency of re-establishing IP connectivity (in implementing MIP) and session user continuity (with a session proxy).

IV. Testbed Scenario

For testing, we mounted a scenario composed of three netbooks with the Linux 2.6.31 operating system.

The first netbook was used as a multi-mode device, with a WLAN interface (atheros) and a 3G interface.

The second netbook was used as a HA and network core of WLAN, providing Internet Gateway, NAT and DHCP for WLAN users.

This netbook also employed our implementation of a SP and a HA. The third netbook was used as a FA and was installed within the IP network of the Laboratory of Interactive Digital TV, UnB.

In this machine, our implementation of a FA was installed as well. Moreover, it also used an access point CISCO / LINKSYS, installed in an IFTO IP network, and a video server, with VLC software, installed in the LabTVDI/UnB IP network.

Importantly, our solution shows results based on an environment in which nothing needs to be inserted into the core of the 3G operators, signalling a possible offer of transmission services, continuous video streaming, free of charge.

V. Conclusions and future works

This study provided evidence supporting our two hypotheses: i) It is possible to reduce the delay caused by the implementation of MIP. This was achieved with the methodology of MIP implementation presented. ii) The use of a SP is also effective in environments in which heterogeneous wireless networks are integrated.

Our main goal was to reduce the delay caused by a vertical handover to minimize its impacts on the receipt of videos.

Using only the techniques of mobility management, some studies have proposed solutions that reduce the latency of the handover in different layers of the OSI model.

Although we also attempted (successfully) to reduce the latency in layer 3, the reduction was not sufficient to maintain the continuity of video sessions after a vertical handover.

Other studies have presented solutions to work around this problem generated by the delay in video connections subjected to a handover. These works have tried to adapt the application to network conditions, often using techniques of video compression and selective transmission.

Our work presents the concept and implementation of a proxy session that mediates the process of accessing the video, performing an activity together between the network and the mobile, which results in effectively maintaining the quality of video received at that session connection.

As a continuation of this work, we are developing a mechanism of Admission Control (CAC), based on distributed brokers that implement a primitive MIH and that can help the mobile to identify and determine the best network to perform the handover, in order to control the entry of the mobile into networks in accordance with their demands for QoS/QoE. We intend to do this by considering brokers independently of the networks available.

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