Investigation of Mobile IPv6 and SIP integrated architectures for IMS and VoIP applications.

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Abstract— **Mobile IPv6 and SIP are protocols designed to support different types of mobility. Mobile IPv6 has been used to support mobility in IP networks and SIP has been used for Voice over IP applications. It is the signalling protocol of the IP Multimedia Subsystem (IMS). In this paper both protocols have been simulated and compared in order to observe their performance for Voice over IP (VoIP) applications. In this paper the architectures proposed by researchers in order to combine Mobile IPv6 and SIP have also been investigated and compared to analyse their advantages and disadvantages. A network scenario, running Mobile IPv6 and SIP for IMS, has also been simulated in order to evaluate the performance offered by the two protocols and to compare them with the results from the simulation of the pure Mobile IPv6 and SIP architectures. The comparison shows that the combined scenario offers better performance similar to the one obtained using only Mobile IPv6 with Route Optimization. The scenario simulated was also compared with the integrated architectures for Mobile IPv6 and SIP that were investigated.**

Index Terms—***Mobile IPv6, SIP, VoIP, Signalling Protocols.***

I. INTRODUCTION

Mobile and cellular communications have had a fast evolution in the last years. The popularity of the Internet as a platform for offering a vast variety of services and applications like Voice over IP (VoIP), audio and video streaming, IPTV (Television over Internet) and instant messaging, has caused the inclusion of some of these services in the 3° Generation of cellular networks. Taking this into consideration, the 3GPP group has been working on a standard platform called IP Multimedia Subsystem (IMS) that will allow users to maintain multimedia sessions across mobile networks. In the future the tendency is that IMS can interact with different access networks. This integration will allow the mobile users to access a variety of services without compromising their mobility.

In order to support the mobility of the users, two main protocols have been developed: Mobile IPv6 and the Session Initiation Protocol (SIP).

Mobile IPv6 is the successor of Mobile IPv4 which was developed to support mobility in IPv4 networks. Mobile IP has been used as a mobility protocol for wireless LAN and for cellular networks.

SIP is a signalling protocol that has been used mainly for VoIP applications. SIP has been selected by the 3GPP group as the signalling protocol for IMS. However, the interaction of IMS with different access networks presents a scenario where Mobile IP and SIP can interact together. This has motivated several researchers to find an architecture where the two protocols can be integrated. The main purpose of this work is to study and compare Mobile IPv6 and SIP and investigate the integrated architectures that have been proposed to combine Mobile IP with SIP. These architectures will be analysed and compared to identify their advantages and disadvantages. Another part of this work is to simulate a network scenario, where both protocols Mobile IPv6 and SIP are being used, in order to evaluate how the protocols interact, their mobility support and their performance for different applications. The simulation is done using OPNET Modeler Software [1].

This paper is organized as follows: Section II contains background information about Mobile IPv6 and SIP. The different architectures that have been proposed by several researchers to combine Mobile IP and SIP are described in Section III. Section IV shows the simulation scenarios with OPNET and their results. Finally, in Section V, the Conclusions of this paper are presented.

II. BACKGROUND

A. *Mobile IPv6*

Mobile IPv6 is a protocol designed to support the mobility of a host across networks using the IPv6 protocol (Internet Protocol Version 6). This protocol works in the network layer of the OSI model. In this way the mobility of the user is transparent to the upper layer protocols like those in the transport and application layer.

The elements of a network running the Mobile IPv6 protocol are the Mobile Node, Correspondent Node and the Home Agent [2].

The protocol operates as follows; when a Mobile Node is in its home network, it is assigned a home address. This address is in the home network and the mobile node is always

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reachable through this address. When the mobile node moves from its home network to a different network, known as the foreign network, it acquires a Care of Address. Once the Mobile Node acquires the care-of-address, it informs its Home Agent with a binding update message. This message contains the association between the home address and the new Care of Address.

The communication between the Mobile Node and the Correspondent Node can be done in two different modes. In the first mode, the Home Agent intercepts all the packets directed to the Mobile Node. The packets are addressed with the Mobile Node's home address. Then a packet sent by the correspondent Node is intercepted by the Home Agent and sent to the Mobile Node using tunnelling and the care-of address of the Mobile Node. Now, the packets sent by the Mobile Node to the Correspondent Node are tunnelled to the Home Agent and then the Home Agent sends the packets to the Correspondent Node. This process is called reverse tunnelled [2].

In the other mode of communication, also know as Route Optimization, the Correspondent Node must be IPv6 capable. In this case the Mobile Node also informs the Correspondent Node about its current Care of Address association with a binding update message. Then the Correspondent Node can send packets directly to the Mobile Node using its Care of Address. The packets sent by the Mobile Node to the Correspondent Node are routing directly to the Correspondent Node using conventional routing mechanisms [2].

B. SIP

The Session Initiation Protocol is a signalling protocol designed to establish and maintain multimedia sessions. Examples of multimedia sessions are voice over IP calls, or videoconferencing calls. In order to provide these services it works with other real protocols like RTP (Real-time Transport Protocol). The Session Initiation Protocol resides in the application layer of the OSI model, so it can work over IPv4 or IPv6.

The main elements of SIP are the following: User Agent (UA), Back-to-back User Agent (B2BUA), Proxy Servers, Registrars, Redirect Server, and Forking Proxy [3, 4].

In SIP the users are identified with a URI (Uniform Resource Indicator). This URI is similar to an email address, for example: pete.red@example.com. A user can have multiple URIs depending on its location. The association of the URI with the location of the user is maintained at the Registrar Server [3, 4].

The sessions in SIP are initiated with an INVITE message followed by an exchange of ACK and OK messages. The sessions are terminated with a Bye message. The messages are originated by the User Agent and forwarded by the Proxy Servers. In SIP the mobility of the user is achieved in the following way: when a user moves from its home network to the foreign network, two processes must happen. First the user must gain connectivity to the foreign network. This can be done using the DHCP protocol. Then the user must send a re-INVITE message to the Correspondent Node in order to resume the session and update the Correspondent Node about the new location [5, 6].

III. MOBILE IPV6 AND SIP INTEGRATED ARCHITECTURES

A. Hybrid Multilayer Mobility Management (HMMM) and Multilayered Mobility Management Scheme (MMMS)

These architectures [7, 8] use Mobile IP to handle the mobility for traffic from non-real applications over TCP and SIP is used for real-time applications that run over UDP.

In the HMMM architecture [7] a new entity is introduced called Enhanced Mobility Gateway (EMG). The EMG separates the real time traffic from the non-real time traffic. It also provides the integration between the micromobility and macromobility protocols. For non-real traffic the Mobile IP protocol is used and the traffic is tunnelled through the Home Agent to the Correspondent Node. For real time traffic the SIP protocol is used, although it is necessary to use NAT in the EMG because of the micromobility protocol (Cellular IP). The Mobile Node is identified with private areas, although if IPv6 is used this issue can be overcome.

The other architecture called MMMS [8] also uses Mobile IP for non-real time traffic and SIP for real time traffic. In order to separate the traffic a policy table is used, which is an entity that processes and forwards each packet. In this architecture the Home Agent is replaced by a new element, called the Mobile IP Location Register (MIP-LR), which stores the mapping of the IP address of the Mobile Node and its Care of Address. The MIP-LR can be replicated across the network and does not necessarily have to be located in the Home Network. The MIP-LR can examine the IP packets, in order to process the non-real time traffic with Mobile IP, and delegate the packet for real time to the SIP application for processing.

In these architectures, when the Mobile Node moves across networks, its location is updated with both the Home Agent and The SIP Server. If a SIP session is in progress, a re-INVITE message is sent to the Correspondent Node. In case a non-real time traffic session is also in progress the Correspondent Node is updated about the new binding of the Mobile Node as well.

It is important to notice that in these architectures the mobile Node must register its location twice; first with the Home Agent, then with the SIP Registrar. This introduces redundancy and a lot of signalling load in the network. It is therefore necessary to have a more efficient architecture that integrates Mobile IP with SIP.

B. Integrated Mobility Management Method using Mobile IP Home Address (INT-HA) and using Mobile IP Care of Address (INT-COA)

These are other architectures designed to integrate Mobile IP and SIP [9]. They reduce the redundancy of signalling required by using Mobile IP to support terminal mobility and SIP to support personal mobility.

In the INT-HA architecture [9] the SIP Registrar only keeps information about the Home Address of the Mobile Node, and for any change of location the new location is updated with the Home Agent. For real and non-real time traffic, the Mobile IP protocol is used to support terminal mobility. When the Mobile Node moves across networks, it updates its Home Agent with its Care of Address. Any communication with the Correspondent Node is tunnelled through the Home Agent. If the Correspondent Node sends an INVITE request to the Mobile Node, the request is sent to the Mobile Node's Home Address and the Mobile Node responds with its Home Address.

This method presents a disadvantage that all the packets to the Correspondent Node must be transmitted through tunnelling. This can cause considerably delay when the Home Network and the Foreign Network are a considerable distance apart. However this issue can be solved using route optimization, which is supported in Mobile IPv6.

In the INT-COA architecture [9] the Mobile Node's Home Address is stored in the SIP Registrar and is used to establish the session. The difference between INT-HA and INT-COA is that in the case of a handover the Mobile Node informs the Correspondent Node about its new Care of Address by sending a re-INVITE message with this information. Once the Correspondent Node acknowledges the message, the real time traffic can be sent between them without the use of tunnelling.

Although INT-COA removes the tunnelling problem, it increases the handover delay due to the interchange of re-INVITE messages between the Mobile Node and the Correspondent Node.

It must be important to mention that both architectures INT-HA and INT-COA have been designed taking into consideration Mobile IPv4. The same principle however, can be used taking into consideration Mobile IPv6.

C. Mobility Management Method Integrating Mobile IPv6 and SIP (MSIP)

This scheme [10] integrates Mobile IPv6 and SIP with changes in the algorithm of the Mobile Node but without making modifications in the protocol stack of the Agents or Servers involved. As in the two previous schemes (INT-HA and INT-COA) [9], Mobile IPv6 is used for terminal mobility and SIP is used for personal mobility. Mobile IPv6 is used to support terminal mobility for non-real and real time traffic.

In this case, if the Correspondent Node wants to initiate a SIP session with the Mobile Node, it sends the INVITE request to the Mobile Node's Home Address. If the Mobile Node is in a foreign network, it responds to the SIP request with its Care of Address. Then the traffic can be sent between the Correspondent Node and the Mobile Node directly without the use of tunnelling. If the Mobile Node moves to a different network while a SIP session is going on, it sends binding update messages about its new Care of Address to both Home Agent and the Correspondent Node, so the SIP session can continue and the traffic can be sent without tunnelling.

In this scheme it is not necessary that the re-INVITE message is sent by the Mobile Node during the handover procedure. This MSIP scheme can be seen as an evolution of the INT-HA and INT-COA architectures, because these architectures were designed taking into consideration Mobile IPv4 instead of Mobile IPv6.

D. Tighly Integrated MIP-SIP Architecture (TI-MIP-SIP)

This architecture merges the SIP and Mobile IP entities that have similar functionality [11]. The Mobile IP Home Agent, the SIP Home Registrar and the SIP Home Proxy Server are merged into a single entity called Home Mobility Server (HMS). A user is identified in SIP with an URI or Address of Record (AOR). The Home Address of the Mobile Host and the URI is stored in the HMS and then any change in the Care of Address is updated in the HMS using the Mobile IP registration [11].

The Mobile IP protocol is used for TCP traffic and SIP for UDP traffic. In the registration and signalling processes however, the messages are sent to the HMS and the Mobile IP registration message is used as well for SIP registration. Because the URI is included in the request, the redundancy is eliminated.

If the outgoing session is a TCP session, the conventional Mobile IP routing is used for the mobility. When the outgoing session is a SIP session, the SIP messages are used to support mobility. If both TCP and UDP sessions are in progress at the same time, the SIP handover messages are used for both sessions.

It must be notice that this architecture has the advantage that the Mobile Host does not have to register with two entities, since the SIP Registrar and the Home Agent are merged in the HMS. Some redundancy in the signalling is removed. During the outgoing session, however, it is still necessary to send Mobile IP signalling messages for TCP and SIP signalling messages for UDP because the architecture makes distinctions between non-real and real time traffic. Another disadvantage is that in order to implement this architecture, it is necessary to make modifications in the network in order to introduce the new entity called HMS and modifications in the protocol signalling messages are also needed.

In order to overcome the disadvantages of implementing the TI-MIP-SIP architecture, the authors also proposed the Loosely Integrated MIP-SIP architecture (LI-MIP-SIP) [11]. In this architecture, Mobile IP is used for TCP traffic and SIP for UDP traffic. The HMS is removed and the Home Agent and the SIP server are kept in the network with their own functionalities. The difference is that in this architecture, the SIP Server can obtain updated location information from the Home Agent in order to locate the user. In this way the Mobile Node does not have to send duplicate registration messages and location information in the event of a handover. If an outgoing UDP session is in progress, however, the Mobile Node must send the re-INVITE message to the Correspondent Node to re-establish the connection.

IV. SIMULATION RESULTS

The following illustrate the results of the mobile IPv6 architecture simulation and SIP architecture simulation.

The figure 1 shows the network scenario configured in OPNET Modeler for the simulation of the pure Mobile IPv6 and SIP architectures.

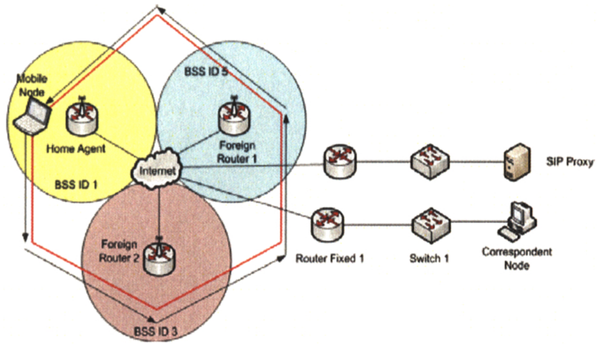

Figure 1. Pure Mobile IPv6 and SIP simulation Scenario.

The network scenario consists of a wireless network and a fixed network connected through the Internet. The Mobile Node is located in the wireless network. This network has three routers which also have Access Point functionality providing coverage for different parts of the network arranged in an Extended Service Set infrastructure. The wireless LAN served by each Access Point is identified by the BSS ID 1, 3 and 5. One of the routers is the Home Agent, and the Mobile Node is moving among the three routers following the path marked by the arrows in the figure. The wireless LAN is using 802.11b with a speed rate of 11 Mbps. Each wireless network corresponds to a different subnet. The addressing protocol used is IPv6 and the routing protocol used is RIP for IPv6 (RIPng: Routing Information Protocol next generation). For the pure Mobile IPv6 simulation the SIP proxy does not take part in the communication. Both modes, conventional Mobile IPv6 and Route Optimization, are simulated and compared in order to analyse their performance.

SIP supports personal mobility and terminal mobility at the application layer. Then, in case of a layer 3 handover, there must be a mechanism that informs the SIP proxy of the change of IP address. This is often done with the re-INVITE message. In the OPNET Modeler, however, it is necessary to configure protocols that allow terminal mobility at lower layers, since the model only supports Proxy server and does not support Registrars. The underlying mobility protocol used was Mobile IPv4.

Another network scenario was simulated. This scenario is referred to SIP-Mobile IPv6. The simulation was done using OPNET Modeler and the models provided with the software. A different SIP model was used, however, in order to illustrate the mobility provided by SIP. This new SIP model was downloaded from OPNET Support site in the contributed models section. It supports mobility between domains as well as IMS functionality since the model has options for the emulation of SIP Proxys, SIP Registrars and SIP Interrogating Servers. This SIP model used in the simulation was designed by [12].

The network scenario is shown in the next figure. Two network domains are shown, each of them under the administration of a different operator. The network domains are visitnet.com and homenet.com. The Mobile Node originally belongs to, and is registered in, its home network with the operator homenet.com. In the scenario, however, the mobile Node is visiting the network with domain visitnet.com. In the visited network the Mobile Node is moving through several wireless LAN. The Home Agent of the Mobile Node is, however, located on the wireless LAN of the Home network. Each wireless LAN represents a different network segment with a different network prefix. The Mobile Node is also establishing a Voice over IP call with the correspondent Node located in the Home Network.

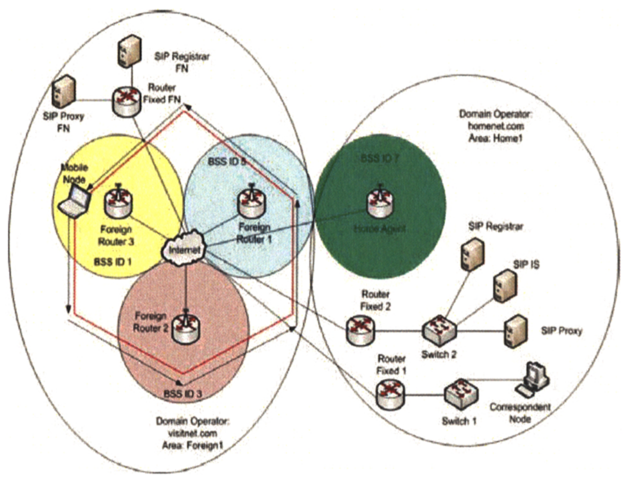

Figure 2. Scenario for Mobile IPv6 - SIP simulation

The signalling required to set up the Voice call is handled by SIP. SIP also provides mobility support across the different networks domains in order to set up the call. This SIP platform consists of the IMS signalling network elements P-CSCF, S-CSCF and I-CSCF located in the home and visited network. In this case, the access network for the Mobile Node is a wireless LAN but for the Correspondent Node the access network is an Ethernet LAN. Mobile IPv6 is used to support layer 3 terminal mobility across the different wireless networks. The Mobile IPv6 protocol is implemented using Route Optimization. The routing protocol used is RIPng.

The Figure 3 shows the comparison of the results for Jitter for the simulation of the different networks scenarios. It must be noted in the graphic that conventional Mobile IPv6 still has the biggest Jitter while Mobile IPv6 with Route Optimization offers better performance. The jitter values obtained for the SIP simulation architecture are very close to the results from the Mobile IPv6 tunnelled simulation.

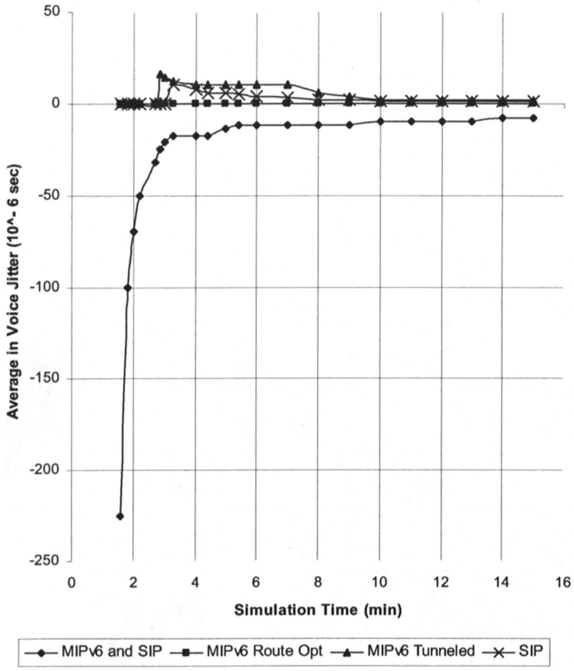

Figure 3 Jitter Results

In the figure 4 the results of the comparison for the End-to-End Delay are shown.

The delay for the SIP-Mobile IPv6 scenario is quite close for the Route Optimization scenario with values around 0.16 sec. Conventional Mobile IPv6 presents the biggest delay, with a maximum of 0.24 sec followed by the SIP scenario with a maximum value of near 0.20 sec.

The SIP-Mobile IPv6 network scenario simulated presents several differences and similarities to the integrated architectures described in the Section 3 of this paper. First in this scenario Mobile IPv6 is used to handle the Mobility of TCP traffic and SIP is used to set up the Voice over IP calls. This approach is similar to the one used in the HMMM, MMMS and TI-MIP-SIP architectures, where Mobile IP is used for applications based on TCP and SIP is used to handled the mobility for applications based in UDP. Another similarity found is that Mobile IPv6 is used to handle the terminal mobility at the network layer of the Mobile Node regardless of the type of application being used and SIP is used to handle the personal mobility and the mobility between different administrative network domains. This approach is similar to the MSIP architecture.

Another difference found is that in the architectures like HMMM and MMMS, a new entity is introduced in the network whose function is to separate the UDP traffic from the TCP traffic in order to be handled by the adequate mobility protocol SIP or Mobile IP. In the TI-MIP-SIP architecture, a new network element is introduced to merge the functions of the Home Agent and the SIP registrar. In the scenario simulated SIP-Mobile IPv6, there are no new elements or entities introduced in the network except for the SIP servers.

It must be noticed in the results that conventional mobile IPv6 shows the biggest jitter and end-to-end delay compared with SIP and Route Optimization Mobile IPv6. This is because of the tunnelled mechanism implemented in Mobile IPv6, since all the traffic must be routed through the Home Agent. Although the SIP implementation simulated uses Mobile IPv4 as an underlying mobility protocol, in Mobile IPv4 the traffic is tunnelled through the Foreign Agents and this offers less delay that the tunnelling procedure implemented in Mobile IPv6.

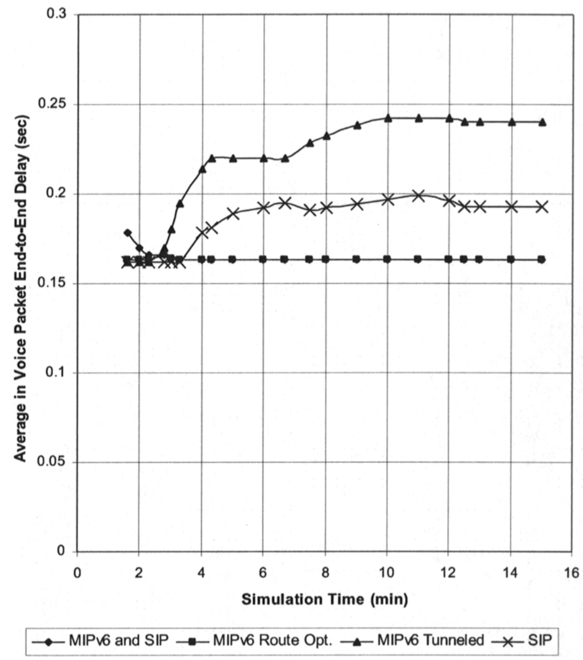

Figure 4. End-to-End Delay

V. Conclusion

The differences between Mobile IPv6 and SIP include the following; both protocols reside in different layers of the OSI Model. Mobile IPv6 is in the network layer and SIP in the application layer. Because SIP resides in the application layer, it does not require major modifications on the network except for the addition of the SIP servers and it supports personal mobility. However SIP requires more time in order to perform the handover since protocols in the application layer require more processing. SIP is also more suitable for real time applications. Mobile IPv6 supports terminal mobility, and it is suitable for real and non-real time applications. Nevertheless Mobile IPv6 requires the use of Route Optimization in order to perform fast handover and this implies an increase of the packet header. The network devices must also be capable of supporting the Mobile IPv6 protocol.

The increased delay obtained using conventional Mobile

IPv6 is due to the routing mechanism used. In conventional Mobile IPv6, all the packets to the Mobile Node must be routed through the Home Agent using tunnelling. This increases the latency, especially when the visited network is far away from the Home Network. This inconvenience is solved using Route Optimization.

HMMS and MMMS integrated architectures have as a disadvantage the fact that the Mobile Node has to register its new location twice, first with the Home Agent and then with the SIP Registrar. The introduction of the new entity also requires modifications of the network. The last also apply to the TI-MIP-SIP. In an implementation like the one simulated in the SIP-Mobile IPv6, however, does not require modifications in the network nor the introduction of new entities apart from the SIP Proxys.

The architectures INT-HA, INT-COA and MSIP have a common feature: they use Mobile IP for terminal mobility and SIP for personal mobility. The scenario simulated SIP-Mobile IPv6 uses a similar approach. Mobile IPv6 supports terminal mobility for all the applications, and SIP is used for mobility between domains when setting up voice over IP calls.

INT-HA has the disadvantage in that it uses tunnelling to send information which introduces delay in the network. INT-COA does not use tunnelling but uses re-INVITE messages between Mobile and Correspondent Node which also increases the delay because these messages are processed at the application layer. MSIP does not use tunnelling. Instead it uses the binding updates message from Mobile IPv6 to update the Mobile Node location. The same approach is used in the scenario SIP-Mobile IPv6 where Mobile IPv6 is used with Route Optimization.

The results from the simulation of the scenario SIP-Mobile IPv6, in comparison with the results obtained from the Mobile IPv6 and the SIP simulation, show that SIP-Mobile IPv6 offers the minimum delay for Voice over IP applications. In this scenario the interaction of the SIP signalling platform for IMS and Mobile IPv6 was observed. The traffic between Mobile Node and Correspondent Node is sent using Route Optimization. Some of the SIP signalling messages are, however, sent to set up the VoIP call using tunnelling.

As can be seen, due to the weaknesses and strengths of Mobile IPv6 and SIP, it would be very advantageous to study the elaboration of an architecture capable of integrating both protocols. The interaction between Mobile IPv6 and SIP, however, raises several issues that must be taken into consideration. The first is to consider what type of mobility is going to be supported by each protocol. Second is the location update of the Mobile Node. If the Mobile Node must update its location with the SIP servers and the Home Agent, then there is a redundancy in signalling overhead, which is not very efficient. Finally, the introduction of new entities and modifications in the network, as a consequence of the integrated architecture, must be considered.

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