Mobile IP Conditional Binding Update

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Abstract— **Mobile IP protocols use a correspondent registration procedure between a Mobile Node (MN) and its Correspondent Nodes (CNs) to maintain a valid and up-to-date binding association between MN's home address and its current care-of-address whenever a handover occurs. This procedure plays a key role in optimizing the routing path between the two parties by avoiding any kind of dog-leg routing across the home network or the previous visited network. However, such a procedure reveals its inefficiency in multicast communication as multicast sources do not need to know the identity of multicast receivers and to interfere with their mobility events. Without an additional intelligence on Mobile IP entities to assess the nature of the communication session established with a CN, such behavior introduces an extra processing and inefficient use of the network resources for both CN and MN. In an attempt to solve these problems, we propose a new adaptive solution to enhance Mobile IP protocols (Mobile IPv4, Mobile IPv6, and Moving Network). In this regard, we extend Mobile IP specifications with two new registration schemes: dynamic address update and non-dynamic address update in response to the multicasting nature of CN. With these two new schemes, MN and their mobility agents will be able to sense their communications and distinguish between multicast and unicast sources and therefore block sending binding information to multicast sources. We evaluate our solution by quantifying analytically the gain of the binding update messages that could be avoided in different mobility management scenarios.**

Keywords-component; *Mobile IP, IP multicast, Handover, and Binding Update.*

I. INTRODUCTION

Since the late 1990's, there has been an explosion of new Internet technologies and the Internet has become a primary medium for academic, business and focus interests. As a result, new applications continue to emerge. These applications require vastly different characteristics of the underlying network versus the original applications of the Internet. Although the original Internet was designed to carry out point-to-point IP traffic, there is an increasing need for multipoint communications (IP multicast) between different parties. Today, users need to work in a group and share audio/video data between them in real time manner. Examples of such applications include video-conferencing, distance learning, large scale content distribution, distributed computing, and TV diffusion. This demand for multiparty applications has required the interest of a large Internet research community, which focused on how to design scalable IP protocols and architecture to support these applications. However, once this issue is resolved, the applications began to evolve from demanding simple IP connectivity to seamless mobility where users can move from one attachment point to another without session interruption. This trend is a direct result of the fast development of mobile and wireless technologies. A nomadic user, who is equipped with smart and small laptop or personal data devices with wireless Internet connectivity, requires working while moving from one location to another without facing an undesirable interruption of its ongoing sessions. Unfortunately, the strengths of multicast face their limits when the member becomes mobile. Indeed, there are serious challenges and conflicts between multicast and mobility: the dynamic nature of mobile users complicates the membership management of multicast groups and the construction of optimal multicast delivery trees and their maintenance. Both basic Mobile IP and multicast protocols have to be revisited and extra enhancements are required to cope with these new challenges [11] [12].

With Mobile IP protocols, a Mobile Node (MN) can move from its home link to a foreign one. Each MN is identified by its IP Home Address (HoA) on the home network and by a Care-of Address (CoA) in the foreign network. In order to maintain undisrupted higher-level session while moving, the MN registers its CoA with its Home Agent (HA). For this purpose, an MN sends a Registration Request message (case of Mobile IPv4) or a Binding Update message (BU, case of Mobile IPv6) to its HA. This message is used to create a binding association between the MN's HoA and the MN's CoA for a given lifetime. The HA acknowledges the registration request by sending either a Registration Reply message (case of Mobile IPv4 [14]) or a Binding Acknowledgement message (case of Mobile IPv6 [16]). As soon as the HA is notified about the MN's CoA, it maintains a binding cache entry per MN that associates both HoA and CoA. Thus, when a Correspondent Node (CN), which is communicating with the MN, sends data packets to the MN's HoA, the HA intercepts them and tunnels them to the MN's CoA. Such procedure of forwarding suffers from triangle routing via the home network. To overcome this problem, route optimization extensions have been proposed to enhance the basic Mobile IPv4 and Mobile IPv6 operations. These extensions consists of bypassing the HA and routing directly the data packets from the CN to MN by using the "*Correspondent Registration*" procedure. This procedure could be initiated by MN itself (case of Mobile IPv6) or by the HA (case of Mobile IPv4) to notify any CN about the new MN's CoA. While this procedure may occurs after each handover, it plays a key role for providing a seamless mobility and optimization the routing between the two parties. Many research works have been carried out to address the different issues of the Correspondent Registration procedure and the BU delivery. However, all of the foregoing studies have not investigated the specific case where MN's correspondent node is a multicast source. Mainly, the focus was concentrated on fastening the transmission of BU [10], securing the registration process [8], optimization the path when CN is a mobile node [7], or accelerating the transmission by bicasting or multicasting the BUs [6][9]. In this regard, we propose to address the impact of a multicast enabled CN on the signaling process of Mobile IP protocols. Then, we propose an adaptive approach to control the generation of BUs by Mobile IP entities. By adaptive, is meant a mechanism that is capable to detect whether a CN is a multicast source or not, and therefore block sending BU to it if necessary. Such adaptive method is justified by the fact that the Correspondent Registration procedure is designed for unicast communication only and does not consider the extra requirement for IP multicast. In addition, there is no mechanism in Mobile IP protocol specifications that prevent an MN to initiate a Correspondent Registration procedure to any CN that may appear or not in its Binding Update List. The former is used to record the identity of CNs and track the exchange of registration messages with them. Hence, we believe that such procedure is inappropriate for the multicast context and extra functionalities have to be introduced to avoid it. Without a context awareness ability where an MN distinguishes between unicast and multicast sources, each mobile multicast receiver will generate extra registration signaling to its multicast source (CN) either directly or through a third party, in occurrence a HA or other related mobility agents. As mobile multicast gets more popular, with more and larger multicast groups, an important Correspondent Registration signaling traffic will be generated by mobile multicast receivers to multicast sources which in return will produce undesirable processing and network overheads and may affect the quality of the multicast application.

In this paper, we propose a new solution that introduces intelligence in the mobile nodes and their mobility agents to trigger the Correspondent Registration procedure based on the nature of CN. In other words, an MN or a HA has to check first whether CN is a unicast or a multicast source before sending a BU. Consequently, our solution requires respectively that MN, Mobile Routers (case of Mobile IPv6 networks), and HA (case of Mobile IPv4 networks) track if CN is sending unicast or multicast packets to them or not. According to such test, new modifications to Mobile IP protocol specification are introduced to prevent MN or mobility agent from sending binding signaling messages to IP multicast sources whenever a handover occurs. Therefore, Mobile IP entities are able to sense their environment and use the suitable registration procedure with their CNs.

Our paper is organized as follow. In Section 2, we start by introducing the background for IP multicast and Mobile IP. Then, we describe the enhancements that we have introduced to the different Mobile IP architectural entities in Section 3. In Section 4, we evaluate analytically the performance of our solution in light of the number of Binding Update messages that we avoid. Finally, we conclude by discussing the strengths and the weakness of our solution.

II. BACKGROUND

Multicasting is an efficient technique to save bandwidth. Rather than sending data to a single receiver (unicasting), or to all receivers on a given network (broadcasting), multicasting aims to deliver the data to a set of selected receivers. In IP multicast [1], a single data packet is sent by the source. The network duplicates the packet as required until a copy of the packet reaches each one of the intended receivers. Thus, IP multicast avoids processing overheads associated with replication at the source and the bandwidth overheads due to sending duplicated packets on the same link. Sending multicast data is slightly different from sending unicast data. In fact, IP multicast defines a special IP multicast address to identify the group of interested receivers. Senders (multicast sources) send to the multicast address without prior knowledge of the multicast receivers. IP multicast does not require senders to a group to be members of the group. However, to receive multicast traffic, an interested receiver requires a mechanism to join the multicast group. The receiver notifies its local router that it is interested on a particular multicast group address; the receiver accomplishes this task by using a membership protocol such as IGMP (Internet Group Management Protocol for IPv4 hosts) [2] or MLD (Multicast Listener Discovery Protocol for IPv6 hosts) [3]. To build a distribution tree from the senders to all receivers, multicast capable routers need a multicast routing protocol to handle the duplication of multicast traffic and conveying multicast packet across the built tree [13]. Today, multicast parties can be mobile. The concept of IP mobility was designed to allow IP mobile host and router to continue receiving services while moving among different IP networks. While moving, the IP address change is kept transparent to the upper application layers in order to avoid their possible interruption. To accomplish that, special protocols need to be deployed in the network for keeping track of the mobile host's current location and being able to forward packets to it upon movement. The movement from one IP network to another is called hereafter the handover. To guarantee the transparency of the handover, the IP routes between a mobile host and its correspondent host, that is the mobile host's communication endpoint, should be updated to reflect the current location of the mobile host. To achieve this, special routes are required between the mobile host and its correspondent host because the mobile host's home address can no longer be used by the conventional IP routing protocols to deliver packets to the mobile host's current location. This is because; the home address is topologically incorrect and cannot be used in foreign network due to ingress filtering restriction. For highly dynamic mobile host, the special routes should be updated regularly. Such update can be done by the mobile host itself or by a third entity on behalf of the mobile host. Depending on the location update and notification mechanisms different mobility management schemes were proposed by the Internet community to support unicast communication. Some schemes were designated to handle IP mobility of IPv4 based mobile hosts [14], where others were developed for IPv6 based ones [16]. In addition some schemes handle micro-mobility, others handle macro-mobility. Micro-mobility schemes address the mobility of a host within the same region and provide transparency to correspondent hosts, which remain unaware of movement of the mobile host within the regional network [15] [17]. On the other hand, macro-mobility schemes handle the mobility across different IP networks and administrative domains, where the whole IP route between the mobile host and its CN should be updated for each movement.

When an MN decides to join a multicast group through the foreign network, it receives the membership query messages from the local multicast router and sends back its report to it as if the MN was a stationary node. This method is simple, allows fast membership discovery, and reduces the join latency. Moreover, the MN does not relies on its HA to keep awareness and defend its membership. Alternatively, an MN can join a multicast group using the home subscription or the bi-directional tunneling approach, which relies on the Mobile IP architectural entities (HA and MN) and uses multicast router located in the home network. In this approach, the HA should be multicast enabled and it is responsible of forwarding periodically multicast group membership control messages to its mobile receiver whenever this latter is away from home. To join a multicast group, the MN establishes a bi-directional tunnel with its HA and tunnels its membership report message to the HA. The membership report is encapsulated within the same tunnel header used for routing unicast packets between the HA and the MN. When the HA receives this membership message, it decapsulates and forwards it to the local multicast router on the home link. The local multicast router referenced by (MR) in Figure 1, intercepts this membership message and sends a join message to the nearest on-tree router of the multicast delivery tree.

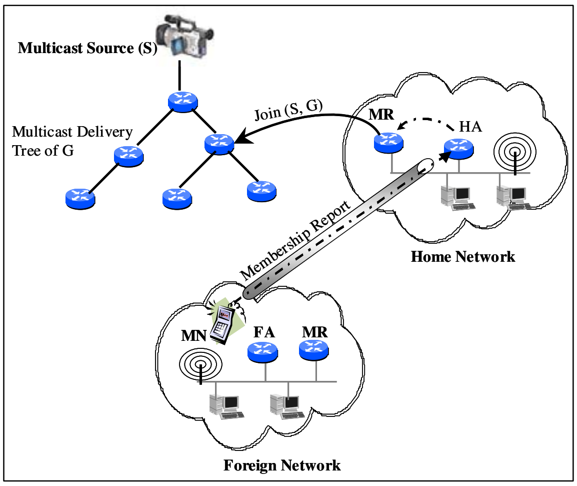

Figure 1. Home Subcription approach

Once the multicast branch is established, the HA forwards the incoming multicast packets down the tunnel to the MN. To do so, the HA should implement the functionalities of a multicast proxy and maintains the list of MNs that have requested to join multicast groups. When the mobile receiver moves to a new foreign network, it does not need to re-join the multicast group since the HA is already informed about its membership. However, the MN requires registering again its new CoA and may initiate a Correspondent Registration procedure with the multicast source. In fact, this procedure does not specify explicitly what is the expected behavior from an MN if this latter is member of a multicast group. In our knowledge, the current specification of all Mobile IP protocols do not have investigated in depth the impact of the multicast membership on the binding signaling mechanisms. Therefore, without an extra awareness from an MN to sense and adapt its binding signaling transmission in a per communication basis, a considerable number of mobile multicast receivers could overwhelm a multicast source with a significant and unnecessary mobility binding signaling traffic. In case of a many-to-many multicast communication such as a distributed military application where all the members could be simultaneously sender and receiver, each mobile member will send, receive and probably refresh periodically binding signaling information with the remaining members. In a highly mobile and dynamic environment, such behavior seems to be prohibitively expensive in terms of traffic load and processing overhead that may result. In brief, mobile nodes need to sense their environment and autoconfigure themselves in a smart way to use efficiently their resources.

In the next sections we will describe how we could eliminate such undesirable impact on the network performance. In addition, we detail how to implement our solution with respect to the existing mobility management protocols.

III. Conditional Binding Update

In order to guarantee a seamless IP mobility, the Mobile IP protocols have introduced the Correspondent Registration procedure between MN and their CNs to optimize the routing and avoid the triangle routing across the home network. However, in the context of multicast application with mobile receivers, such mechanism is unnecessary for many reasons. First, following the current Mobile IP specification (Mobile IPv4 and Mobile IPv6), there is no method that prevent an MN or a HA from initiating the Correspondent Registration procedure with the known CNs. Secondly, if such behavior occurs, any CN can request periodically to refresh its binding information whenever the lifetime of an MN's CoA expires. For this purpose, the CN sends a binding refresh request message to MN, which may misuse the rare power resources of mobile devices if it is highly solicited. Moreover, IP multicast is by nature receiver-initiated and the source does not require knowing the identity of the receivers. Therefore, if mobile receivers are not prevented from sending binding information to the multicast source, this latter may be overwhelmed with unnecessary traffic. To solve these problems, we propose to enhance Mobile IP specifications (Mobile IPv4, Mobile IPv6, and Moving Network) by introducing two registration modes. In the first mode called "**dynamic address update**", an MN and eventually a mobility agent, continues to send normal binding update messages to CN to optimize the routing. This mode is similar to the current Mobile IP specification proposed by the IETF. However, it is only applied for unicast sources. In the former mode called "**non-dynamic address update**", an MN or a mobility agent analyses first whether a CN is a multicast source or not and autoconfigures itself to stops sending binding messages to it. With these two modes, the mobile receiver will be able to distinguish multicast sources from unicast ones and reacts accordingly. In the next sections, we will detail the extensions that we have introduced to Mobile IP protocols to implement our solution. Then, we evaluate analytically the binding signaling overhead that we our solution eliminates in basic, hierarchical, and moving network mobility management scenarios.

A. *Case of Mobile IPv4 based protocols*

In Mobile IPv4 the Correspondent Registration procedure is initiated by the Home Agent (HA) on behalf of the Mobile Node (MN). To implement our solution, we suggest introducing a new data structure called Correspondent Binding List. This list will be maintained and updated by a HA to cache binding messages related information that were sent to CNs. Typically, a HA sends binding messages to CN to order it to send packet directly to the new MN's CoA and therefore avoid encapsulation them. In this context, we propose that each entry of this Correspondent Binding List should contain the following fields:

- The global unicast address of the CN.
- A unicast flag (**U**). This flag is set to 1 if the CN is a unicast source for the MN.
- A multicast flag (**M**). This flag is set to 1 if the CN is a multicast-source-only node with respect to MN.
- The initial lifetime of the BU.
- The remaining lifetime of the BU.
- The sequence number.
- The time at which a BU was last sent to this destination.
- The state of any retransmissions needed for this BU.
- A security associated for this CN if required.

The HA relies on the destination address of all the packets sent by the CN and the multicast membership information that it hold about its MNs to check if the CN is a multicast source or not. If the **M** flag is set to 1, the HA does not send a Binding Update message to CN. Consequently, the HA autoconfigure itself to operate under the non-dynamic address update mode for this specific CN. Otherwise, it switches back to the basic dynamic address update mode, which is similar to the current behavior of Mobile IPv4 protocol. In this situation, all the fields of Correspondent Binding List will be updated and the M flag will be set to 0. If CN is simultaneously a unicast and a multicast source for MN, the dynamic address update mode is preferred.

B. *Case of Mobile IPv6 based protocols*

Compared to the Mobile IPv4 based protocols, in Mobile IPv6 based protocols (Mobile IPv6, FMIPv6, HMIPv6 and Moving Network), an MN initiates itself the Correspondent Registration procedure and therefore sends Binding Update message to CN upon each movement. To avoid sending such message to a multicast source node, the MN, respectively an MR (Mobile Router), checks the destination address of all the IP packets that it has already received either directly or through the Mobile IP bi-directional tunnel. If the destination address is a multicast address, the MN, respectively an MR (Mobile Router) does not send a Binding Update message to CN. In such case, the MN will operate under the non-dynamic address update mode with the CN.

To implement our solution, we add a simple extension to the Correspondent Update List that is already designed by Mobile IPv6 based protocols and that is maintained by each Mobile Node and Mobile Router. Our extension consists of introducing a two new flags to this list to differentiate between unicast and multicast source-only node. Therefore, the list will contain the following fields:

- The IPv6 address of the CN.
- A unicast flag (**U**). This flag is set to 1 if the CN is a unicast source with respect to MN.
- A multicast flag (**M**). This flag is set to 1 if the CN is a multicast-source-only node with respect to MN.
- The MN's home address or the previous CoA.
- The CoA address of the BU.
- The initial lifetime of the BU.
- The remaining lifetime of the BU.
- The sequence number.
- The time at which a BU was last sent to this destination.
- The state of any retransmissions needed for this BU.
- A permission denied flag for security purposes.

For a Mobile IPv6 Router, the HoA and the CoA fields are replaced respectively by the home and foreign network prefixes. Therefore, based on the type of the communication between MN and CN, an MN or an MR will switch to the appropriate address update mode and updates the Correspondent Update List.

C. *Advantages and limitations*

Our solution is simple and has many advantages. First, our solution is applicable to all Mobile IP protocols. This means that our solution can be applied to any mobile receiver entity that is a member of a multicast group. Second, our solution is easy to implement as it does not change the format of the Binding Update message used in the Correspondent Registration procedure. Third, our solution is independent of the standardization status (optional or mandatory) of the Correspondent Registration procedure in various Mobile IP protocols. Our solution makes an enhancement to these protocols, as an implementation improvement that does not interfere with the operation of these protocols. Fourth, our solution is independent of the methods of how IP multicast is delivered to the mobile receiver entity. In other words, it may be applied to both the Remote Subscription and the Home Subscription based approaches or any hybrid approach. Finally, our solution is generic enough to cover future alternative and/or enhanced technologies in the support of IP mobility and mobile multicast. The benefits to be gained from our solution are most substantial with regard to the wireless bandwidth available to the mobile receiver entity. This bandwidth is limited and potentially costly and we save it significantly as we will demonstrate in the next section.

IV. PERFORMANCE EVALUATION

We evaluated the gain of our solution with respect to the number of avoided Binding Updates messages (BUs) that could be sent to a multicast source. This number depends on the number of mobile receivers and their corresponding handover frequencies within a multicast group. To compute the handover frequencies of a given MN, we used an analytical model, which relies on the study done by [4] and [5]. We compute the number of the expected handovers of a given MN by using two mobility managements: basic IP mobility [14] [16] and hierarchical mobility [15] [17]. Using these handover frequencies, we compute the number of BUs for a given multicast group.

A. *Handover frequencies*

In order to reflect the mobility of users and their calling habits in a consistent way, we used an analytical model. This model uses the handoff probability, which is defined as the probability that a call needs at least another handover before its completion. Such probability is useful for the design of predictive schemes and for the computation of network performance parameters such as the handoff traffic rate, packet loss, etc. The handover frequency depends on MN's motion within cell geometry [5]. To vary the handover frequency, we considered two parameters: the *cell residence time* and the *call holding time* [4]. These two parameters fluctuate according to the overall scenery and the actual mobility event. In our simulation we assumed that the cell residence time is exponentially distributed with parameter η and that the holding time is exponentially distributed with parameter α. By using these two parameters, we are able to compute the probability for the occurrence of a handover and the number of expected handovers. We have computed the value of these two metrics in the two cases: basic Mobile IP and hierarchical Mobile IP schemes. From the number of handovers, we derive the number of binding messages.

1) *Basic IP mobility management*

According to [4] the probability for the occurrence of a handover from one cell to another in basic IP mobility management is:

$$P_{Handover} = \frac{1}{1+\rho}, where, \rho = \frac{\alpha}{\eta} \qquad \text{Eq (1)}$$

From Equation 1, we can compute the number of expected handovers ($\varepsilon_{Handovers}$) as a function of ρ which is called hereafter the "*Call-to-Mobility Factor*".

$$\varepsilon_{Handovers} = \sum_{i=1}^{\infty} i.(\frac{1}{1+\rho})^i = \frac{1}{1+\rho^2} + \frac{1}{1+\rho} \qquad \text{Eq (2)}$$

2) *Hierarchical mobility management*

In case of hierarchical mobility management model, we assume that each Domain Mobility Agent (DMA) such as MAP (HMIPv6) or GFA (HMIPv4) serves **K** downstream Mobility Agents (MA) such as Access Routers and Foreign Agents. The parameter K indicates the attachment points where an MN can move from its home network.

In this case, the cell residence time changes to $\eta_{DMA}^{-1} = \sqrt{K}.\eta_{MA}^{-1}$ and the handover probability changes to

$$P_{Handover} = \frac{1}{1+\sqrt{K}.\rho} \qquad \text{Eq (3)}$$

From the previous equation, we can compute the number of expected handovers ($\varepsilon_{Handovers}$) as a function of ρ and **K**.

$$\varepsilon_{Handovers} = \sum_{i=1}^{\infty} i.(\frac{1}{1+\sqrt{K}.\rho})^i = \frac{1}{1+K\rho^2} + \frac{1}{1+\sqrt{K}.\rho} \qquad \text{Eq (4)}$$

B. *Number of Binding Updates*

The number of BUs that an MN or its corresponding mobility agent may send to a multicast source during a given multicast session is proportional to the number of expected handovers that an MN may have. This number depends on the mobility management schemes and varies from the IPv4 context to the IPv6 one. In case of IPv4 mobility management (basic or hierarchical), this number can be calculated analytically to:

$$\beta(MIPv4)_{Bindings} = N * \varepsilon_{Handovers} \qquad \text{Eq (5)}$$

where **N** is the number of mobile receivers within a given multicast group and ($\boldsymbol{\varepsilon}_{\mathbf{Handovers}}$) is the expected handovers per member in both the MIPv4 and the HMIPv4 protocols.

In case of IPv6 mobility management (basic or hierarchical), the number of BUs is accompanied by a similar amount of HoTi and CoTi messages, which are required for the Return Routability procedure used to secure the exchange of BU. If we assume that these messages are equivalent to a BU message, and that they are exchanged only once (during the first handover occurrence) per a given multicast session, then the number of BUs in case of IPv6 mobility management will be:

$$\beta(MIPv6)_{Bindings} = N*(2+\varepsilon_{Handovers}) \qquad \text{Eq (6)}$$

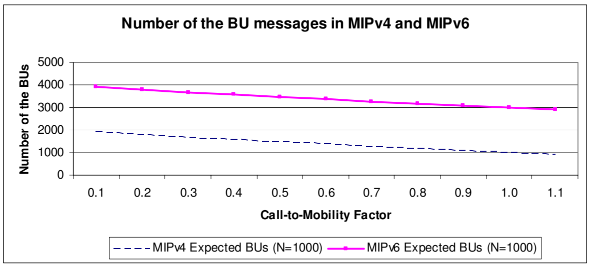

Figure 2. Expected BUs in MIPv4 and MIPv6 as function of ρ

As Figure 2 illustrates the number of BUs that our solution avoids in case of IPv6 is higher than that of IPv4. This is due to fact that mobile receivers establish a security association before sending BU messages to the multicast source. In addition, the number of expected BUs decreases as the handover frequency decrease. This is justified by the fact that the handover probability is decreasing as the mobility is lower (i.e. when the call-to-mobility factor is higher).

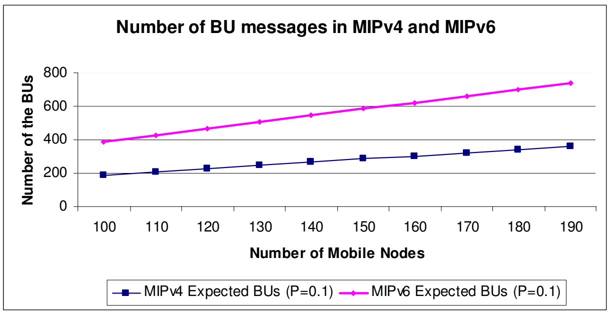

Figure 3. Expected BUs in MIPv4 and MIPv6 as function of the number of Mobile Nodes

From the results represented by Figure 3, 4, 5 and 6, we conclude also that our solution has similar results for the mobility hierarchical management schemes. In summary, our solution avoids all the expected number of BU messages as zero BU message is sent when an MN or a mobility agent autoconfigures itself with the non-dynamic address update mode in multicasting context. Consequently, we save the network bandwidth and the processing resource of both mobile receivers and multicast sources. Obviously, the gain will be more important in case of a many-to-many multicast application with highly mobile members.

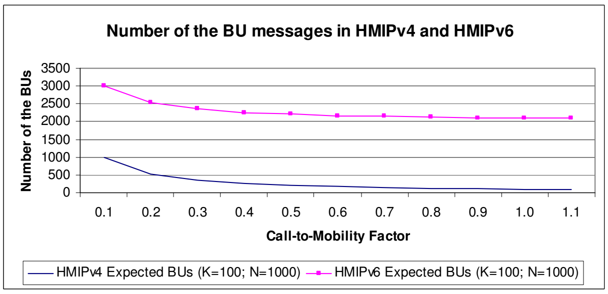

Figure 4. Expected BUs in HMIPv4 and HMIPv6 as function of ρ

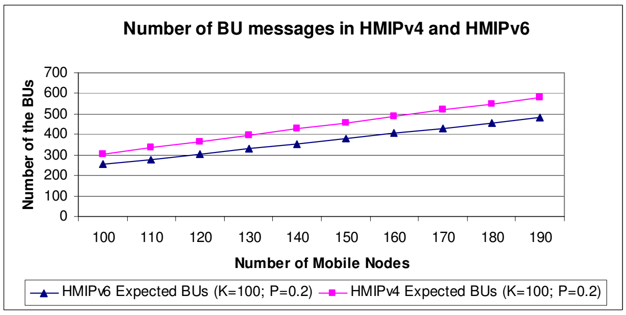

Figure 5. Expected BUs in HMIPv4 and HMIPv6 as function of the number of Mobile Nodes

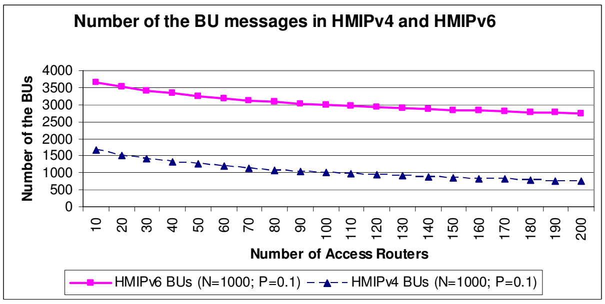

Figure 6. Expectation Values of BUs in HMIPv4 and HMIPv6 as function of the number of Access Routers

V. CONCLUSION

In this paper we have presented a new solution, which avoids exchanging Binding Update messages between mobile receivers and multicast sources based on the multicast characteristic of the source. We have evaluated the performance of our solution with respect to the number of bindings that we can avoid during a given multicast session. We computed this number by considering different mobility management schemes and IP network infrastructures (IPv4 and IPv6). We found that our solution avoids more binding messages in case of the Mobile IPv6 based schemes compared to Mobile IPv4 based ones as Mobile IPv6 uses a Return

Routability procedure between MN and CN to secure BU messages. Moreover, the number of bindings increases if the number of multicast sources increases. Thus, our solution optimizes the support of IP multicast for mobile parties by identifying and eliminating unnecessary Mobile IP Correspondent Registration signaling. Without this technique and intelligence in the Mobile IP architectural entities, the amount of Mobile IP Correspondent Registration signaling produced tend to be significant given the nature of IP multicast with many multicast receivers. In the mobile wireless environment, such reduction of signaling is also important in the wireless link. We believe that the new registration schemes that we have introduced are relevant as IP multicast applications will increase in the future. For a many-to-many multicast application with mobile members, the number of bindings may affect the session performance since every member will receive/send binding from/to all other members. This impact may increase in case of short sessions with highly mobile receivers. While we strongly believe that our solution modifies slightly the current Mobile IP protocol specifications, we think that our solution is generic enough to cover future alternative and/or enhanced technologies in the deployment of IP mobility and mobile multicast and it is easy to implement. The benefits to be gained from our solution are most substantial with regard to the wireless bandwidth available to the mobile receiver entity.

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