Performance Analysis of Multicast Mobility in a Hierarchical Mobile IP Proxy Environment*

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Abstract

Mobility support in IPv6 networks is ready for release as an RFC, stimulating major discussions on improvements to meet real-time communication requirements. Sprawling hot spots of IP-only wireless networks at the same time await voice and videoconferencing as standard mobile Internet services, thereby adding the request for multicast support to real-time mobility.

This paper briefly introduces current approaches for seamless multicast extensions to Mobile IPv6. Key issues of multicast mobility are discussed. Both analytically and in simulations comparisons are drawn between handover performance characteristics, dedicating special focus on the M-HMIPv6 approach.

1 Introduction

Mobility Support in IPv6 Networks [1] is expected to become a proposed standard within these days. Outperforming IPv4, the emerging next generation Internet infrastructure will then be ready for implementation of an *elegant*, transparent solution for offering mobile services to its users.

At first users may be expected to cautiously take advantage of the new mobility capabilities, i.e. by using Home Addresses while away from home or roaming their desktop 'workspaces' between local subnets. Major scenarios in future IPv6 networks, though, move towards the convergence of IP and 3GPP devices, strengthening the vision of ubiquitous computing and real-time communication. The challenge of supporting voice and videoconferencing (VoIP/VCoIP) over Mobile IP remains, as current roaming procedures are too slow to evolve seamlessly, and multicast mobility waits for a convincing design beyond MIPv6 [3].

Synchronous real-time applications s. a. VoIP and VCoIP place new demands on the quality of IP services: Packet loss, delay and delay variation (jitter) in a constant bit rate scenario need careful simultaneous control. A spoken syllable is about the payload of 100 ms continuous voice traffic. Each individual occurrence of packet loss above 1%, latencies over 100 ms or jitter exceeding 50 ms will clearly alienate or even distract the user. Serverless IPv6 voice or videoconferencing applications s. a. the DaViKo software [4],[5] need to rely on mobility management for nomadic users and applications [6] as well as multicast support on the Internet layer.

Challenges are tightened by multicast-based group communication. In conferencing scenarios each member commonly operates as receiver and as sender. A mobile environment consequently needs to cope with the tardy source specific construction of multicast routing trees.

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Our ongoing work is concerned with the design and the analysis of multicast mobility solutions. In the present paper we focus on the essential performance aspects of handovers as applied in the currently available Internet Drafts Fast Multicast Protocol for MIPv6 [7] and M-HMIPv6 [8]. Following a simple reference model, these aspects are measured quantitatively both, in theory and in simulations.

This paper is organised as follows. In section 2 we discuss related works on multicast mobility and briefly introduce the currently available Internet drafts M-HMIPv6 and M-FMIPv6. Section 3 formalises evaluation criteria and presents our results, derived from analytical models as well as stochastic simulations. Conclusions and an outlook follow in section 4.

2 Multicast Mobility Management

2.1 Generals

Multicast group communication raises quite distinctive aspects within a mobility aware Internet infrastructure: On the one hand Multicast routing itself supports dynamic route configuration, as members may join and leave ongoing group communication over time. On the other hand multicast group membership management and routing procedures are intricate and too slow to function smoothly for mobile users. In addition multicast imposes a special focus on source addresses. Applications commonly identify contributing streams through source addresses, which must not change during sessions, and routing paths in most protocols are chosen from destination to source.

In general the roles of multicast senders and receivers are quite distinct. While a client initiates a local multicast tree branch, the source may form the root of an entire source tree. Hence multicast mobility at the sender side poses the more delicate problem.

Three principal approaches to multicast mobility are commonly considered (see [9] and [10] for a detailed discussion): Bi-directional Tunneling (BT), Remote Subscription (RS) and Agent-based approaches. The MIPv6 draft proposes BT through Home Agents as a minimal multicast support for mobile senders and listeners. Since Home Agents remain fixed, mobility is completely hidden from multicast routing at the price of triangular paths. In BT the Mobile Node always uses its Home Address for multicast operations. In the contrary, Mobile Nodes following a RS strategy always utilize their link-local addresses, thereby displaying all movements to multicast routing. Routing in turn adapts to optimal paths, on the price of unpredictably slow handovers. A mobile source sending with its link-local address remains immobile with respect to application persistence, as multicast sessions are source address aware.

A discussion on various Agent-based approaches is ongoing. Suggestions converge in tunneling multicast traffic through agents at fixed positions within the network. They diverge in the way agents are positioned, in the roles they attain and their interactions with multicast routing protocols. Two aspects we would like to stress in the spirit of our discussion:

- Multicast agents should remain in close distance to the mobile multicast member, as extensive tunnels seriously impact network performance.
- The multicast network components should comply with unicast mobility infrastructure.

Agent support has also been proposed to MIPv6 unicasting, to smooth and accelerate handover procedures. A proxy architecture for Home Agents introduces the Hierarchical MIPv6 [11] as a counter measure on topological dependencies, when Home Agents are

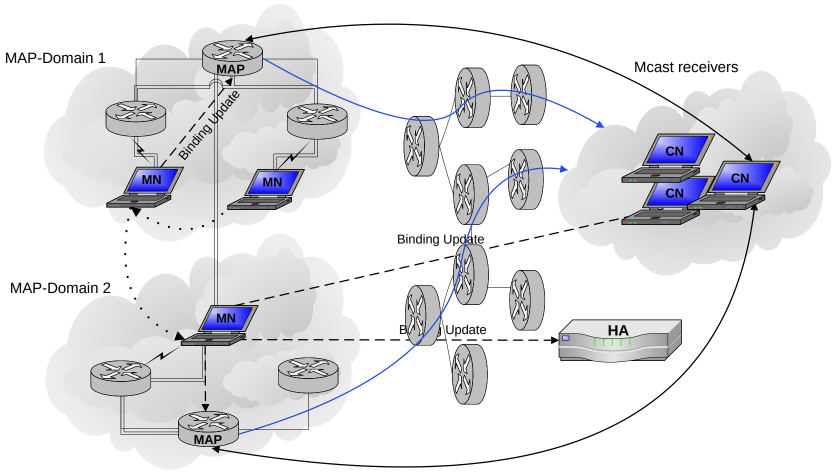

Figure 1: Multicast handover for M-HMIPv6 senders.

located in far distance. Latency hiding based on predictive handovers has been added to IPv6 mobility by the Fast MIPv6 [12] proposal. Handover negotiations in FMIPv6 are performed at access routers, which act as topology aware forwarding agents.

The two multicast mobility approaches introduced below are built on top of either one of these unicast agent approaches. Little modifications to HMIPv6 resp. FMIPv6 signaling are requested and both proposals remain neutral with respect to multicast routing protocols in use.

2.2 M-HMIPv6 — Multicast Mobility in a HMIPv6 Environment

"Seamless Multicast Handovers in a Hierarchical Mobile IPv6 Environment (M-HMIPv6)" [8] extends the Hierarchical MIPv6 architecture to support mobile multicast receivers and sources. Mobility Anchor Points (MAPs) as in HMIPv6 act as proxy Home Agents, controlling group membership for multicast listeners and issuing traffic to the network in place of mobile senders.

All multicast traffic between the Mobile Node and its associated MAP is tunneled through the access network. Handovers within a MAP domain remain invisible in this micro mobility approach. In case of an inter–MAP handover, the previous anchor point will be triggered by a reactive Binding Update and act as a proxy forwarder. A Home Address Destination Option, bare of Binding Cache verification at the Correspondent Node, has been added to streams from a mobile sender. Consequently transparent source addressing is provided to the socket layer. Bi-casting is used to minimize packet loss, while the MN roams from its previous MAP to a new affiliation (s. fig. 1). A multicast advertisement flag extends the HMIPv6 signaling.

In cases of rapid movement or crossings of multicast unaware domains, the mobile device remains with its previously associated MAP. Given the role of MAPs as Home Agent proxies, the M-HMIPv6 approach may me viewed as a smooth extension of BT through the Home Agent supported in basic MIPv6.

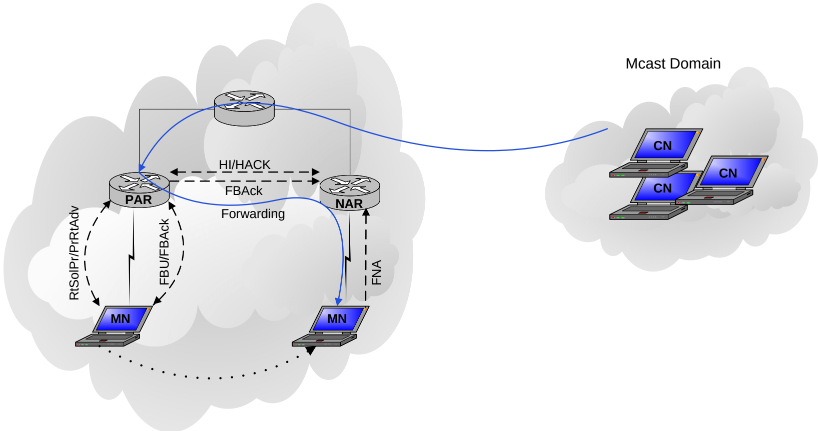

Figure 2: Multicast handover for Fast MIPv6

2.3 M-FMIPv6 — Multicast Mobility in a FMIPv6 Environment

"Fast Multicast Protocol for Mobile IPv6 in the Fast Handover Environments" [7] adds support for mobile multicast receivers to Fast MIPv6. On predicting a handover to a next access router (NAR), the Mobile Node submits its multicast group addresses under subscription with its Fast Binding Update (FBU) to the previous access router (PAR). PAR and NAR thereafter exchange those groups within extended HI/HACK messages (s. fig. 2). In the ideal case NAR will be enabled to subscribe to all requested groups, even before the MN has disconnected from its previous network. To reduce packet loss during handovers, multicast streams are forwarded by PAR as unicast traffic in the FMIPv6 protocol.

Due to inevitable unreliability in handover predictions — the layer 2 may not (completely) provide prediction information and in general will be unable to foresee the exact moment of handoff — the fast handover protocols depend on fallback strategies. A reactive handover will be performed, if the Mobile Node was unable to submit its Fast Binding Update, regular MIPv6 handover will take place, if the Mobile Node did not succeed in Proxy Router inquiries. Hence the mobile multicast listener has to newly subscribe to its multicast sessions, either through a HA tunnel or at its local link. By means of this fallback procedure fast handover protocols must be recognised as discontinuous extensions of the MIPv6 basic operations.

3 Analysis of Multicast Handover Schemes

3.1 Aspects of Relevance

Both handover approaches introduced in the previous section attempt to assure the continuous reception of real–time data streams for mobile multicast listeners. M–HMIPv6 uses a reactive handover mechanism, whereas M–FMIPv6 prefers to fulfill a handover prediction, with a fallback to a reactive procedure.

To evaluate these schemes in a comparative analysis, let us first fix the relevant qualitative aspects:

Handover performance: packet loss, delay and jitter occur, while the Mobile Node switches between networks. Packets are lost, while it is disconnected and no packet buffering takes effect. Delay and jitter are added by the handover procedure, if packets are buffered or transmitted through indirect paths.

Number of performed handovers determines the frequency of changes between networks, while the Mobile Node moves.

Number of processed handovers denotes the frequency of handover procedures processed within the infrastructure. The processed handovers may exceed the actual handover completions, as predictive techniques tend to initiate artificial handover procedures.

Overhead in signalling and traffic distribution depends on the handover protocols in use and places an extra burden to mobility tasks.

Robustness is the expression of dependence of the handover performance on changes in network geometry or rapid movement.

The above aspects summarize the amount of disturbance produced by the roaming procedures, the effort of support requested from the networking infrastructure and the overall price to be paid in overhead costs.

3.2 Handoff Performance

In the event of a Mobile Node switching between access networks, it may completely disconnect from the link layer. Thereafter it needs to perform an IP reconfiguration and Binding Updates to its infrastructure. Until completion of all these operations the MN is likely to experience disruptions or disturbances of service, as are the result of packet loss, delay and jitter increases. In general the handover process decomposes into the geometry independent local handoff, the Layer 2 link switching and the IP readdressing, and the geometry dependent Binding Update activities. Consequently the following decomposition of temporal handover holds:

$$t_{handoff} = t_{L2} + t_{local-IP} + t_{BU}. \quad (1)$$

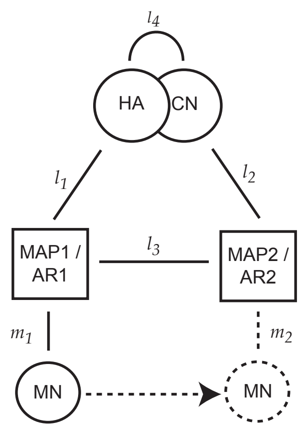

Figure 3: A simple analytical model

Both multicast mobility schemes under consideration attempt to optimize the non-local update procedures by means of proxying and anticipating delay hiding techniques.

To proceed into a more detailed analysis of the handover schemes, we consider a simple analytical model (s. figure 3) in this section: A MN moves from access router 1 (AR1) to access router 2 (AR2) with intermediate 'link' l_3. From it we will analytically derive basic properties and present a stochastic simulation of handover performance on its basis.

Within this model ARs have been identified with mobility anchor points 1 and 2 for comparative reasons. This simplification merely affects the link dimensions m_1/m_2 to the MN, which may not assumed to be of one-hop-type, but nevertheless small. Distances l_1 and l_2 to HA or CN must be viewed as possibly large and represent the strongest topological dependence within the model. The distance between the access routers, l_3, should be viewed as a variable, but characteristic geometric entity. As the MN moves between