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MI3M: A framework for media independent multicast mobility management

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ABSTRACT

The evergrowing explosion in data generation and consumption is of paramount relevance for network operators. Operators strongly rely on techniques which enable efficient and scalable high-bandwidth data distribution, while coping with stricter user expectations in increasingly demanding scenarios, such as mobility in heterogeneous accesses. Primarily designed for efficient transport, IP multicast will be crucial for the successful deployment of video services such as Personal Broadcasting, but faces several technical limitations in such mobile scenarios.

This work proposes a novel architecture enabling media-independent multicast mobility management of both multi-interface sources and receivers, while assuring efficient multicast data transport. The architecture provides localized mobility management through PMIPv6 protocol, and is supported by IEEE 802.21 for handover optimization. A full implementation was deployed in a physical testbed, enabling its evaluation in two main scenarios: receiver and source mobility. Its evaluation from the network and video consumer perspective shows that our scheme results in minimal handover impact in mobile multicast environments, for both consumers and producers.

1. Introduction

The mobile data boom is simultaneously a threat and an opportunity for mobile operators, allowing them to finally improve their role beyond a bit pipe of Internet access providers, while challenging current mobile networks capacity. With the scale of today's networks, transport efficiency is of paramount importance.

Designed for efficient data transport, IP multicast might prove as a valuable mechanism to overcome such challenges. While its inclusion within operator networks found initial inertia due to issues like difficult service management, it has been incrementally incorporated for delivering services such as IPTV. With the definition of clearer use cases in mobile scenarios, its support within cellular networks is closer to real deployment with 3GPP's evolved Multimedia Multicast Broadcast Service (eMBMS) [1]. The massive increase in user content production is expected to originate novel scenarios and services where not only the content subscribers, but also the multicast source [2] are on the move, also referred as Personal Broadcasting Services [3]. With the proliferation of devices such as GoPro cameras and wearables like Google glasses in the near future, a variety of scenarios such as real time journalism in warfare or natural catastrophes, and the live showcase of a locality or city during seasonal festivities to a group of subscribed users are to be expected. As with unicast communications, IP multicast was not designed taking into account mobility scenarios, with the resulting issues depending on the role performed by the Mobile Node (MN) or the adopted communication model [4]. For instance, receiver mobility has local impact only, while source mobility affects all subscribed users. Such

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complexity has led to partial solutions, first in Mobile IPv6 (MIPv6) [5], and more recently in its network-based counter-part, Proxy Mobile IPv6 (PMIPv6) [6], which is being addressed in Multicast Mobility (MULTIMOB) Work Group [7]. For instance, some solutions preserve IP multicast efficiency in mobility environments, but do not provide fast multicast mobility. Additionally, there's no reference on how to jointly support multicast mobile receivers and sources when deploying Protocol Independent Multicast (PIM) in Mobility Access Gateways (MAGs), although such is described for source mobility [8].

Adding to this, limited work was focused at the specificities of multicast mobility within heterogeneous environments. A switch between interfaces means buffering, address and general connectivity management challenges, and there is no holistic approach harmonically providing seamless IP multicast mobility, which limits its wide adoption in mobile networks. IEEE 802.21 Media Independent Handover (MIH) [9] is a popular technology proposed for mobility management in heterogeneous scenarios. It enhances and facilitates mobility procedures (e.g. network selection and handover) in heterogeneous access technologies by providing a framework able to (1) abstract the specificities of each link technology and (2) exploit that abstraction to control and obtain information from such links within a geographical area.

In this work, we follow two design goals: avoid multicast transport inefficiency driven from tunnel replication and minimize service disruption due to a host handover. For meeting these goals, we apply multicast routing instead of typically considered Multicast Listener Discovery (MLD) Proxy [10], and propose the use and extension of IEEE 802.21 as the common multicast mobility enabler and facilitator, as opposed to solutions relying on a stack of redundant and costly mechanisms and protocols. We present a full architecture enabling mobility for multicast MNs in PMIPv6, which leverages on the interaction between IEEE 802.21 and multicast routing information for supporting transparent mobility for multicast MNs, either when acting as receivers – achieved via MIH-triggered multicast context transfer – or as senders – through proactive source path tree reconstruction.

The contributions of this work can thus be summarized as follows:

- Design of a novel cross-layer architecture using MIH messages, enabling integrated multicast receiver and source mobility support in both homogeneous or heterogeneous PMIPv6 environments. For the former, MIH triggers and assists the multicast context transfer, and updates the multicast service interface if needed, solving the subscription latency on receiver mobility; in the latter, MIH aids in the multicast tree (re)construction, enabling transparent multicast source mobility support for both Any Source Multicast (ASM) [11], where users subscribe to a group, and Source Specific Multicast (SSM) [12], where users subscribe to group IP address – source IP address pair, also referred as channel. More on the two models is presented in Section 2.1.
- Extensive comparison between different state of the art network mechanisms devised for alleviating or avoiding multicast service disruption during receiver handover.
- Implementation, validation and integration of the architecture in a physical testbed, leveraging on multicast routing,[1] PMIPv6[2] and IEEE 802.21[3] open source solutions, and lessons learned from this.
- Extensive performance evaluation of the architecture for two relevant scenarios – multicast source and receiver mobility – both from a network and user perspective.

The structure of the article is the following. Section 2 presents a brief description of base technologies, before dwelling into problems and previous works regarding multicast support in mobility environments, in Section 3. Section 4 scrutinizes different receiver mobility solutions, providing a gap analysis to be filled by the solution developed. In Section 5, the proposed architecture is described, enlisting involved modules and respective functionality. In Section 6, the adopted implementation setup is described, and the architecture is evaluated by assessing network performance and perceived quality measurements under two different scenarios: source mobility and receiver mobility. Finally, the paper is concluded in Section 7.

2. Base concepts

In the following section, a review of the three base technologies for our work is presented: IP multicast, PMIPv6 and IEEE 802.21.

2.1. IP multicast

IP multicast services rely on two main network functions: IP multicast subscription management and multicast routing. The former function, using Internet Group Management Protocol (IGMP) [13] in IPv4, or MLD [14] in IPv6, provides multicast routers with awareness to interested receivers and respective subscriptions; it is complemented by the latter function, which allows routers to build the transport paths or multicast trees for delivering multicast traffic.

Throughout this document we focus on IPv6, and thus on MLDv2. MLD is an asymmetric protocol where receivers send MLD Reports stating their interests towards multicast routers, which process these and operate according to the multicast routing protocol. Protocol Independent Multicast (PIM) is a popular family of multicast routing protocols which do not implement its own topology discovery mechanism, but instead use information supplied by unicast routing protocols. Two relevant derivations from this protocol include PIM Sparse Mode (PIM-SM), originally designed for ASM model only, and its SSM mode PIM Source-Specific Multicast (PIM-SSM) [15].

In a shared media Local Area Network, there may be more than one multicast router. A Designated Router

[1] http://fivebits.net/proj/mrd6/.
[2] http://helios.av.it.pt/projects/opmip.
[3] http://atnog.av.it.pt/odtone/.