Unencapsulated Mobile Multicast Routing for Next Generation Video Networks

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Abstract. Mobile multimedia communication will particularly rely on IP multicasting, as users commonly share frequency bands of limited capacities. This paper is dedicated to the problem of mobile Source Specific Multicast (SSM) senders. We propose extensions to multicast routing for transforming (morphing) previous delivery trees into optimal trees rooted at a relocated source. This extension scheme only requires basic signaling mechanisms, explicit joins and prunes. First evaluations grounded on real-world Internet topologies indicate network performance superior to traditional distribution schemes. As corresponding application we further on introduce a videoconferencing and communication software of distributed architecture. It is built as a simple, ready-to-use scheme for distributed presenting, recording and streaming multimedia content over next generation unicast or multicast networks.

1 Introduction

Mobile visual devices accepting synchronous or streaming media become more and more ubiquitous. It is a challenge for the next generation Internet and its recently released MIPv6 [1], to introduce voice and video conferencing over IP (VoIP/VCoIP) to mobiles, so that IP will be pervasive and prevalent across all digital communication devices. Conferencing parties will then soon request seamless real–time performance of a mobility aware group communication service, thereby attaining the simultaneous roles of mobile multicast listener and source. Intricate multicast routing procedures, though, are not easily extensible to comply with mobility requirements. Significant effort has been already invested in protocol designs for mobile multicast receivers. Only limited work has been dedicated to multicast source mobility, which poses the more delicate problem [2, 3].

Source Specific Multicast (SSM) [4], still in its design process, is considered a promising improvement of group distribution techniques. In contrast to Any Source Multicast (ASM), optimal source trees are constructed immediately from (S, G) subscriptions at the client side, without utilizing network flooding or RendezVous Points. Source addresses are to be acquired by out of band channels,

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which for conferencing is easily achieved by SIP. As a consequence, routing simplifies significantly, but invalidates with source addresses changing under mobility. SSM source mobility is known as an unsolved problem.

Addresses in Internet mobility carry the dual meaning of logical *and* topological identifiers. While MIPv6 operates dual addresses transparently at end points, SSM routing needs to account for logical subscription *and* topological forwarding. In the present paper we start from this observation and present an approach to SSM routing, which adapts to source mobility. This scheme operates fast, efficient without encapsulation and does not cause additional packet loss.

This paper is organized as follows: In section 2 we review the basic problems of SSM source mobility and related work. Section 3 introduces our new approach and presents first evaluations. The subsequent section 4 is dedicated to our group conferencing application, discussing selected deployment scenarios. Finally section 5 gives conclusions and an outlook.

2 The Mobile Multicast Source Problem

2.1 Problem Statement

Any next generation Internet support for multicast source mobility management is required to operate transparently w.r.t. the socket layer. Specific protocol operations or extensions are thus bound to a multicast aware MIPv6 stack and the Internet routing layer. Recalling the address duality problem, modified multicast routing protocols must be foreseen, as routing at the occurrence of source movement is required to transform any (S, G) state into (S', G), while listeners continue to receive multicast data streams. Hence any simple mobility solution such as the remote subscription approach of MIPv6 [1] loses its receivers and will no longer function in our context.

With SSM an additional address problem needs consideration: A multicast listener, willing to subscribe to an (S, G) state, needs to account for the current location of the mobile source. Concurrently a general intricacy derives from the principle decoupling of multicast source and receivers: Any multicast source submits data to a group of unknown receivers and thus operates without feedback channel. Address updates on handovers of an SSM source have to proceed without means of the mobile source to inquire on properties of the delivery tree or the receivers.

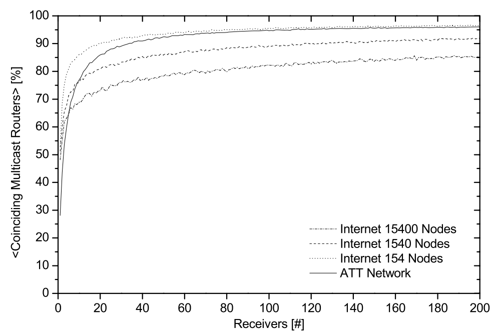


Fig. 1. Relative router coincidence in subsequent multicast trees

All of the above severely add complexity to a robust multicast mobility solution, which should converge to optimal routes and, for the sake of efficiency, should avoid data encapsulation. Bearing in mind characteristic applications, i.e. multimedia distribution, handover delays are to be considered critical. The distance of subsequent points of attachment, the 'step size' of the mobile, may serve as an appropriate measure of complexity. Figure 1 visualises the relative change of distribution trees as a function of receiver multiplicity for a medium step size of 5. It is interesting to note that even in large networks 75 to 85 % of multicast distributing routers remain unchanged under a mobility step. For details of the simulation we refer to section 3.

2.2 Related Work

Two principal approaches to SSM source mobility are presently around.

Bi-directional Tunneling: The MIPv6 standard proposes bi-directional tunneling through the home agent as a minimal multicast support for mobile senders and listeners. In this approach the mobile multicast source (MS) always uses its Home Address (HoA) for multicast operations.

Inter–Tree Handovers: Several authors propose to construct a completely new distribution tree after the movement of a mobile source. These schemes have to rely on client notification for initiating new trees. At the same time they need to preserve address transparency to the client. To account for the latter, Thaler [5] proposes to employ binding caches and to obtain source address transparency analogous to MIPv6 unicast communication. Initial session announcements and changes of source addresses are to be distributed periodically to clients via an additional multicast tree based at the home agent. Source–tree handovers are then activated on listener requests. Jelger and Noel [6] suggest handover improvements by employing anchor points within the source network, supporting a continuous data reception during client–initiated handovers. Even though it has not been applied to SSM, additional work is of relevance to this paper:

Tree Modification Schemes: Very little attention has been given to procedures, which modify existing distribution trees to continuously serve for data transmission of mobile sources. In the case of DVMRP routing, Chang and Yen [7] propose an algorithm to extend the root of a given delivery tree to incorporate a new source location in ASM. Focusing on interdomain mobile multicast routing in PIM-SM, the authors in [8] propose a tunnel–based backbone distribution of packets between newly introduced "Mobility-aware Rendezvous Points" (MRPs). Finally O'Neill [9] suggests a scheme to overcome reverse path forwarding (RPF) check failures originating from multicast source address changes, by introducing an extended routing information, which accompanies data in a Hop-by-Hop option header.

3 Tree Morphing: An Algorithm to Source Mobility

3.1 Introducing Routing Trees Adaptive to Mobility

In the present section we will briefly introduce our new concept of multicast routing, adaptive to source mobility. A mobile multicast source (MS) away from home will transmit *unencapsulated* data to a group using its HoA on the application layer and its current CoA on the Internet layer, just as unicast packets are transmitted by MIPv6. In extension to unicast routing, though, the entire Internet layer, i.e. routers included, will be aware of the permanent HoA. Maintaining address pairs in router states like in binding caches will enable all nodes to simultaneously identify (HoA, G)–based group membership and (CoA, G)–based tree topology.

When moving to a new point of attachment, the MS will alter its address from previous CoA (pCoA) to new CoA (nCoA) and eventually change from its previous Designated multicast Router (pDR) to a next Designated Router (nDR). Subsequent to handover it will immediately continue to deliver data along an extension of its previous source tree. Delivery is done by elongating the root of the previous tree from pDR to nDR (s. fig. 2). All routers along the path, located at root elongation or previous delivery tree, thereby will learn MS's new CoA and implement appropriate forwarding states.

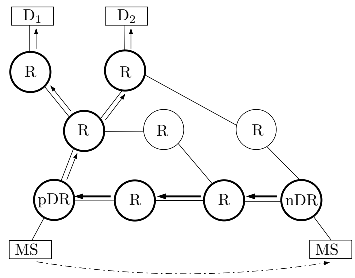


Fig. 2. Elongation of the Tree Root

Routers on this extended tree will use RPF checks to discover potential short cuts. Registering nCoA as source address, those routers, which receive the state update via the topologically incorrect interface, will submit a join in the direction of a new shortest path tree and prune the old tree membership, as soon as data arrives. All other routers will re-use those parts of the previous delivery tree, which coincide with the new shortest path tree. Only branches of the new shortest path tree, which have not previously been established, need to be constructed. In this way the previous shortest path tree will be morphed into a next shortest path tree as shown in figure 3. Note that this algorithm does not require data encapsulation at any stage.

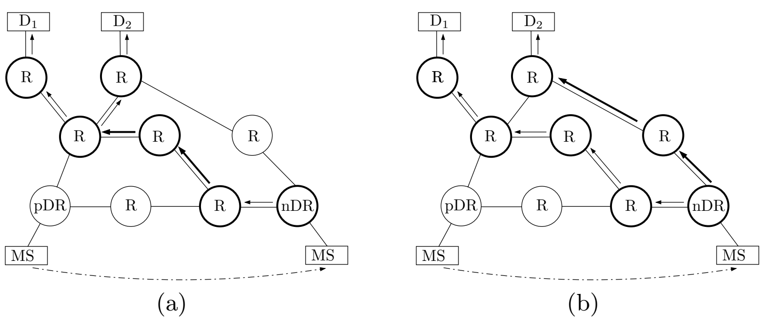


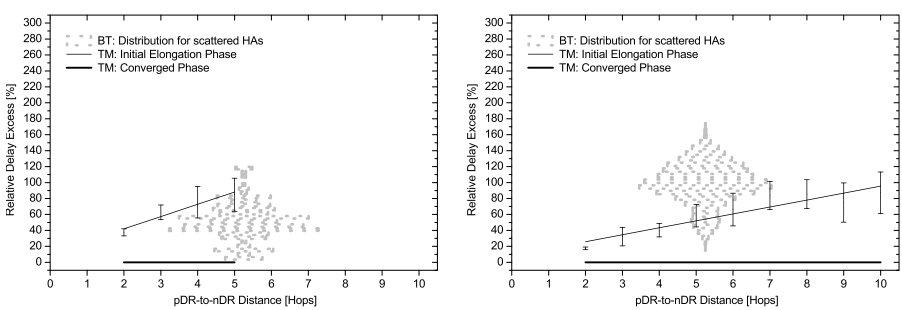
Fig. 3. Morphing States

3.2 Performance Evaluation & Simulation

Mobility initiated handovers may in general lead to packet loss and delay. The tree morphing multicast routing scheme will not produce any packet loss in addition to mobile IP handovers, as can be easily concluded from primary packet forwarding relying on unicast source routes. For a first evaluation measure we will subsequently concentrate on handover initiated packet delay as a result from initially suboptimal delivery trees. Based on real-world Internet topologies we simulate the packet distribution and compare our results to the bi-directional tunneling approach [1], which currently is the only stable mobility solution for SSM source mobility.

We analyze its delay effects within realistic Internet topologies. We performed a stochastic discrete event simulation based on the network simulator platform OMNeT++ 3.1 [11] and several real–world topologies of different dimensions. The selection of network data in our simulation must be considered critical, as key characteristics of multicast routing only make an impact in large networks, and as topological setup fixes a dominant part of the degrees of freedom in routing simulations.

We chose the ATT core network [12] as a large (154 nodes), densely meshed single provider example. For inter–provider data we extracted sub-samples of varying sizes from the "SCAN + Lucent" map [13]. Sample sizes, 154, 1.540 and 15.400 nodes, vary by two orders of magnitude. The delay excess relative to optimal routes has been calculated as characteristic performance measure under the assumption of homogeneous link delays. Extreme values, i.e. maximal delays at initial elongation phase and minimal after convergence, were evaluated for tree morphing (TM) as functions of the distance from pDR to nDR. Comparisons are drawn with bi-directional tunneling (BT), which does not depend on designated router distances, but on HA position. The delay excess in BT as function of HA position does not converge to a characteristic value, but rather admits a broad distribution derived from scattering HA positions uniformly. It should be noted that these simulations concern delays for all three distribution trees in



(a) ATT Core Network (b) Internet 15.400 Nodes

Fig. 4. Excess Delay of Optimal Routes: Comparison of BT and TM, Initial and Converged Phase, for Different Network Topologies

presence and thus qualitatively cover the solutions discussed in section 2. Aside from signaling overhead, BT reflects the delays of [5], TM those of [6].

The results of our simulations are displayed in figure 4. pDR to nDR distances were chosen between 2 and 10, except for the ATT network, which exhibits a maximal edge router separation of 5. Error bars indicate the standard deviation of initial TM delay excess, as calculated from events differing in location of the mobile source. Delay excess distributions for scattered HAs in BT are laid underneath TM curves in grey dots. It can be observed that initially maximal delays of the tree morphing scheme tend to remain below the average of permanent BT packet retardation. Convergence of the TM then will lead to (relatively) undelayed packet delivery, which is never met in BT. Little dependence on network size becomes visible for TM — relative delays more strongly change with topologic characteristics. In a densely meshed provider network such as the ATT core, packet transitions are rapid and therefore initial delays from tree elongation account more dominantly for our relative measure. In the contrary it is interesting to note that delays from BT admit a systematic dependence on network size. The tree morphing even in its initially weakest phase exhibits fairly uniform performance, no matter how large the underlying network is (see [10] for a more detailed analysis).

4 A Distributed Video Communication System

4.1 The Basic Software

In this section we introduce a digital audio-visual conferencing system, realised as a server-less multipoint video conferencing software without MCU developed by the authors[14]. It has been designed in a peer-to-peer model as a lightweight Internet conferencing tool aimed at email-like friendliness of use. The system is built upon a fast H.264/MPEG-4 AVC standard conformal video codec implementation [15]. It is a Baseline profile implementation, optimized for real-time decoding and encoding by several accelerating measures like diamond shape motion search, MMX enhanced SAD motion estimation, fast mode selection and a fast subpel search strategy. There is also application-tailored fast wavelet-based video codec [16] used for higher available data rate. By controlling the coding parameters appropriately, the software permits scaling in bit rate from 24 to 1440 kbit/s on the fly. All streams can be transmitted by unicast as well as by multicast protocol. Audio streams are prioritized above video since audio communication is more sensitive to distortions in erroneous networks.

An application-sharing facility is included for collaboration and teleteaching. It enables participants to share or broadcast not only static documents, but also any selected dynamic PC actions like animations including mouse pointer movements. All audio/video (A/V) - streams including dynamic application sharing actions can be recorded on any site. This system is equally well suited to intranet and wireless video conferencing on a best effort basis, since the audio/video quality can be controlled to adapt the data stream to the available bandwidth.

The joined use of high bandwidth UDP traffic with TCP updates bound to real-time demands is known to suffer from distortions due to TCP traffic suppression. Application sharing in conferencing applications thus is endangered to encounter disruptions in the event of network congestion. For a service enhanced synchronous use of UDP media sessions and application sharing with reliable data transport requirements, we implemented end-to-end load balancing employing proprietary extensions to UDP, reliable (RUDP), we work on its packet identifiers to control application sharing data flows. On the occasion of a significantly many (e.g., 5) unacknowledged packets, we slow down video packet transmission to reserve required resources for real-time application updates. Audio communication remains undisturbed of load-balancing actions.

4.2 Application Scenarios

Based on the systems capabilities, various new scenarios for synchronous and asynchronous distributed learning and communication evolve:

(i) *Synchronous distributed learning scenario:* Teacher and students are connected by LAN or WLAN, establishing mutual connections. The teacher can send his PC presentations and applications to the students PCs. Students (outside or inside the lecture room) can participate active and/or passive by real-time audio/video with latencies (in LANs) well below 50 ms. Since all participants can send their presentations or applications via WLAN to a beamer in a conference room, this can be used as a "wireless" connected beamer which can present full video formats. All participants can also initiate cooperations in small groups, so that each student within the peer–to–peer network can share and work on any PC applications for collaboration. There is also a live streaming option.

(ii) *Asynchronous distributed learning scenario:* Each station can record all sessions. The recordings can be stored locally or made netwide accessible a by converting it e.g. into a MS streaming format and uploaded to an e-learning platform. Lecture room presentation or distributed group work are thus ready to be played back anywhere at any time by streaming video.

(iii) A *fast broadband conference version* of the system is in operation to connect two distant medical campuses in Berlin city by high resolution video. The presentations are digitized by a high performance XGA frame grabber. This video stream will be encoded with a very fast software wavelet-based codec.

(iv) The system has been used for *tests with mobile video over UMTS* transmissions within a convergence project carried out by Fraunhofer Research Institute Berlin and local companies. It aims to seamlessly interconnecting WLAN, UMTS 3Gbeyond (4G) and DVB services. Results from the T–Mobile network using a Multimedia Network Card show varying bandwidth results for the upstream direction. With TCP we observed in subsequent measurements of 30s intervals 26 – 59 kbps and with UDP 48 kbps (with 4 % loss) to 54 kbps (2 % loss). The downstream direction is less critical for our scenario. We received 211 kbps over TCP and 338 kbps without loss over UDP, also measured in 30 s intervals. Typical echo round trip delays were around 500 ms. These experiments show that mobile video over UMTS works in principle with reasonable quality.

5 Conclusions and Outlook

In this paper we discussed the mobility problem in multicast routing and presented and analysed a novel scheme to solve it by morphing a previous distribution tree into a new shortest path tree. Correspondingly a video conferencing and communication software was introduced ready for immediate use mobile Internet multicasting. In future work we will embed this application in SSM-capable extensions of SIP dialogs. Further on we will quantify and compare further characteristic measures of the multicast routing scheme.

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