Exploring the Routing Complexity of Mobile Multicast – A Semi-empirical Study *

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ABSTRACT
Protocol extensions for a mobile Internet have been developed within the IETF, but a standard design of mobile multicast is still awaited. Multicast routing, when adapting its distribution trees to moving listeners or senders, needs to newly established forwarding states. In this paper we quantize the number of states minimally required for servicing listener or sender mobility. Independent of the actual routing protocol in use, these results serve as an inherent measure of complexity for multicast mobility management. Results are based on current Internet measurements and a topological analysis from network simulations. They show a surprisingly low mobility overhead as compared to general multicast forwarding state management.

Keywords
Multicast mobility management, Internet topology, measurement, shortest path trees

1. INTRODUCTION
Many of today's mobile devices carry individual IP addresses and Internet services are expected to extend to mobility management in the near future. Voice and video (group) conferencing, as well as large scale content distribution (e.g., IPTV) and massive mutliplayer games (MMORPGs) are considered the key applications for the next generation ubiquitous Internet. Inexpensive, point-to-multipoint enabled technologies such as 802.16 or DVB-H/IPDC emerge on the subnetwork layer and facilitate large-scale group communication deployment. Unlike point-to-point mobility and despite of ten years of active research, mobile multicast protocol development is still in an early, premature state [1].

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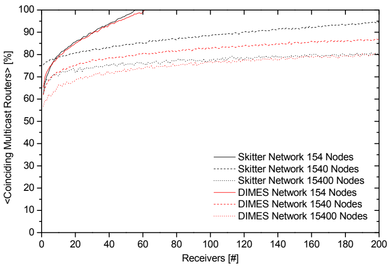
The complexity of multicast forwarding state management, as already present in static environments, may be recognized as one of the major reasons for hesitant engagement at the IETF. To acchieve optimal routing, any client subscribed to a group while in motion, requires delivery branches to pursue its new location. Any mobile source requests the entire delivery tree to adapt to its changing positions. However, multicast distribution trees arising from handover scenarios are not independent, but highly correlated. It is the aim of this paper to give realistic quantitative estimates on handover-initiated state establishment and thereby to provide a minimal bound on the complexity of mobile multicast routing. Our analysis concentrates on source specific shortest path trees (SPT) and is therefore valid for shared and source specific tree protocols at the receiver side, but restricted to SPT based routing for senders.

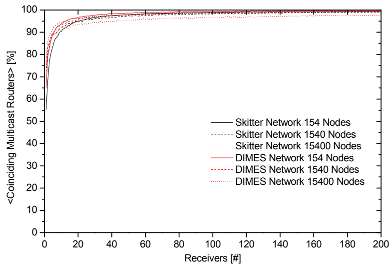
The methodic work along with the developed toolchain is described in section 2. Results are presented and discussed in section 3, which includes conclusions.

2. SIMULATION ANALYSIS & TOOLS
The effect of source or receiver movement on the stability of shortest path trees is directly addressed by constructing and comparing multicast distribution trees. As key characteristics of multicast shortest path trees only make an impact in large networks, and as topological setup fixes a dominant part of the degrees of freedom in routing simulations, realistic Internet topology data is needed for our analysis. For comparison we select two distinct data sources from current large-scale measurement projects Skitter [2] and DIMES [3] and perform multicast simulations on these topologies in parallel and for different dimensions. IP level measurements of October 2006 are converted to a uniform syntax by our BRITE im- and export extensions. Skitter data is aggregated over all monitor points, DIMES data must be pre-processed to revise incorrect node identifiers causing a distorted hop recognition, otherwise.[1] The creation of subgraphs with a size of 154, 1540 and 15400 nodes has been performed on the "Map Sampling" algorithm

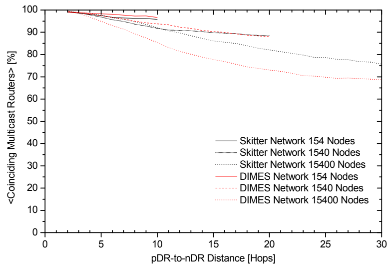
[1]The BRITE extensions and the pre-process script can be downloaded at www.realmv6.org/brite-extension.html.



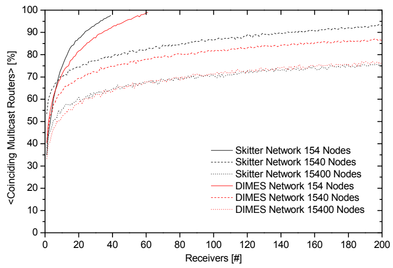
(a) Mobile receiver



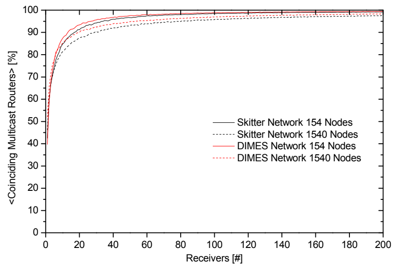
(b) Mobile sender



(c) Mobile sender



(d) Mobile receiver



(e) Mobile sender

Figure 1: Relative router coincidence for subsequent multicast trees at pDR-nDR distances 5 & 10

[4], which we also integrated in the topology generator BRITE for generating a comprehensive tool chain.

The multicast tree analysis has been realized based on the network simulator OMNeT++ 3.1. In detail, we uniformly sample receivers and sources as attached to, and designated multicast routers from the edge nodes of the given topology data sets. Edge nodes are identified as routers of degree one and represent transition points to 'customer' networks within the Internet core systems. A source resp. *one* receiver node is selected as mobile and moved from previous (pDR) to next designated router (nDR). The routing distance from pDR to nDR forms a basic measure of mobility impact and is chosen at varying but predefined hop count. The next distribution tree is then spanned from the nDR to all receivers in the mobile source scenario and with altered branch on the path from source to the mobile in the receiver scenario. These trees are then analyzed w.r.t. changes in forwarding interfaces.

3. SEMI-EMPIRICAL RESULTS

Results for the relative change of distribution trees as a function of receiver multiplicity are shown in figure 1 for a step size of 5 (1(a), 1(b)) and 10 hops (1(d), 1(e)), as well as a function of DR-distances (1(c)). It is noteworthy that even in large networks and for moderate receiver numbers more than 80% of multicast tree routes remain fixed under a handover.

An increasing number of receivers within the network will broaden its coverage with distribution states and lead to lower state changes under mobility (cf. 1(a) - 1(e)). Conversely, the decreasing stability of multicast SPTs for increasing mobility impact is clearly visible from figure 1(c). When comparing mobility scenarios, it is noticeable that network size significantly influences multicast tree stability only for moving receivers, due to the relevance of receiver-to-overall-node ratio. Source movement remains fairly unaffected, which suggests a scaling law argument, i.e., a self-similar nature of multicast (sub-)trees added at distance in larger networks.

The coincidence rate for receivers remains below the results for mobile sources. Even though a moving source changes the tree root, its leaves represented by fixed receivers remain unchanged and advance the correlation of mobility related distribution trees. This scenario does not apply for mobile receivers and the results suggest that the intersection between the old and the new tree is located close to the mobile. In the overall it can be concluded that the stability of multicast distribution trees under mobility is surprisingly large, which raises hope for an efficient solution in the near future.

4. REFERENCES

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