Large-Scale Measurement and Analysis of One-Way Delay in Hybrid Multicast Networks

Sebastian Meiling, Thomas C. Schmidt, and Matthias Wählisch
smeiling@ieee.org, t.schmidt@ieee.org, waehlisch@ieee.org

Internet Technologies Group
HAW Hamburg, Germany

October 24th, 2012
Motivation
Why Multicast

Evolution of Internet Applications
- IPTV, Software-Updates
- OSNs, MMORPGs, AV-Conferencing
- Sensor networks, Internet of Things

Common communication pattern
- Global distribution systems and interactive services
- Group communication: one-to-many and many-to-many

Demand for Internet-wide group communication service.
Motivation

Why Multicast

Evolution of Internet Applications
- IPTV, Software-Updates
- OSNs, MMORPGs, AV-Conferencing
- Sensor networks, Internet of Things

Common communication pattern
- Global distribution systems and interactive services
- Group communication: one-to-many and many-to-many

Demand for Internet-wide group communication service.
Motivation
Why Multicast

Evolution of Internet Applications
- IPTV, Software-Updates
- OSNs, MMORPGs, AV-Conferencing
- Sensor networks, Internet of Things

Common communication pattern
- Global distribution systems and interactive services
- Group communication: one-to-many and many-to-many

Demand for Internet-wide group communication service.
Agenda

1. Hybrid Multicast
2. Methodology
3. Measurement Setup
4. Measurement Results
5. Conclusion & Outlook
Hybrid Multicast

Problem Statement

Multicast Challenges

- Many flavors (ASM, SSM) and technologies (IP, OLM, ALM)
- Divergent states of deployment, no global multicast service
- No standardized, generic API covering all multicast variants

Must select multicast technology at compile time!

Hybrid Multicast

- Inter-connect heterogeneous multicast technologies
- Approaches: Universal Multicast, Island Multicast, and H∀Mcast

Is hybrid multicast performance suitable for global group communication applications?

Sebastian Meiling

iNET – HAW Hamburg
Problem Statement

Multicast Challenges

- Many flavors (ASM, SSM) and technologies (IP, OLM, ALM)
- Divergent states of deployment, no global multicast service
- No standardized, generic API covering all multicast variants

**Must select multicast technology at compile time!**

Hybrid Multicast

- Inter-connect heterogeneous multicast technologies
- Approaches: Universal Multicast, Island Multicast, and ∀Mcast

**Is hybrid multicast performance suitable for global group communication applications?**
Problem Statement

Multicast Challenges
- Many flavors (ASM, SSM) and technologies (IP, OLM, ALM)
- Divergent states of deployment, no global multicast service
- No standardized, generic API covering all multicast variants

Must select multicast technology at compile time!

Hybrid Multicast
- Inter-connect heterogeneous multicast technologies
- Approaches: Universal Multicast, Island Multicast, and H∀Mcast

Is hybrid multicast performance suitable for global group communication applications?
Simulation Results

- Estimator for hybrid multicast schemes based on empirical data\(^1\)

\(^1\)Wählisch et al. *An a Priori Estimator for the Delay Distribution in Global Hybrid Multicast*, ACM SIGCOMM CoNEXT’09 Student Workshop
Overview

- Evolutionary architecture to enable a universal multicast service
- Common multicast API\(^2\) with an abstract naming scheme introducing a locator-identifier split for multicast groups
- Inter-domain Multicast Gateways (IMGs) to connect multicast domains of different technologies and administration

Software Components

- Common Multicast API (C++, Java)
- System-centric Middleware (C/C++)
- Localhost socket based IPC API ↔ MW
- Technology modules (C/C++)

\(^2\)Wählisch et al. A Common API for Transparent Hybrid Multicast, IRTF Draft
Evaluating Multicast

Measurement Considerations

- Multicast decouples sending and receiving nodes (connectionless)
- Typical unicast metrics such as RTT not suitable for multicast
- Analyzed metrics: one-way packet delays, link stress, routing paths
- Go large scale and real world: utilize Planet-Lab (PL) testbed

Multicast Packet Tracking

- Trace selected packets along paths in hybrid multicast networks
- Use extended packet tracking framework (Fraunhofer FOKUS)

\(^a\)Santos et al. *Multi-hop Packet Tracking for Experimental Facilities*, ACM SIGCOMM’10 Demo Session
Evaluating Multicast

Measurement Considerations

- Multicast decouples sending and receiving nodes (connectionless)
- Typical unicast metrics such as RTT not suitable for multicast
- Analyzed metrics: one-way packet delays, link stress, routing paths
- Go large scale and real world: utilize Planet-Lab (PL) testbed

Multicast Packet Tracking

- Trace selected packets along paths in hybrid multicast networks
- Use extended packet tracking framework (Fraunhofer FOKUS)\(^a\)

\(^a\)Santos et al. *Multi-hop Packet Tracking for Experimental Facilities*, ACM SIGCOMM’10 Demo Session
Evaluating Multicast

Measurement Considerations

- Multicast decouples sending and receiving nodes (connectionless)
- Typical unicast metrics such as RTT not suitable for multicast
- Analyzed metrics: one-way packet delays, link stress, routing paths
- Go large scale and real world: utilize Planet-Lab (PL) testbed

Multicast Packet Tracking

- Trace selected packets along paths in hybrid multicast networks
- Use extended packet tracking framework (Fraunhofer FOKUS)\(^a\)

\(^a\)Santos et al. *Multi-hop Packet Tracking for Experimental Facilities*, ACM SIGCOMM’10 Demo Session
Clock Synchronization
In the Planet-Lab Testbed

Problem
- Manual clock synchronization not allowed on PL nodes
- Average clock offset was > 1 s for most nodes

Solution
- Continuously save clock offset of each node during experiments
- Adapt packet timestamps before further processing steps
- Used weighted average of clock offset to counteract variability
Clock Synchronization
In the Planet-Lab Testbed

Problem
- Manual clock synchronization not allowed on PL nodes
- Average clock offset was $>1$ s for most nodes

Solution
- Continuously save clock offset of each node during experiments
- Adapt packet timestamps before further processing steps
- Used weighted average of clock offset to counteract variability
Framework
Overview on Components

(A) Obtain Clock Offset

(B) Save Clock Offset

(C) Packet Tracking Data

Methodology
Test Setup

Deployment

- 200 Nodes at 100 globally different Planet-Lab sites
- Hybrid multicast based on H\textregistered Mcast implementation
- 100 receivers, other nodes as IMGs and multicast forwarder
- Messages with 1000 B \textit{payload} at interval of 1 s

Multicast Technologies

- (emulate) IPv4 multicast in edge-network domains
- Scribe ALM to inter-connect multicast islands
Scenarios

**Unicast**
- Each receiver (N) known to sender
- N separate send operations

**Hybrid Switched**
- Large overlay multicast domain
- 1 IMG and 1 IP receiver per site

**Hybrid Routed**
- Interconnect geographically close domains
- 1 IMG or forwarder and 1 receiver per site
One-Way Message Delays I
End-to-End Distribution

![CDF graph showing delay distribution for hybrid routed, hybrid switched, and unicast.]
One-Way Message Delays II
Average & Maximum

- Average and maximum message delays over all receivers
- Additional delay for hybrid schemes influenced by placement of Scribe rendez-vous point relative to sending nodes
- Hybrid routed limits maximum delay at around 700 ms
Relative Delay Penalty
Average (RAD) and Maximum (RMD)

- RAD
- RMD

Relative Penalty
- Hybrid switched
- Hybrid routed

Sebastian Meiling
iNET – HAW Hamburg
Link Stress Analysis
Absolute and Statistical Results

- Maximum link stress of unicast amounts to number of receivers
- Hybrid multicast limits link stress, thereby reducing network load
- Unicast exhibits large standard deviation and confidence interval
Conclusion & Outlook

Summary

- Method for large scale measurements of hybrid multicast in real-world deployment on the Planet-Lab testbed
- Results demonstrate feasibility and suitability of hybrid multicast communication for dissemination group applications
- Interactivity constrained by high deviation in packet delays
- Hybrid multicast limits link stress and eliminates bottlenecks

Future Work

- Analysis individual components of hybrid multicast system
- Improve performance for interactive group applications
Conclusion & Outlook

Summary

- Method for large scale measurements of hybrid multicast in real-world deployment on the Planet-Lab testbed
- Results demonstrate feasibility and suitability of hybrid multicast communication for dissemination group applications
- Interactivity constrained by high deviation in packet delays
- Hybrid multicast limits link stress and eliminates bottlenecks

Future Work

- Analysis individual components of hybrid multicast system
- Improve performance for interactive group applications
Thank you for your attention. Questions?

iNET: http://inet.cpt.haw-hamburg.de
HAMcast: http://hamcast.realmv6.org
References


