Multicast Issues
- Reliable transfer
- Congestion control
- Assigned reading
  - [F+97] A Reliable Multicast Framework for Light-Weight Sessions and Application Level Framing
  - [MJV96] Receiver-driven Layered Multicast

Overview
- Reliability
  - Scalable Reliable Multicast
  - Reliable Multicast Transport Protocol
  - Lightweight Multicast Service
  - Receiver-driven Layered Multicast
  - Other Issues

Loss Recovery
- Sender-reliable
  - Wait for ACKs from all receivers. Re-send on timeout or selective ACK
  - Per receiver state in sender not scalable
  - ACK implosion
- Receiver-reliable
  - Receiver NACKs (resend request) lost packet
  - Does not provide 100% reliability
  - NACK implosion

Implosion
Packet 1 is lost
All 4 receivers request a resend

Retransmission
- Re-transmitter
  - Options: sender, other receivers
  - How to retransmit
    - Unicast, multicast, scoped multicast, retransmission group, ...
  - Problem: Exposure
Exposure
Packet 1 does not reach R1; Receiver 1 requests a resend
Packet 1 resent to all 4 receivers

Ideal Recovery Model
Packet 1 reaches R1 but is lost before reaching other Receivers
Only one receiver sends NACK to the nearest S or R with packet
Repair sent only to those that need packet

Aside: Using the Routers
• Routers do transport level processing:
  • Buffer packets
  • Combine ACKs
  • Send retransmissions
• Model solves implosion and exposure, but not scalable
• Violates end-to-end argument

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SRM
• Originally designed for wb
• Receiver-reliable
  • NACK-based
• Every member may multicast NACK or retransmission

SRM Request Suppression
Packet 1 is lost; R1 requests resend to Source and Receivers
Packet 1 is resent; R2 and R3 no longer have to request a resend
Delay varies by distance
### Deterministic Suppression

![Diagram showing deterministic suppression]

Time data

\[ \text{Delay} = C_d \times d_{S,R} \]

### SRM Star Topology

Packet 1 is lost; All Receivers request resends

Packet 1 is resent to all Receivers

Delay is same length

### SRM: Stochastic Suppression

![Diagram showing stochastic suppression]

Delay = \( U[0, D] \times d_{S,R} \)

### SRM (Summary)

- NACK/Retransmission suppression
- Delay before sending
- Delay based on RTT estimation
- Deterministic + Stochastic components
- Periodic session messages
- Full reliability
- Estimation of distance matrix among members

### Local Recovery

- Application-level hierarchy
- Fixed v.s. dynamic
- TTL scoped multicast
- Router supported

### What’s Missing?

- Losses at link (A,C) causes retransmission to the whole group
- Only retransmit to those members who lost the packet
- [Only request from the nearest responder]
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RMTP

- Reliable Multicast Transport Protocol by Purdue and AT&T Research Labs
- Designed for file dissemination (single-sender)
- Deployed in AT&T’s billing network

RMTP: Fixed Hierarchy

- Rcvr unicasts periodic ACK to its Designated Receiver (DR)
- DR unicasts its own ACK to its parent
- Rcvr chooses closest statically configured (DR)
- Mcast or unicast retransmission
  - Based on percentage of requests
  - Scoped mcast for local recovery

RMTP: Comments

- +: Heterogeneity
  - Lossy link or slow receiver will only affect a local region
- -: Position of DR critical
  - Static hierarchy cannot adapt local recovery zone to loss points

Overview

- Pragmatic General Multicast

Pragmatic General Multicast

- Cisco’s reliable multicast protocol
- NACK-based, with suppression
- Repair only forwarded to the NACKers
Pragmatic General Multicast

Packet 1 reaches only R1; R2, R3, R4 request retransmissions

Packet 1 resent to R2, R3, R4; Not resent to R1

Routers remember resend requests

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Packet 1 reaches only R1; R2 requests resend

Resend requests from each receiver follow replier links

Light-weight Multicast Service (LMS)

- Enhance multicast routing with selective forwarding
- LMS extends router forwarding - what routers are meant to do in the first place
- No packet storing or processing at routers
- Strictly IP: no peeking into higher layers

The LMS Concept

Heavy-weight model
LMS: Receiver acts as surrogate

- Router stores packets, receives NACKs and sends retransmissions
- Router chooses a receiver as a surrogate
- Router steers all control messages to surrogate
- Router relays messages from surrogate to the subtree

LMS: Definitions

- Replier
  - Receiver volunteered to answer requests
- Turning point
  - Where requests start to move downstream
- Directed mcast
- Mcast to a subtree

LMS with Replier Links

Packet 1 reaches only R1; R2 requests resend

Resend requests from each receiver follow replier links
LMS with Replier Links

Request from replier links go up towards the Source

Packet 1 is resent to all Receivers

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Multicast Congestion Control

- What if receivers have very different bandwidths?
- Send at max?
- Send at min?
- Send at avg?

Layered Media Streams

- R1 joins layer 1, joins layer 2
- R2 joins layer 1, join layer 2, fails at layer 3
- R3 joins layer 1, fails at layer 2

Video Adaptation: RLM

- Receiver-driven Layered Multicast
- Layered video encoding
- Each layer uses its own mcast group
- On spare capacity, receivers add a layer
- On congestion, receivers drop a layer
- Join experiments used for shared learning

LMS: Comments

- Replier problems
- Selection? Fault tolerance?
- Works with unidirectional shared trees (PIM)
- Needs to relay requests from core/RP to sender
- Difficulties with bi-directional shared trees
- Needs per-source state
Drop Policies for Layered Multicast
- **Priority**
  - Packets for low bandwidth layers are kept, drop queued packets for higher layers
  - Requires router support
- **Uniform (e.g., drop tail, RED)**
  - Packets arriving at congested router are dropped regardless of their layer
- Which is better?
  - Intuition vs. reality!

**RLM Intuition**
- **Uniform**
  - Better incentives to well-behaved users
  - If oversend, performance rapidly degrades
  - Clearer congestion signal
  - Allows shared learning
- **Priority**
  - Can waste upstream resources
  - Hard to deploy
- RLM approaches optimal operating point
  - Uniform is already deployed

**Receiver-Driven Layered Multicast**
- Each layer a separate group
- Receiver subscribes to max group that will get through with minimal drops
- Dynamically adapt to available capacity
- Use packet losses as congestion signal
- Assume no special router support
- Packets dropped independently of layer

**RLM Join Experiment**
- Receivers periodically try subscribing to higher layer
- If enough capacity, no congestion, no drops
  - Keep layer (& try next layer)
- If not enough capacity, congestion, drops
  - Drop layer (& increase time to next retry)
- What about impact on other receivers?

**Join Experiments**

![Graph showing uniform vs. priority dropping](Image)
RLM Scalability?

- What happens with more receivers?
- Increased frequency of experiments?
  - More likely to conflict (false signals)
  - Network spends more time congested
- Reduce # of experiments per host?
  - Takes longer to converge

RLM Receiver Coordination

- Receiver advertises intent to add layer
- Other receivers
  - Avoid conflicting experiments
  - If experiment fails, will see increased drops =>
    don’t try adding layer! (shared learning)
  - OK to try adding lower layer during higher layer experiment
    - Won’t cause drops at higher layer!

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Inferring Topology

- What if packet is lost on link?
  - All children of link will not get packet
  - Idea: use loss “fingerprints” to identify siblings
  - Siblings will have the most similar fingerprints
  - Various techniques to build tree from collection of fingerprints

Session Messages

- SRM
  - Identify what node knows about global state
- Multimedia & other applications
  - Identify list of members
  - Communicate loss rates possibly for congestion control or other feedback
  - What if it is a large group?
    - Periodic transmissions can flood network!!

Next Lecture: QOS & IntServ

- QOS
- IntServ Architecture
- Assigned reading
  - [She95] Fundamental Design Issues for the Future Internet
  - [CSZ92] Supporting Real-Time Applications in an Integrated Services Packet Network: Architecture and Mechanisms