Network Simulation and Testing

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P2P Papers

- Salman A. Baset and Henning Schulzrinne. An Analysis of the Skype Peer-to-Peer Internet Telephony Protocol. In Proceedings of IEEE Infocom 2006.
- Kuan-Ta Chen, Chun-Ying Huang, Polly Huang, and Chin-Laung Lei. Quantifying Skype User Satisfaction. In Proceedings of ACM SIGCOMM 2006.
- X. Zhang, J. Liu, B. Li, and T.-S. P. Yum. CoolStreaming/DONet: A Data-driven Overlay Network for Efficient Live Media Streaming. In Proceedings of IEEE INFOCOM 2005
- Meng-Ting Lu, Jui-Chieh Wu, Kuan-Jen Peng, Polly Huang, Jason J. Yao, Homer H. Chen. Design and Evaluation of a P2P IPTV System for Heterogeneous Networks. IEEE Transactions on Multimedia, Vol. 9, No. 8, pp. 1568-1579, Dec. 2007

Multimedia P2P

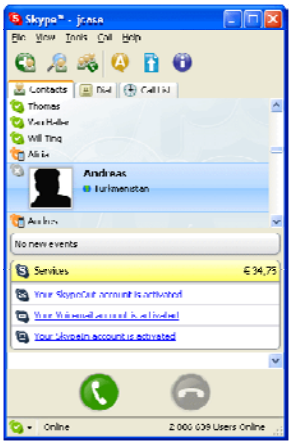
Skype

CoolStreaming

HotStreaming

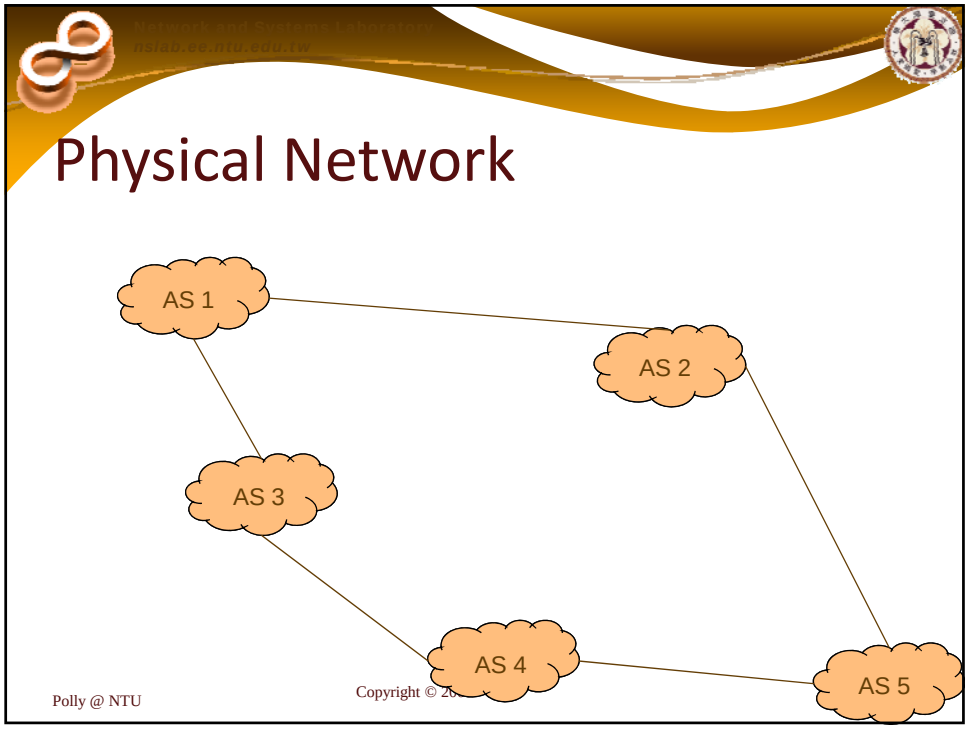
What is it?

- A peer-to-peer (P2P) overlay network for VoIP
- By the KaZaA developers
- To an average user, it is an Instant Messaging system that supports instant voice



Secret of Success

- Codec (provided by Global IP Sound)
  - 67 bytes packet payload
  - 24 to 120 kbps
- NAT and firewall traversal
- **Alternative paths!**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Physical Network
AS 1
AS 2
AS 3
AS 4
AS 5
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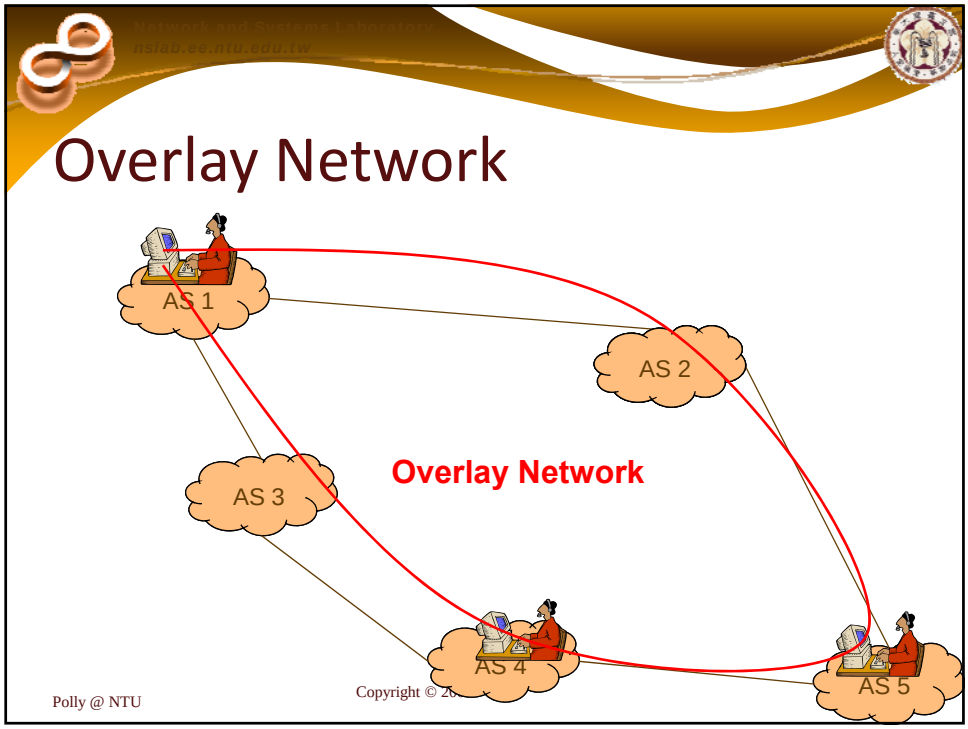
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Overlay Network
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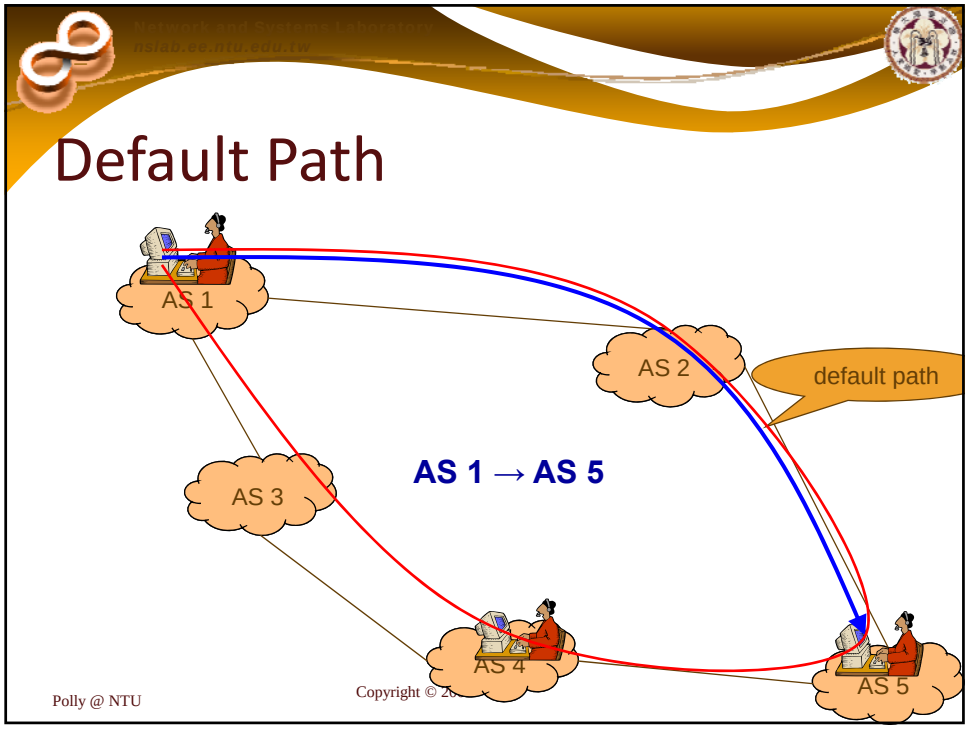
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Default Path
AS 1
AS 2
default path
AS 3
AS 1 → AS 5
AS 4
AS 5
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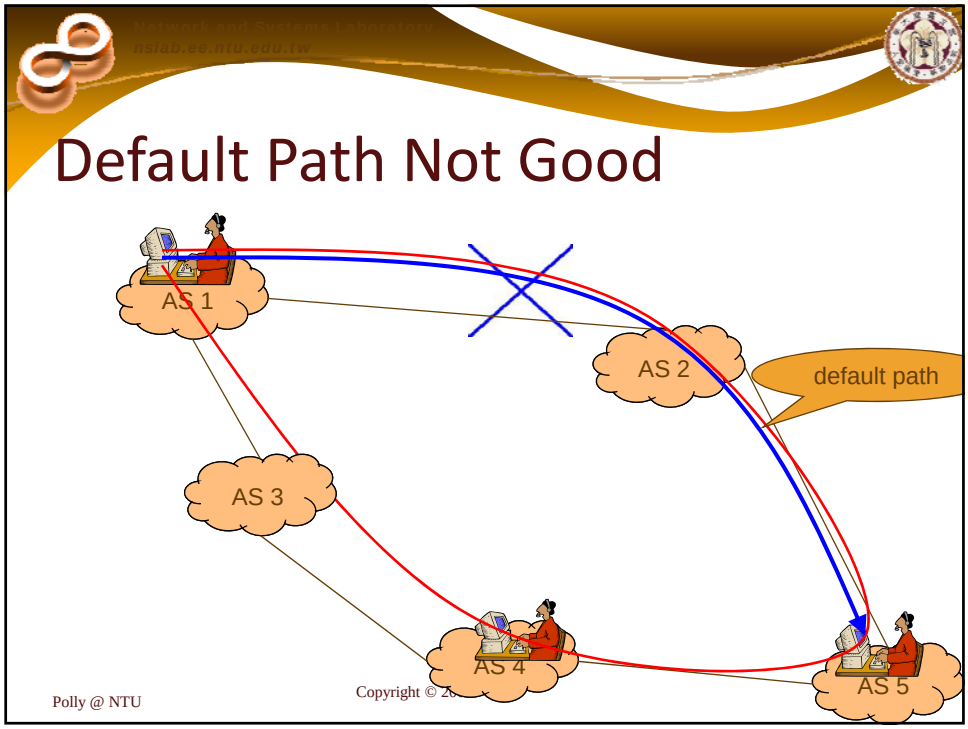
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Default Path Not Good
AS 1
AS 2
default path
AS 3
AS 4
AS 5
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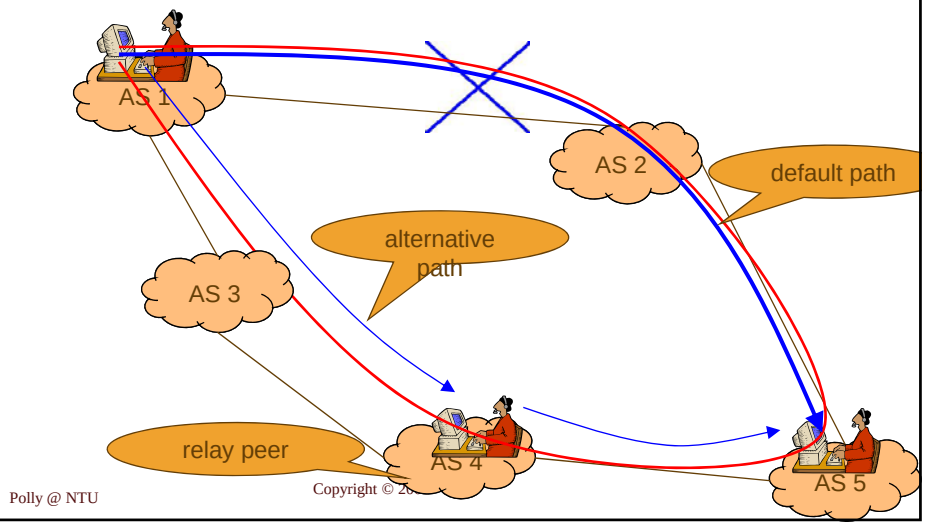
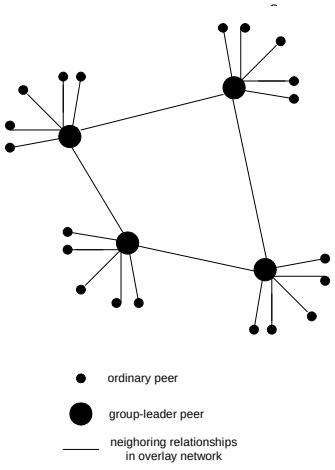
Find an Alternative Path



Based on KaZaA

- A hybrid solution
  - Some are group leaders
    - Super nodes or SN
  - Most are ordinary peers
    - Ordinary nodes or ON
- 1st level
  - Between a group leader and its ordinary peers
  - Napster-like
- 2nd level
  - Between group leaders
  - Gnutella-like



Phase I: Login

- Send 'I'm alive' to other peers
  - Showing in your friends' Friend lists
- Determines the type of NAT and firewall it is behind
  - More details if time allow
- **Discover online SNs**

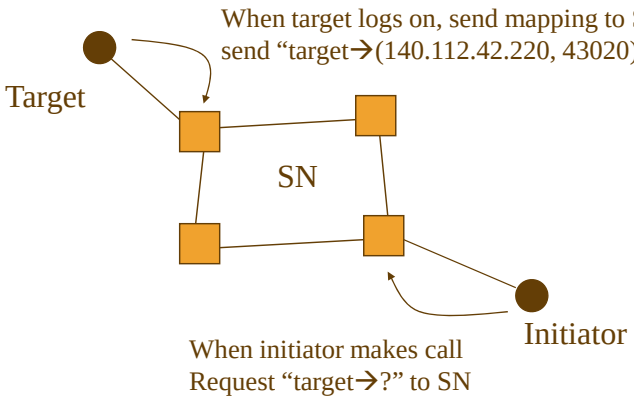
Where are the SNs?

- 1st-time use of Skype
  - Connect first to a **bootstrap** server to acquire a candidate SN list
  - Select one from the list
  - Report to the SN meta data about user/files to be shared
  - Acquire from the SN the updated list of candidate SN
  - Cache the candidate SN list
- 2nd-time+ use of Skype
  - Select one from the cached candidate SN list
  - The rest is the same

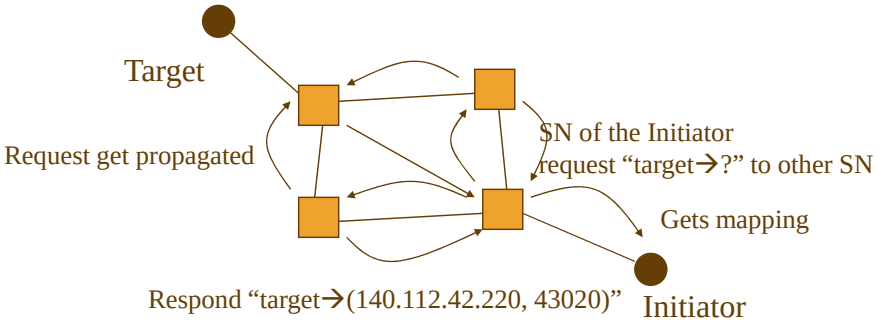
Phase II: Address Lookup

- Initiator calling target
  - Calling pollyhuang…
  - Where is pollyhuang at?
- Username → (IP, port) address mapping
  - The meta data about users stored in SNs

Address Lookup Service



P2P Style Search

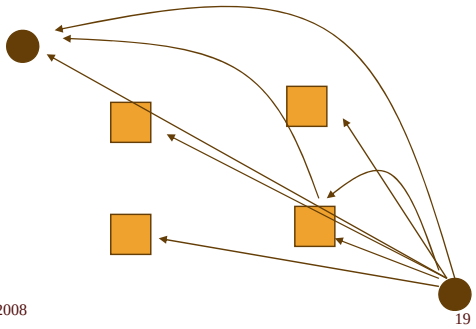


Phase III: Call Establishment

- Two directions
  - Initiator connects to target first
  - Target connects back to initiator
- Operation for each direction is identical

The Operation

- Probe a list of nodes
  - Target, candidate relay nodes (RN)
- Pick the best to connect
  - If target is picked
    - Connect to target
  - If RN is picked
    - Connect to RN
    - RN connect to target



Candidate Relay Nodes (RN)

- Pre-defined and change dynamically
- Simply the candidate SNs in the host cache (HC)
- Probes can be a priori in low frequency
  - Shorten the delay in call establishment

Who should be the relay peer?

such that the alternative path
is **better** than the default
one…

Skype's Solution

Round-Trip Delay & Loss Rate (Probably)

[ICDCS 06] S. Ren, L. Guo, and X. Zhang, ``ASAP: an AS-Aware Peer-relay protocol for high quality VoIP with low overhead", *Proceedings of the 26th International Conference on Distributed Computing Systems* (ICDCS'06), Lisbon, Portugal, July 4-7, 2006

A Fundamental Question

Which is the right path selection criteria?

Source Rate?
Congestion Level?
Delay?
Combination of the above?

User Satisfaction

$$USI = 2.15 * \log(\text{bit rate}) - 1.55 * \log(\text{jitter}) - 0.36 * RTT$$

bit rate:	data rate of voice packets
jitter:	level of network **congestion**
RTT:	round-trip times between two parties

[SIGCOMM 06] Kuan-Ta Chen, Chun-Ying Huang, Polly Huang, Chin-Laung Lei, "Quantifying Skype User Satisfaction," *ACM SIGCOMM* 2006

Secret of Success

- Codec (provided by Global IP Sound)
  - 67 bytes packet payload
  - 24 to 120 kbps
- **NAT and firewall traversal**
- Alternative paths!

Special Ports

- Skype client listening on a randomly selected port
- If blocked by firewall, use
  - 80 -- HTTP
  - 443 -- HTTPS

TCP Connection

- Skype client listening using UDP
- If blocked by firewall, use
  - TCP

NAT Traversal

- STUN
  - Simple Traversal of UDP through NATs
  - **More details if time allows**
- TURN
  - Traversal Using Relay NAT
  - I.e., the relay node approach

Secret of Success

- **Codec** (provided by Global IP Sound)
  - 67 bytes packet payload
  - 10 to 120 kbps
- NAT and firewall traversal
- Alternative paths!

Codecs

- iLBC
  - 13.3 kbps (30 ms frames) 15.2 kbps (20 m frames)
  - Better than G.729A and G.723.1
- iSAC
  - 10-120 kbps (**adaptive and variable**)
  - Wideband communication
- No silence suppression

Multimedia P2P

Skype

CoolStreaming

HotStreaming

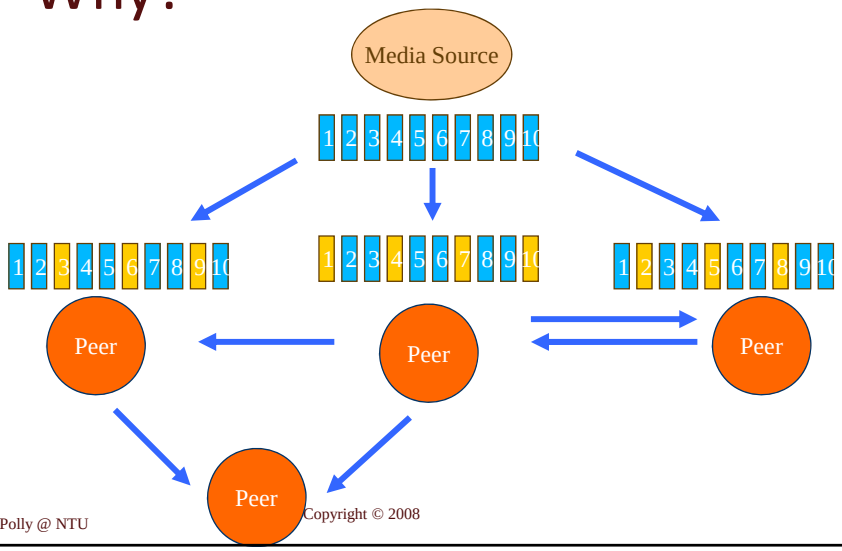
CoolStreaming → PPLive

- A peer-to-peer (P2P) overlay network for IPTV
- Hongkong-China based
- To an average user, it's free live sports event broadcast service
- 10,000s of subscribers

Secret of the CoolStreaming's Success

- Free content
- Smooth and quality video
- The more users, the better the quality

Why?



Major Technical Components

	CoolStreaming
P2P Network Formation	Pure random
Frame Scheduling	Fewest copies first Dead-line oriented
Codec	Mpeg-4, windows WMA

Outline

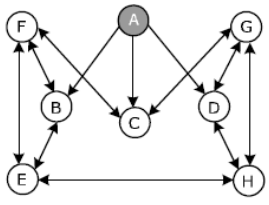
- **Design of DONet**
- Performance Evaluation
- CoolStreaming
- Conclusion

DONet

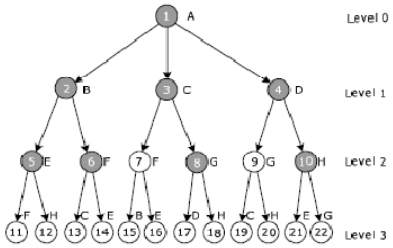
(Data-driven Overlay Network)

- Concept
  - Form a gossip P2P network
    - Essentially, a peer connect to other peers **randomly**
  - P2P network dynamically updated
    - Essentially, which peer connect to which peers is changed **periodically**
- Characteristics
  - Easy to implement
  - Robust and resilient
  - Efficient

P2P Network Topology



Mesh



As opposed to a tree

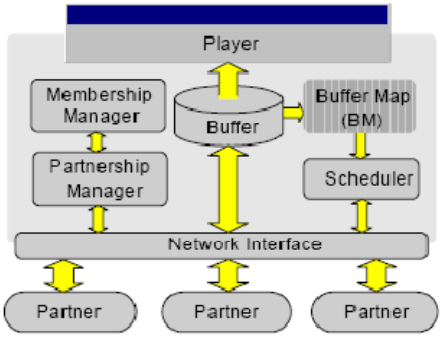
The rest of the network can still function with a node fails!

Network Comparison

	DONet	CoopNet
Base	mesh	tree
Load	balanced	unbalanced
Supplier/Client	not specified*	specified
Structure	distributed	centralized
Dynamic switch	robust	vulnerable

Design of DONet

- 3 Key modules
  - Membership Manager
  - Partnership Manager
  - Buffer Map & Scheduler
- Terminology
  - Member → active nodes on t overlay network
  - Partner → nodes can exchan data (**a subset of members**)



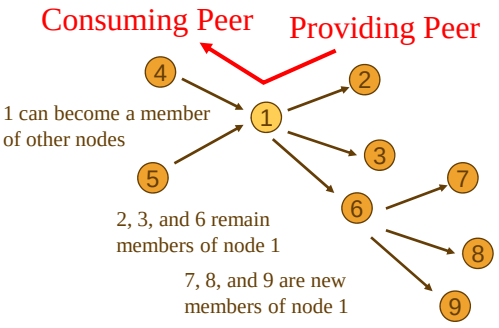
Membership Management

- SCAMP (Scalable Gossip Membership protocol)
- Join
  - A newly joined node contacts first a bootstrap node
    - Redirected to a deputy node
    - Randomly selected from the bootstrap node's mCache*.
  - Deputy node gives the new node its mCache
- Maintain
  - **Periodical membership messages to update mCache**
  - Nodes will be removed from the list after a fixed amount of time

*The membership cache contains a partial list of active nodes in DONet.

Implementation

Membership Relationship



Every peer:
1. Periodically send
2. An advertisement message (ADV)

Upon receiving the ADV:
1. Roll a dice
2. If win, select the ADV sender to provide video segments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Partnership Management
Periodically establish new partnerships with nodes randomly selected from mCache
Reject the lowest rating partner
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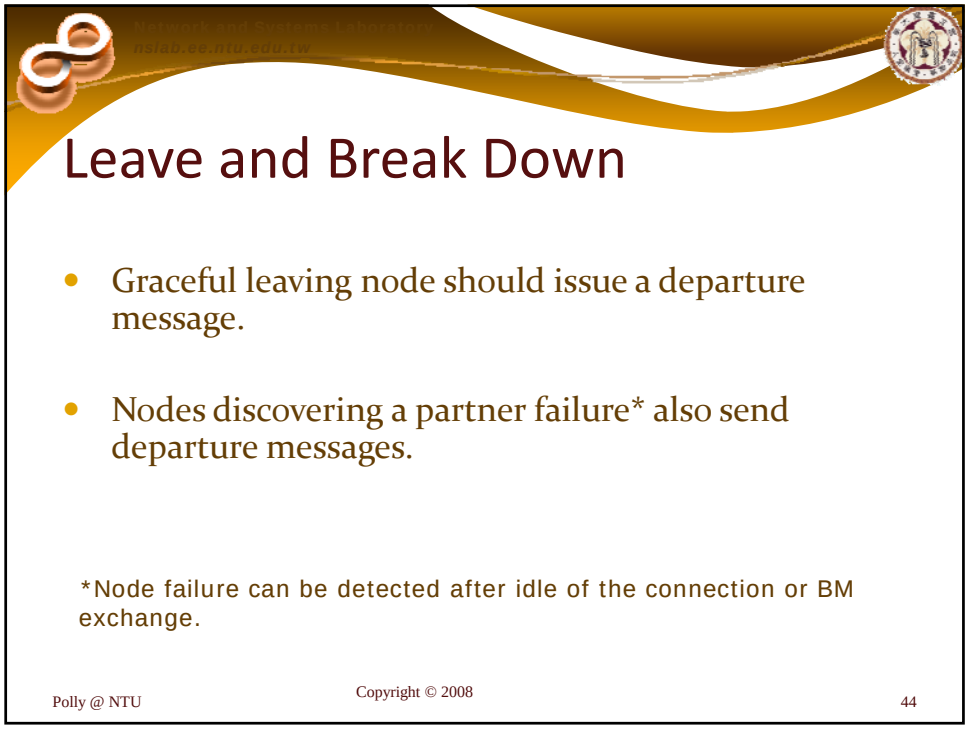
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Leave and Break Down
Graceful leaving node should issue a departure message.
Nodes discovering a partner failure* also send departure messages.
*Node failure can be detected after idle of the connection or BM exchange.
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Buffer Map Management

- Buffer Map
  - Semi-synchronized playback progresses.
  - A **sliding window of 120 segments** can effectively represent the buffer map. Segments outside the window is ignored.
  - Use **120 bits** to record BM, with bit 1 indicating that a segment is available.
  - The **sequence number of the first segment** in the sliding window is record by another **2 bytes**.
- Each node continuously exchanges its BM with the partners.

Scheduling Algorithm

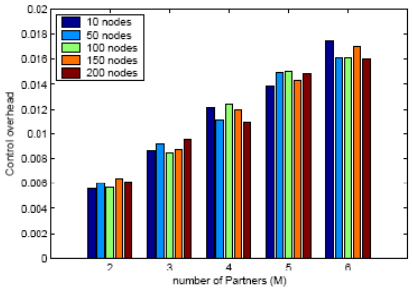
- Two constrains
  - Playback deadline for each segment
  - Heterogeneous streaming bandwidth
- Minimize segments missing deadlines.
- Heuristic algorithm
  - Calculate the number of the potential suppliers for each segments.
  - Less suppliers means higher risks of missing the deadlines.
  - Determine the supplier of each segment starting from the one with **lowest potential suppliers**.
  - Among the supplier candidates, pick the one **with higher BW** and enough available time.

Outline

- Design of DONet
- **Performance Evaluation**
- CoolStreaming
- Conclusion

Performance Evaluation*

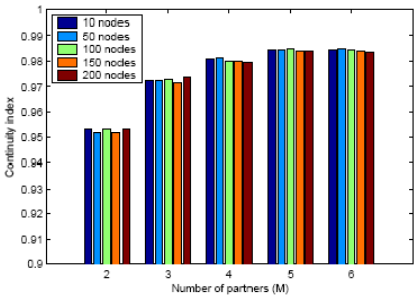
- Control overhead
  - Control traffic volume /Video traffic volume
- Continuity index
  - Number of segments that arrive in time over the total number of segments
- On/Off period
  - Average of node join/leave-period, which is exponentially distributed
- Stable Environment



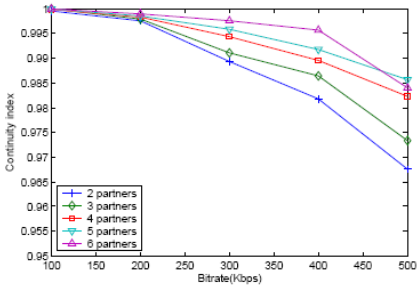
Control overhead vs. Partner #

*Experiments are conducted in PlanetLab.

Stable Environment

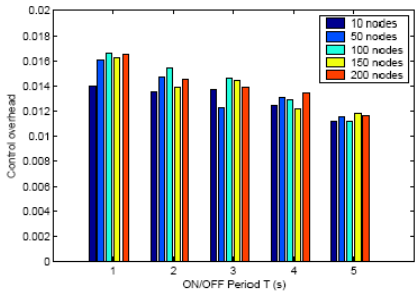


Continuity index vs. Partner #

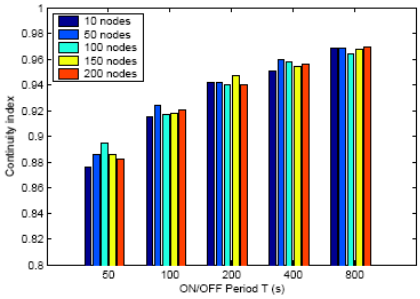


Continuity index vs. Bitrate

Dynamic Environment

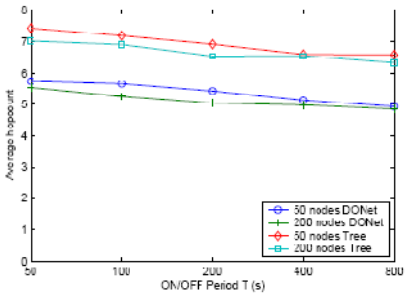


Control overhead vs. On/Off period

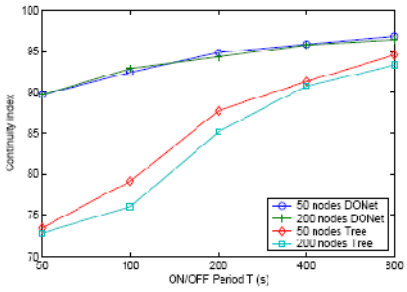


Continuity index vs. On/Off period

Compared with Tree Overlay

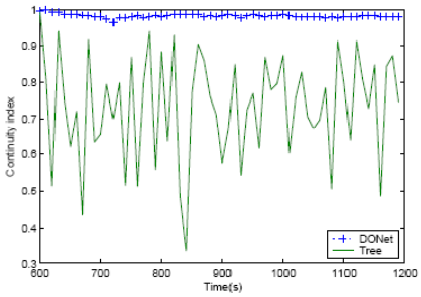


Average hopcount vs. On/Off period



Continuity index vs. On/Off period

Fluctuation Over Time



Continuity index vs. Time

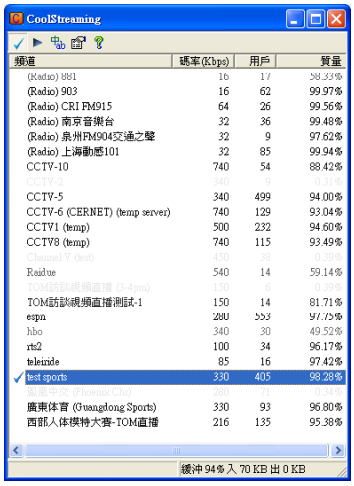
- DONet summary
  - Low control overhead (1% of the video traffic)
  - Better playback continuity and smaller end-to-end delay, especially under dynamic environments
  - Scalable both in overlay size and streaming rate
  - Stable quality

CoolStreaming

- TFRC (TCP friendly rate control) protocol
- About 5~10 minutes to settle down the

	ESPN	Test Sports	Channel V
Bitrate (kbps)	280	330	450
Online user	5000	2500	67
Server quality	95%	50~60%	75%
Buffer level	80%+	50%	90%
Video quality	good	poor	Mediocre

*CoolStreaming v 0.0.42 released at March 1, 2005



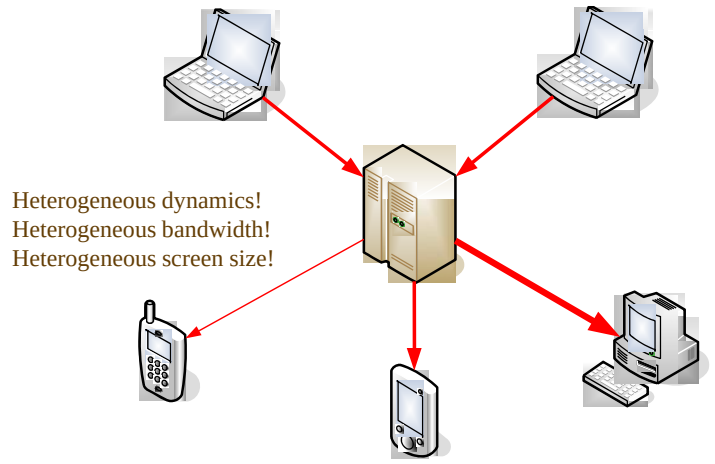
Summary

- DONet is a **capacity amplifier** between a content provider and clients.
  - The larger the data-driven overlay is, the better the streaming quality it delivers.
- DONet doesn't maintain an explicit overlay structure
  - A mesh-based overlay network
  - Scalable and robust
- The problem of user behind Firewall can be solved by TCP connection.
  - Statistical results show that more than 95% of the nodes can become relay nodes.

Multimedia P2P

Skype
CoolStreaming
HotStreaming

Mobile IPTV



Differences

	CoolStreaming	HotStreaming
Partnership Formation	Pure random	Preferential random (rotate)
Frame Request Scheduling	Heuristic: (fewest copies first Earliest Deadline first)	Optimal: (min loss under bw constraint)
Codec	Mpeg-4, windows WMA	Mpeg-4, interleaving MDC (bw heterogeneity)

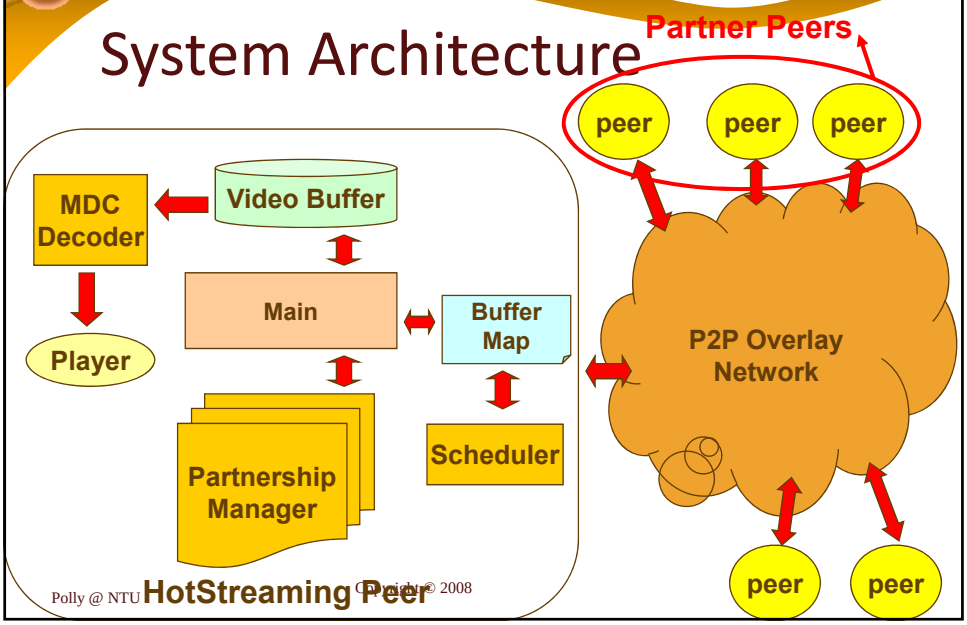
System Advantages

	HotStreaming	Advantages
Partnership Formation	Preferential random (rotate)	Stability
Frame Request Scheduling	Optimal: (min loss under bw constraint)	Minimum loss
Codec	Mpeg-4, interleaving MDC (bw heterogeneity)	Sustainable quality for heterogeneous users

Three Components

- Partnership formation
- Multiple description coding
- Video segment scheduling

System Architecture



Qualitative Comparison

- SCAMP
  - Forwarding of ADV
    - To all partners
  - Selection of partner
    - Depending on current #partners
- TYPHOON
  - Forwarding of ADV
    - To partners who have few partners
    - To avoid peers being isolated → better stability
  - Selection of partner
    - Depending on current #partners
    - Bounded by the max #partners → better load balance

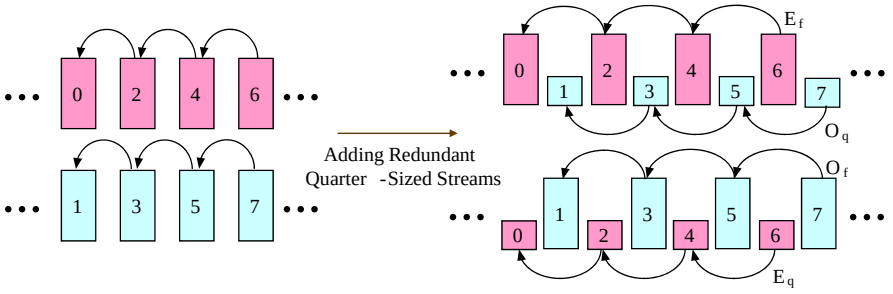
Quantitative Comparison

	SCAMP	TYPHOON
Connected Time (sec)	59180	74320
Disconnected Time (sec)	15820	680
Disconnected Node (N)	305	18
Instability Index	51700	2580

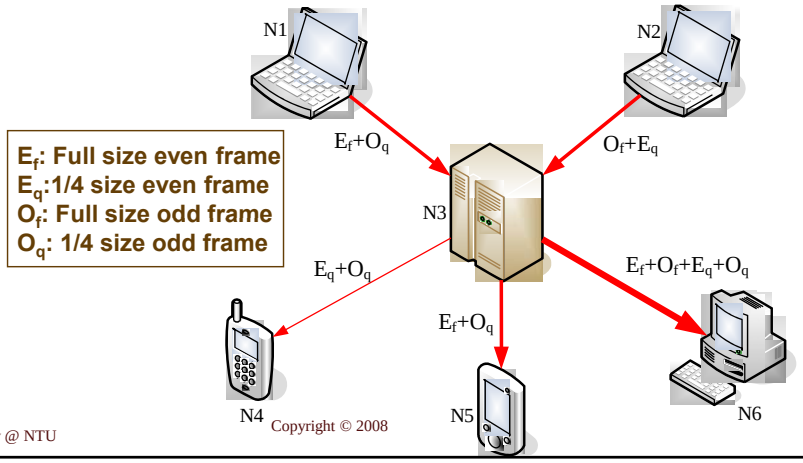
Stability Improvement ~ 20 fold

MDC: Idea

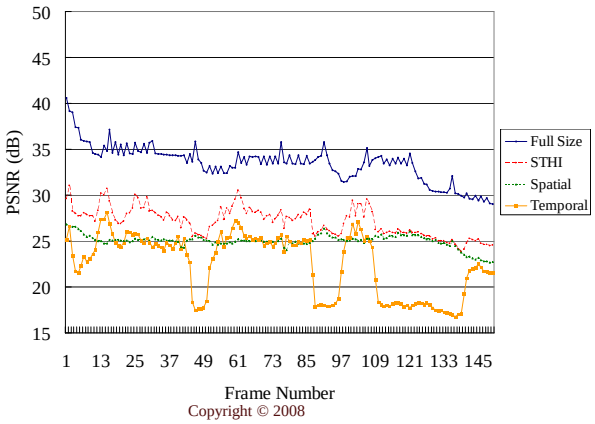
MDC-STHI:
MDC with Spatial-Temopral Hybrid Interpolation



Very Key to Mobile IPTV



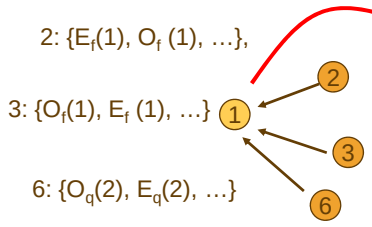
PSNR: Stefan (CIF)



Segment Request Scheduling

- From a peer's partners
  - Available segment type (e.g. E_f, O_q) and size
- The peer calculates
  - Maximize the video quality
    - Score of full-sized segments > quarter-sized ones
  - Under 2 constraints
    - Estimated time for segment to arrive < playback time
    - Total segments to request < estimated available bandwidth
- A linear programming problem
  - Efficient approximation algorithm
  - Computation < 10s milliseconds

Segment Request: Illustrated



Variables

x_i^j : a schedule that requires MDC type j for segment i

Maximize

$$\sum_{i=1}^{K}\sum_{j=1}^{L} x_i^j U_i^j$$

Subject to

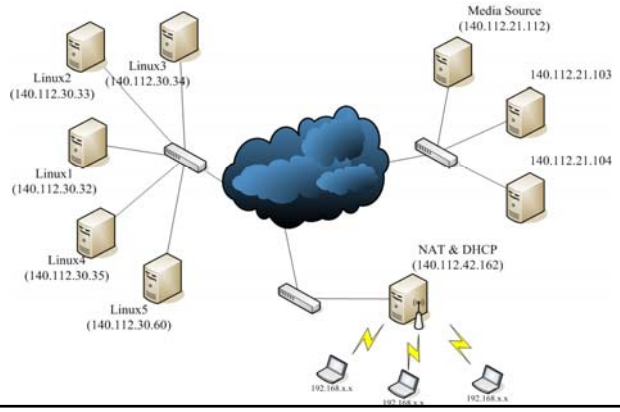
$$T_i = T_{i-1} + 1 - \sum_{j=1}^{L} \frac{S_i^j}{B} x_i^j > 0, 1 \le i \le K$$

$$0 \le \sum_{j=1}^{L} x_i^j \le 1, 1 \le i \le K$$

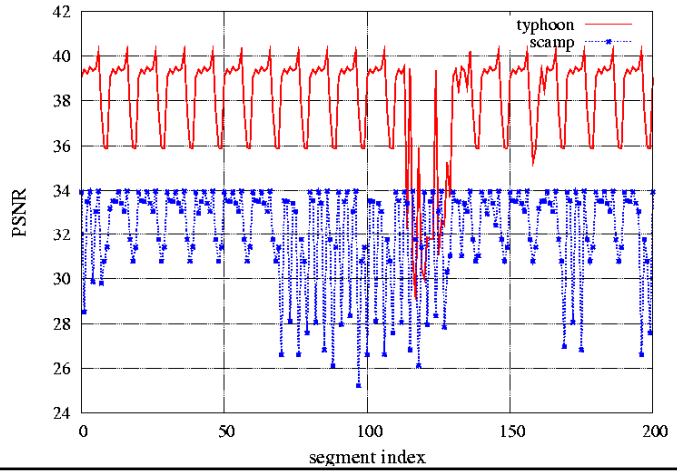
$$x_i^j \in \{0,1\}, 0 \le x_i^j \le 1, 1 \le i \le K, 1 \le j \le L$$

Testbed Experiments

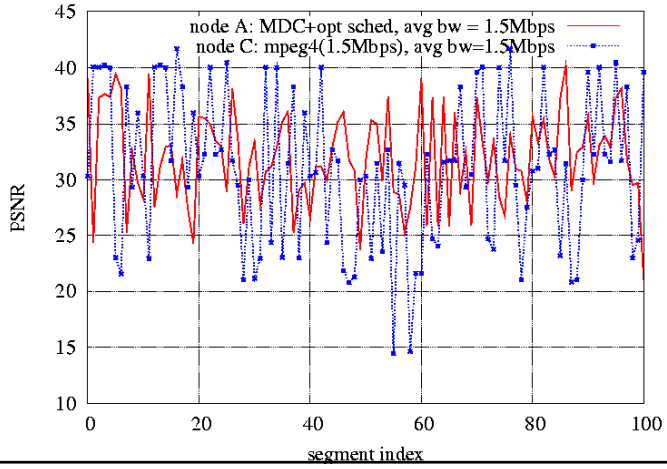
- All three components integrated



Impact of TYPHOON



Impact of MDC-STHI+ Opt Schedule



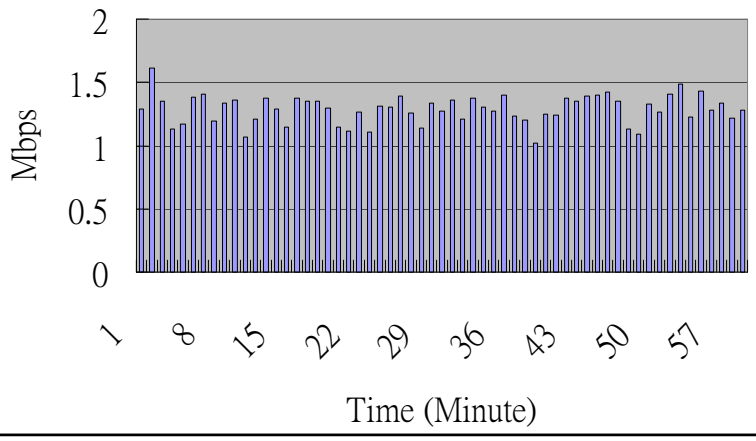
Summary

	HotStreaming	Advantages
Partnership Formation	Preferential random (rotate)	Stability
Frame Request Scheduling	Optimal: (min loss under bw constraint)	Minimum loss
Codec	Mpeg-4, interleaving MDC (bw heterogeneity)	Sustainable quality for heterogeneous users

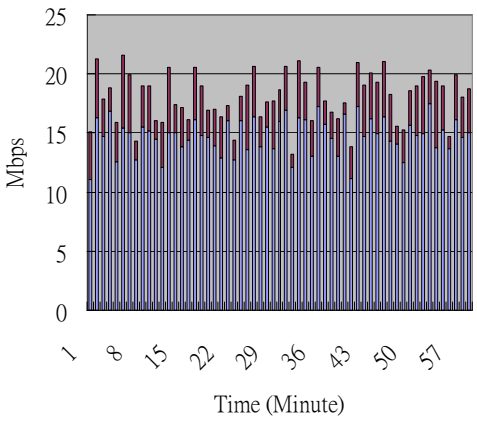
PlanetLab Results

- Small-scale testing on Campus Network
  - 15-node scale testing
  - 1 server, 14 peer users
  - 1 Mbps video source for an hour
- Network centric measurement
  - Scalability
  - Packet loss rate (arrival rate within deadline)
  - Control message overhead

Video Receiving Rate: per Peer



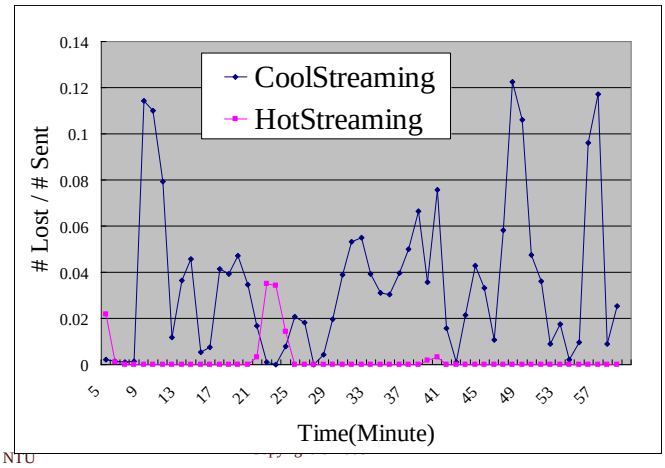
Video Sending Rate: Total



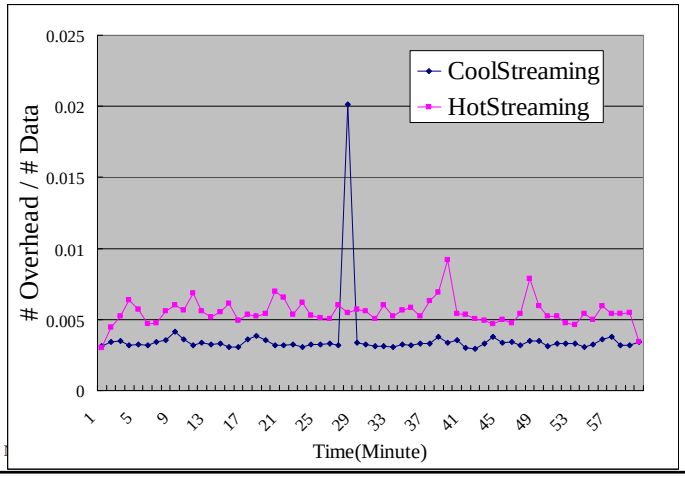
Scalability (server load)
MOD ~ stream_size * #user
P2P ~ stream_size * in_degree

→ For non-live-programs, no user limit on HotStreaming!

Playback Continuity



Overhead

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Questions?
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