Effects of Internet Path Selection on Video-QoE

by

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Streaming Multimedia and the Internet

- Each day, YouTube alone generates more than one thirds of *all* Internet traffic.

- An average user spends 40% of her browsing time watching multimedia content.

-More than **91% of *all* consumer traffic** will carry multimedia content by 2012.

- An estimated $4.3 million from revenue generation is predicted for Internet video, with an annual growth rate of 36%.

- Advent of 3D television and tele-immersive environments
    - More multimedia content over the Internet.

- *The Internet is a playground for multimedia content, and will continue to be so in the coming decade.*

Streaming content on Internet

- Already, a plethora of players offer online video services all over the world:

Internet is not optimized for streaming

-The Internet is a *shared* resource, with *no* guarantees.

- *Fundamental limitation*: Internet works with a "best-effort" packet delivery model

- Internet has been traditionally designed for reliable data traffic: HTTP, WWW, email etc.
    - Elastic applications

- Streaming content requires timely delivery more than reliability.
    -Sensitive to loss, delay and jitter.

-Internet Path Selection is based on AS reach ability

- How do we know that the Internet is ready for multimedia?
    - Existing support from Internet enough?

What is Internet QoE?

- Existing (limited) support from Internet: QoS
    - Router compliance across AS impossible

- Even QoS assurance, if implemented, does not assure quality

-Statistical guarantees do not assure high perceptual quality
    - Video Sequences with same QoS but different QoE

- Video quality is best measured in terms of *perceptual quality*

- This leads us to the concept of "quality of experience" , or QoE
    - The concept has been successfully applied to other domains

Contributions of this work

-Part I: Characterize Internet outages w.r.t video
    -Extensively analyze end-to-end path

-Part II: Map these outages to perceptual QoE
    - Generate video sequences and conduct surveys

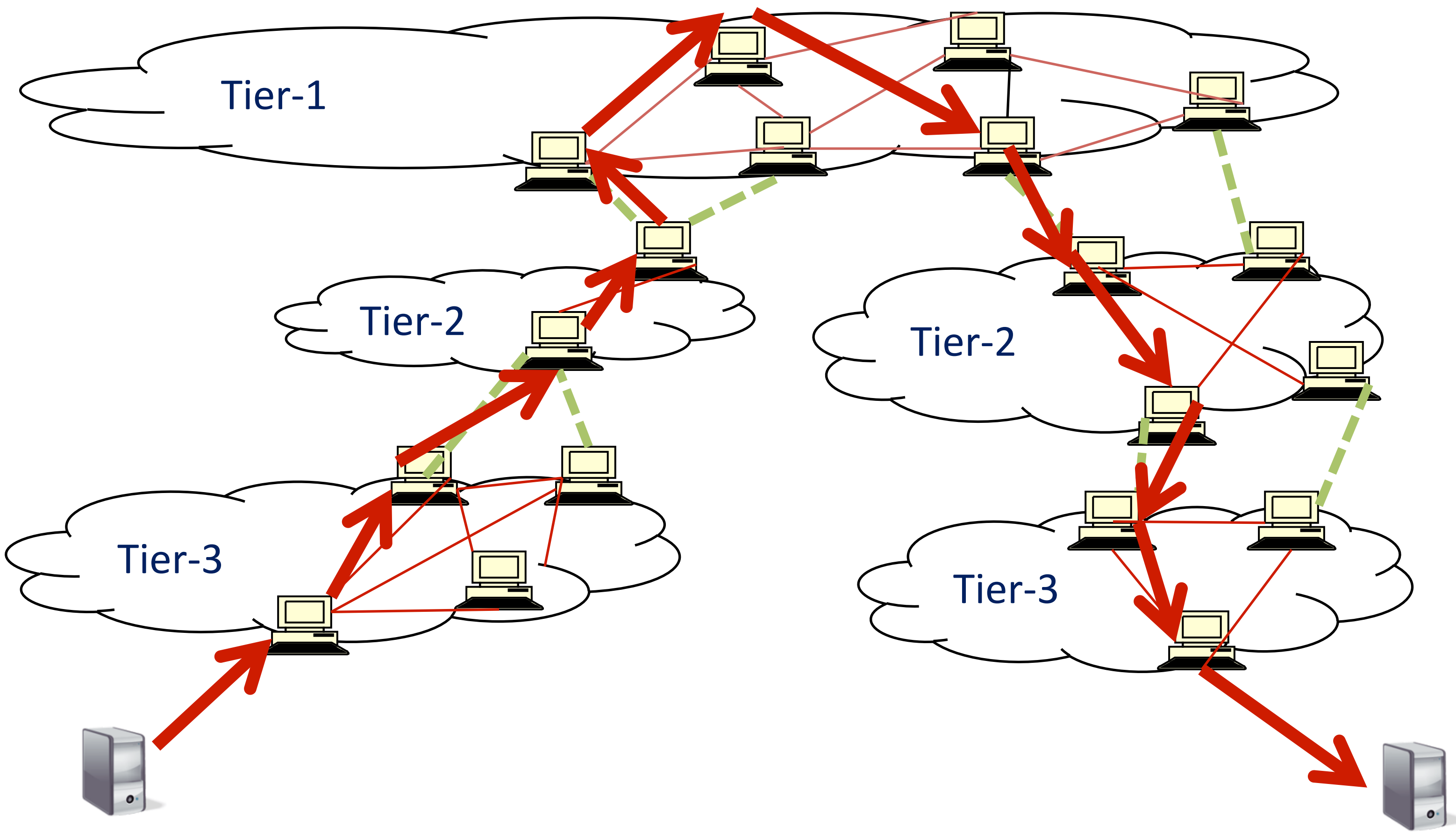
- Part III: Investigate work-around from these outages
    - Use alternate source routing

Part I

Characterize Internet outages w.r.t. video

Introduction to Internet Routing

- Autonomous Systems (AS) and Internet Service Providers (ISPs)



How good are end-to-end Internet paths?

- Where in the *path* do outages occur?

- How long do these outages persist?

- What is the recurring frequency of these outages?

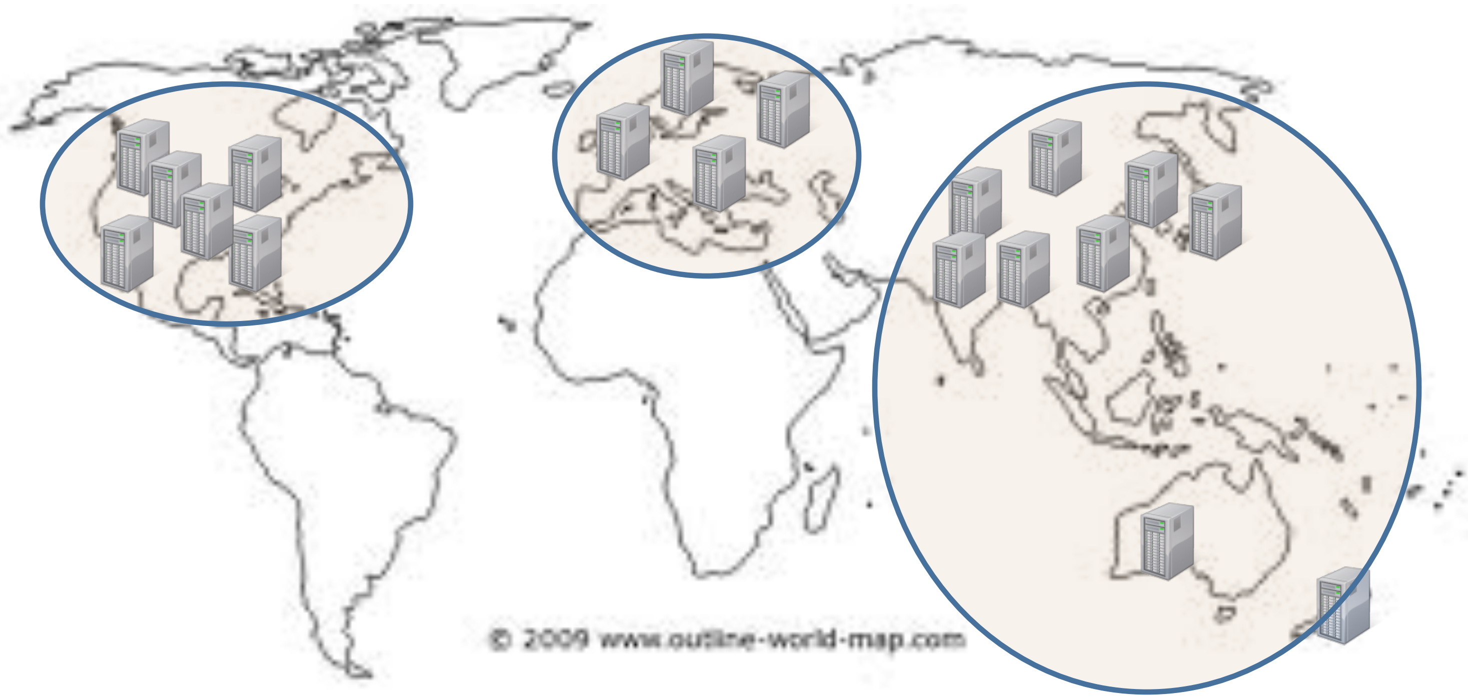
- What is the effect of these outages on *perceptual* quality?

- How long do degradations persist on-screen?

- What fraction of these outages are recoverable by smarter path selection?

- *This part provides answers to these questions and proposes workaround to these outages*

Probing popular video destinations



Path Measurement Methodology

- 62 Vantage Points: Streaming services reflective of client location
    - U.S., Germany, France, Belgium, Korea, China etc.

- Destination Set: Representative of real Internet Destinations
    - Top 200 IPTV and VoD service providers
    - A set of 1,200 Gnutella IP-crawl

- Probed destination from vantage point mimicking a "fetch"
    - Upon probe loss, issue TCP-traceroute

- Used IP-traces of 3 low motion and 2 high motion clips
    - Clips recorded at IP-level using Ineoquest Media Analyzer

- Probing continued for 7 consecutive days
    - Every 5 mins, one clip chosen to probe a destination

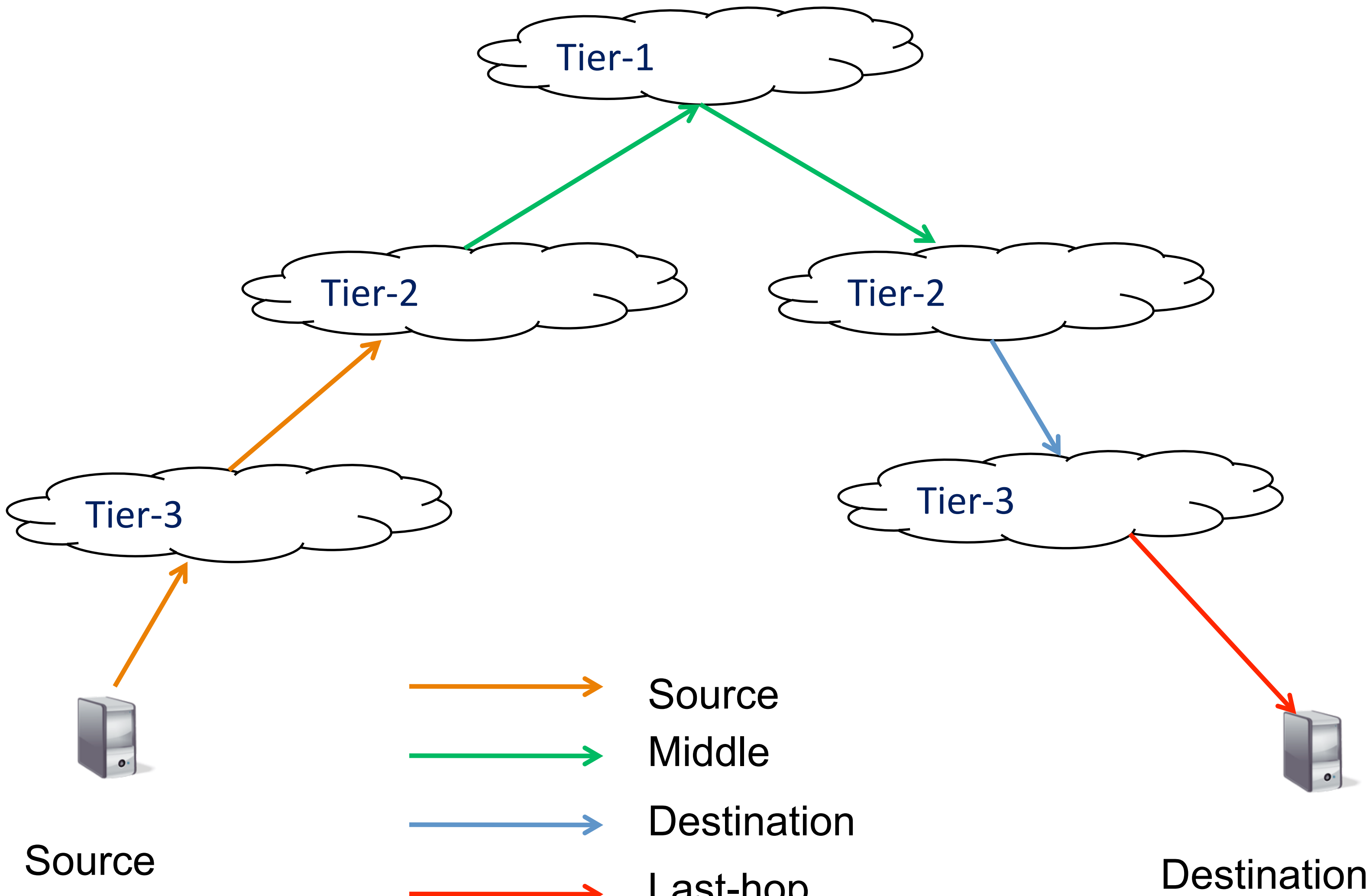
High Level Results: Failures v/s Outages

Event	**Servers**	**P2P hosts**
paths probed	18,600	62,000
Failure Events	4,181	16,724
Path failures	1829	6743
Classifiable path failures	915	3439
Last hop failures	101 (11%)	1308 (38%)
Non last hop failures	814 (89%)	2131 (62%)
Unclassifiable	914	3304

- *Failure Event*: Loss of three consecutive probe packets

- *Path Failure*: Additional traceroute failure

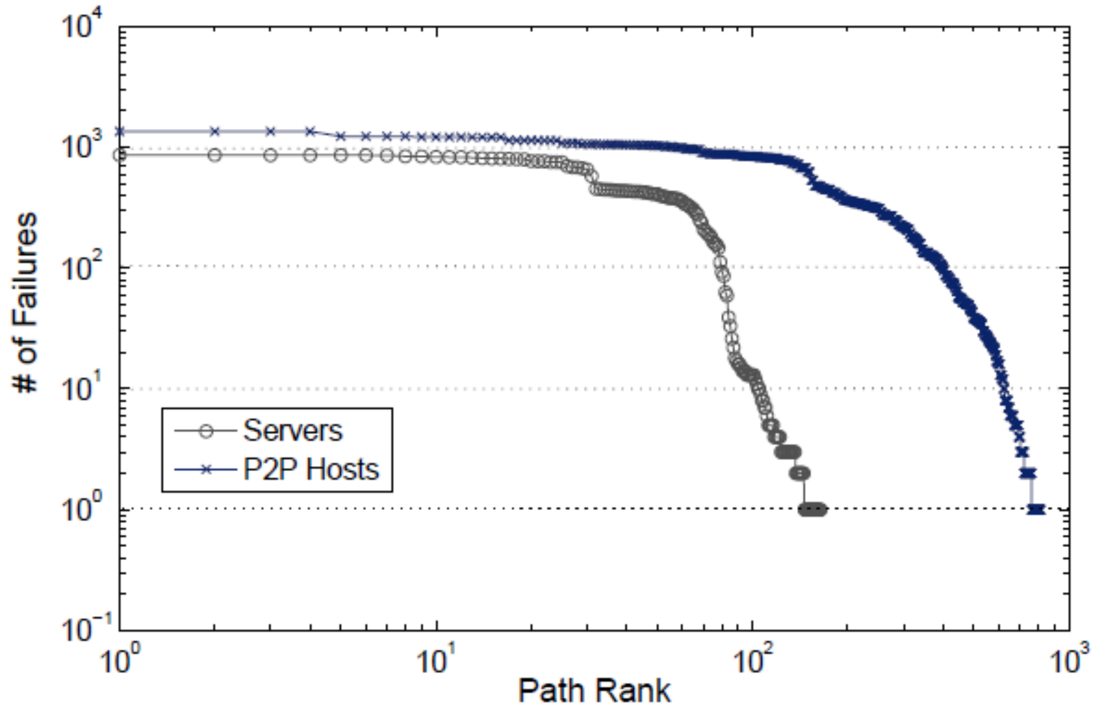
Failure Location



Failure Location

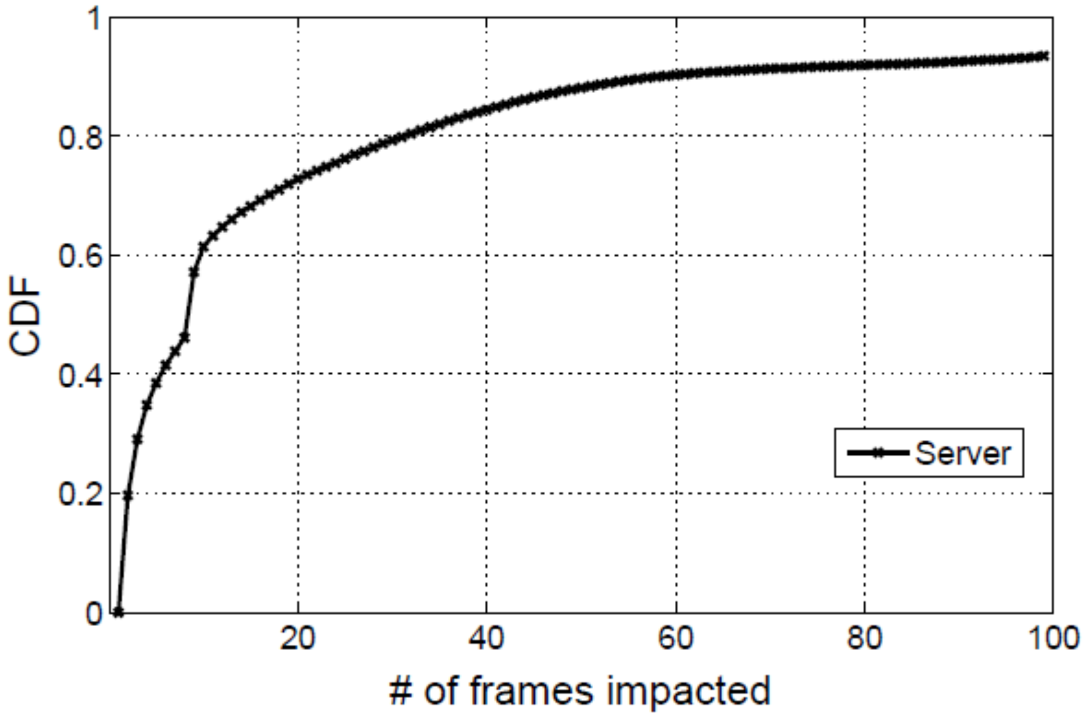
- *Last-hop* failure: Access link or `destination unreachable'
- *Middle*: Between POP at source ISP and backbone hop
- Last-hop < *Source* < Middle
- Middle < *Destination* < Last hop

Failure Frequency



-Few paths experience a majority of failures
- Could use redirection

Failure Duration



- When a loss is detected, number of *consecutive* frames impacted
  - Counted until reception of an intact frame

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How do outages impact perceived quality?

- We studied Internet links and paths, and have a rich IP-level packet reception trace

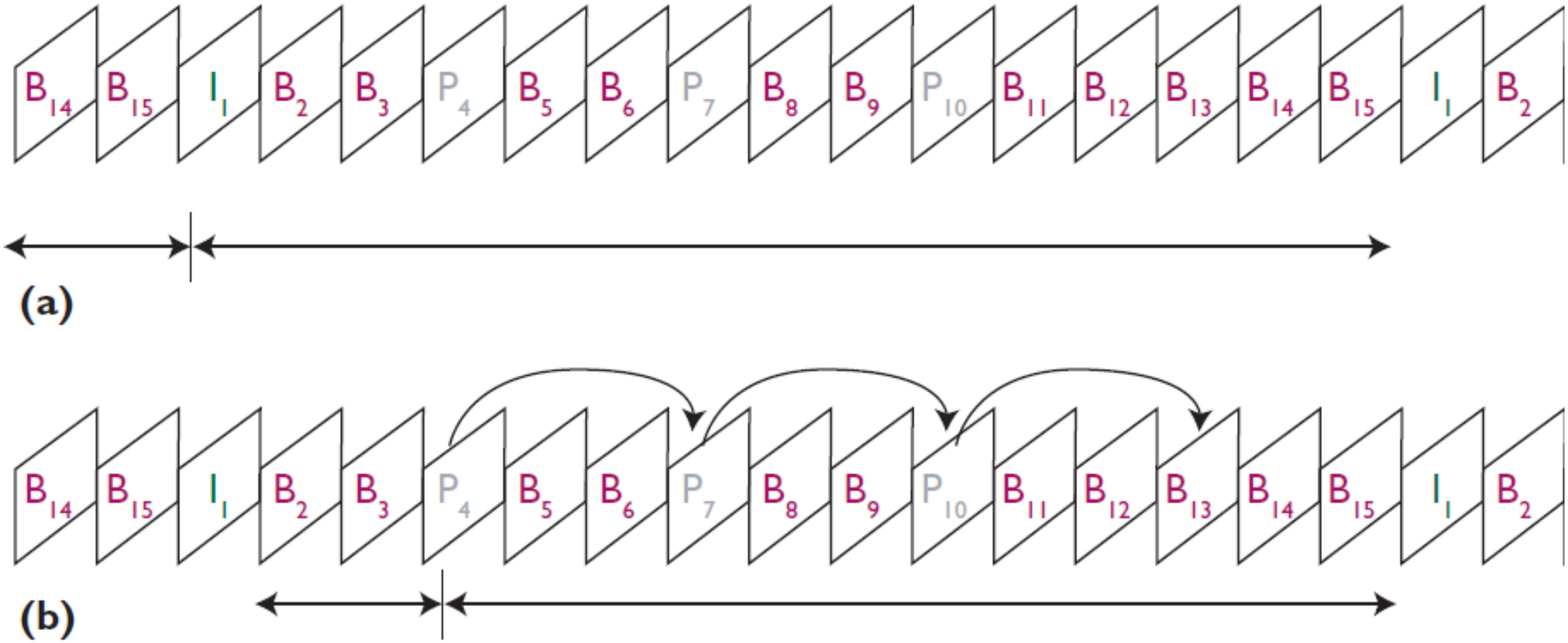
- We seek to map the most commonly occurring loss patters to perceptual quality

- We chose *loss*, encoding *bit-rate*, and *motion complexity* as criterions.

- A set of *54 video clips* were put together that mirrored these loss patterns

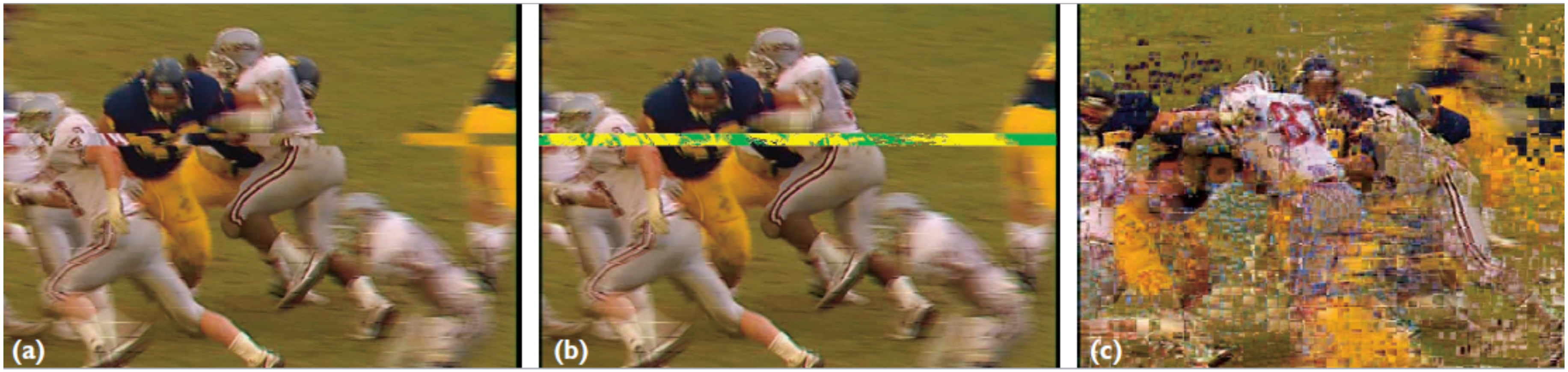
- Subjective surveys were conducted to gain a deeper understanding

MPEG-2 Overview



- (a) Structure of a GOP
- (b) *P*– and *B*- frame loss propagation

Video Artifacts

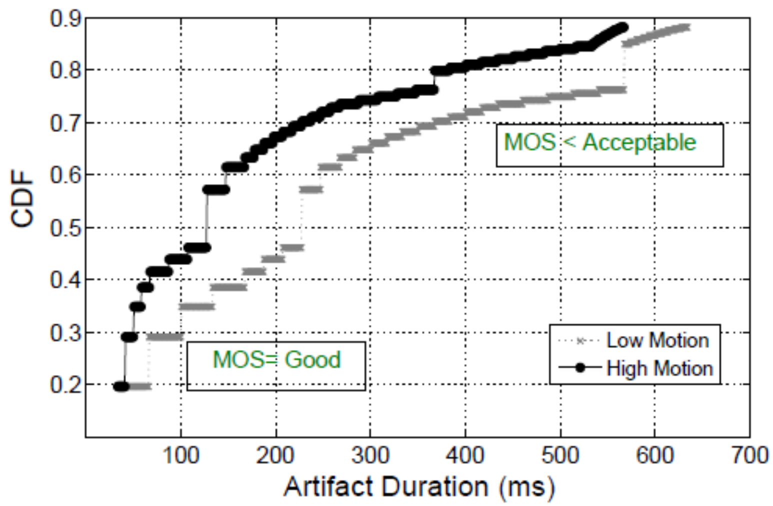


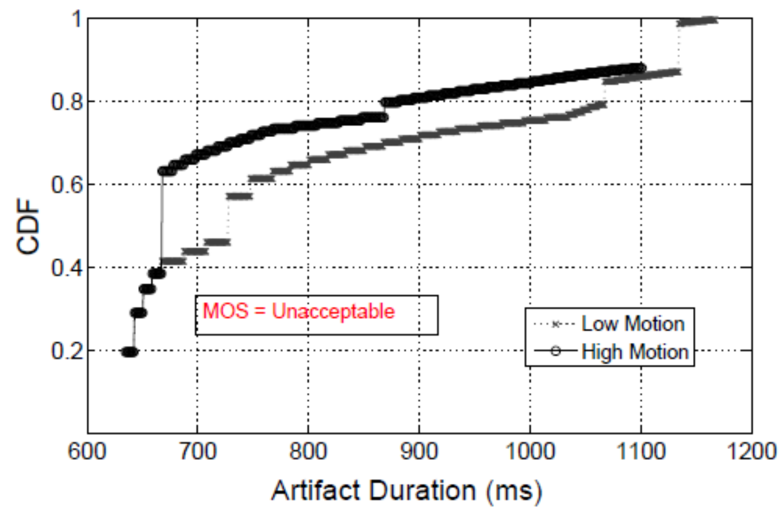
-(a) single B-frame corrupt: *Freezing*

- (b) single P-frame corrupt: *Slicing*

- (c) corrupt I-frame: *Ghosting*

Impact on Perceived Quality





- Low Motion v/s High Motion clips: survey with human subjects
  - Perceptual quality different

- Low Motion clips (*left*):
  - Longer GOP, more compression, little change of scene

- High Motion Clips (*right*):
  - Smaller GOP, low compression, lots of scene change

Recovering from Perceptual Degradations

- **Preserve key frames**
  - Restoring the *next* key frame can result in recovery

- **Switch paths when degradations are observed**
  - Internet outages can go unchecked
  - Can impact multiple frames

- **Maintain interactivity**
  - Choose “bound” appropriately
  - Interactivity affects perceptual quality

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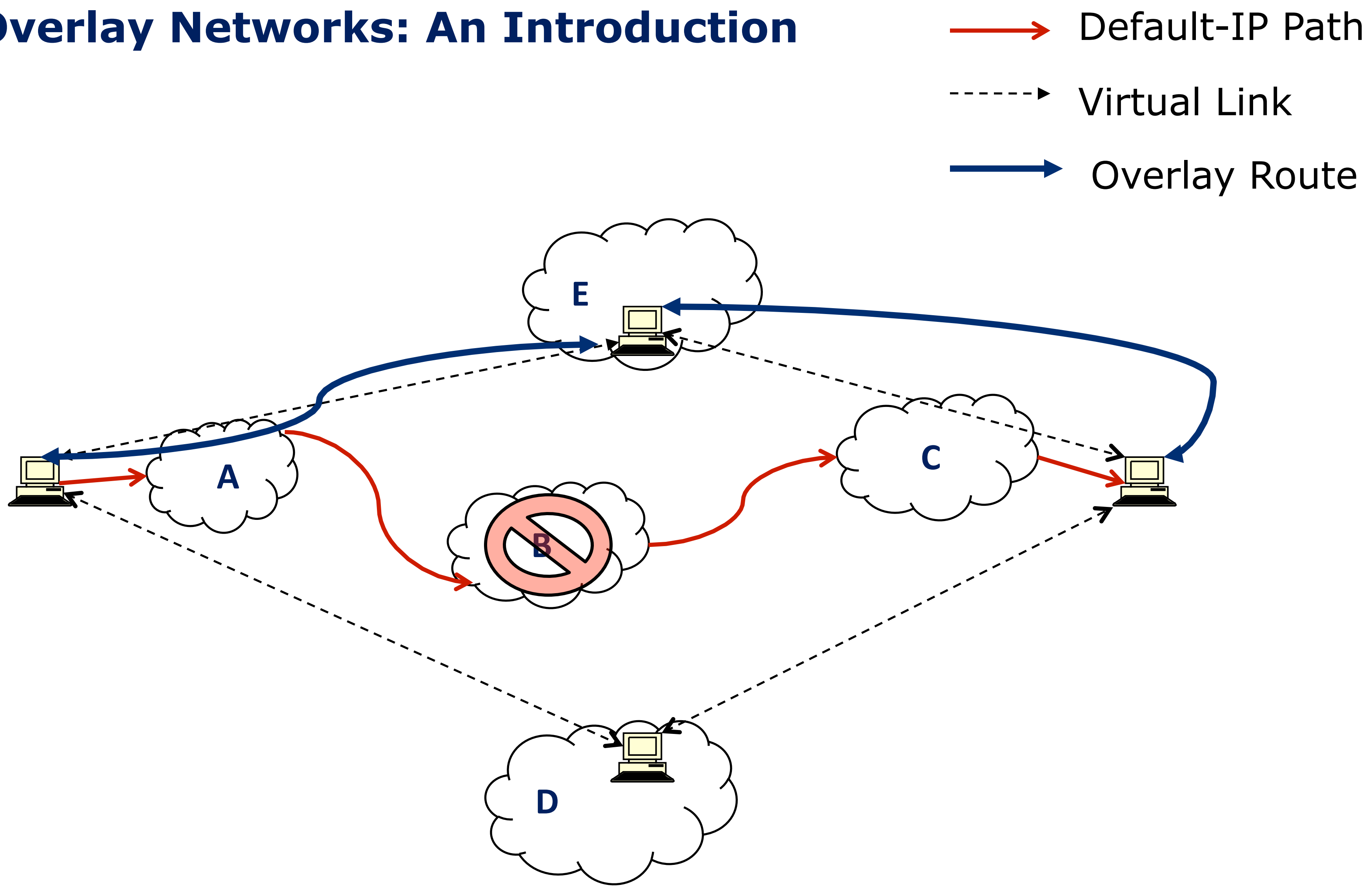
Overlay Networks: An Introduction



Overlay Networks

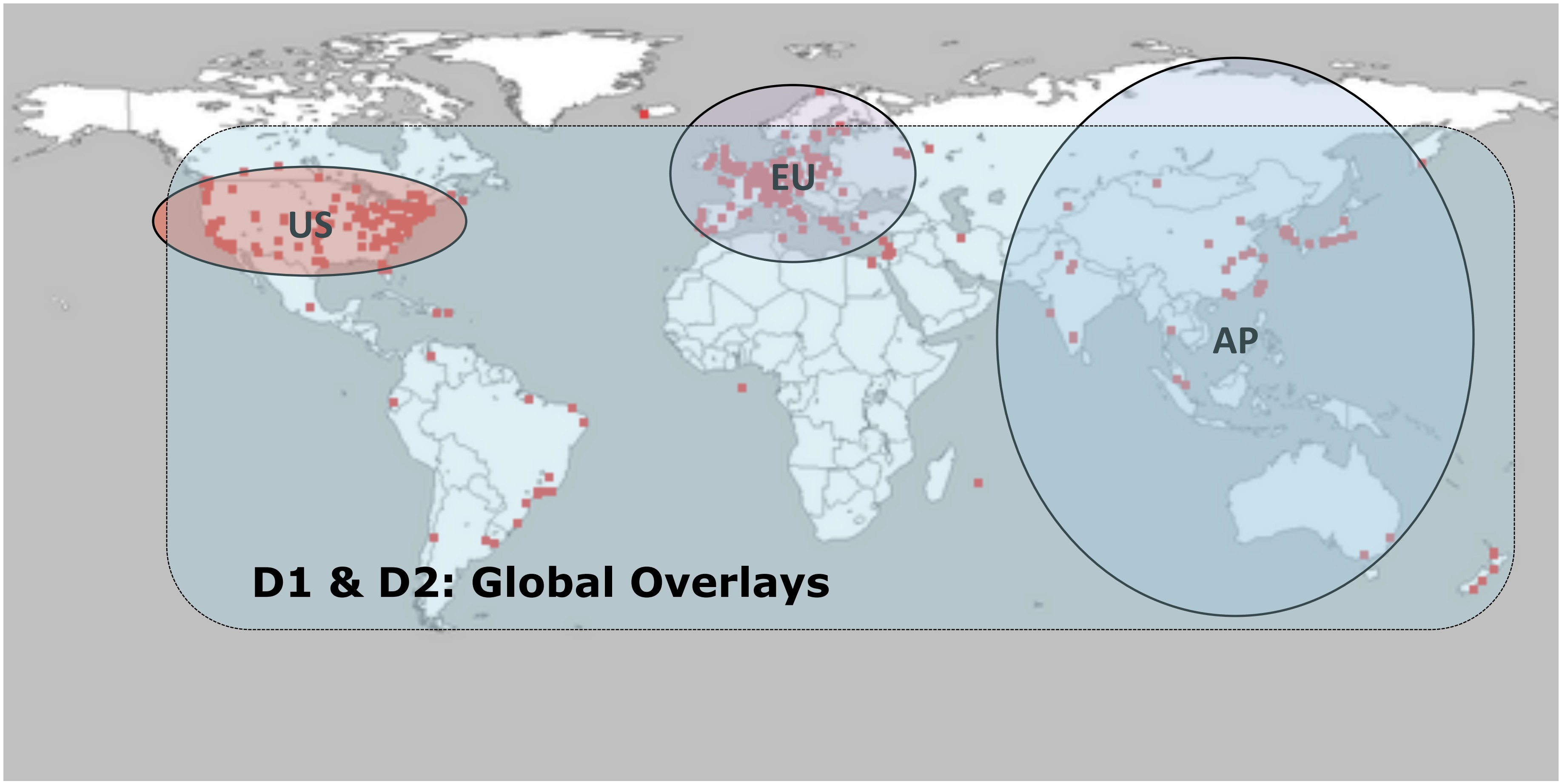
- A logical network built on top of a physical network
  - Overlay links are tunnels through the underlying network

- Nodes are often end hosts
  - Acting as intermediate nodes that forward traffic
  - Providing a service, such as access to files

- Who controls the nodes providing service?
  - Distributed collection of end users (e.g., peer-to-peer)

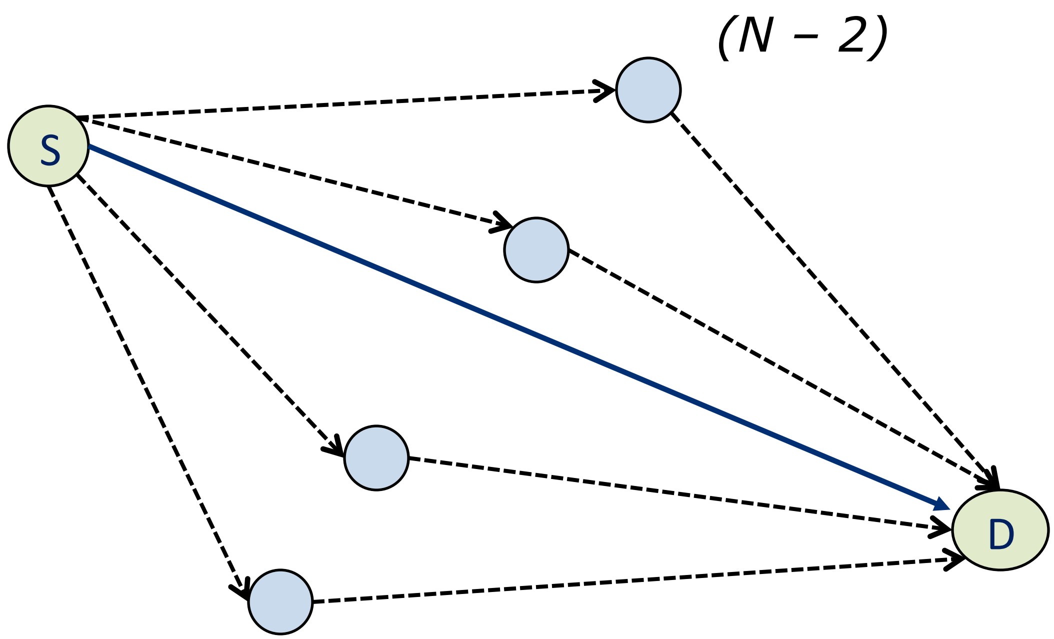
- **Limitations: Proposed Architectures not scalable**
  - **Requires monitoring *$O(n^2)$* paths to be monitored**

Experimental Setup



- Five measurement overlays deployed to measure path quality

Data Collection Methodology

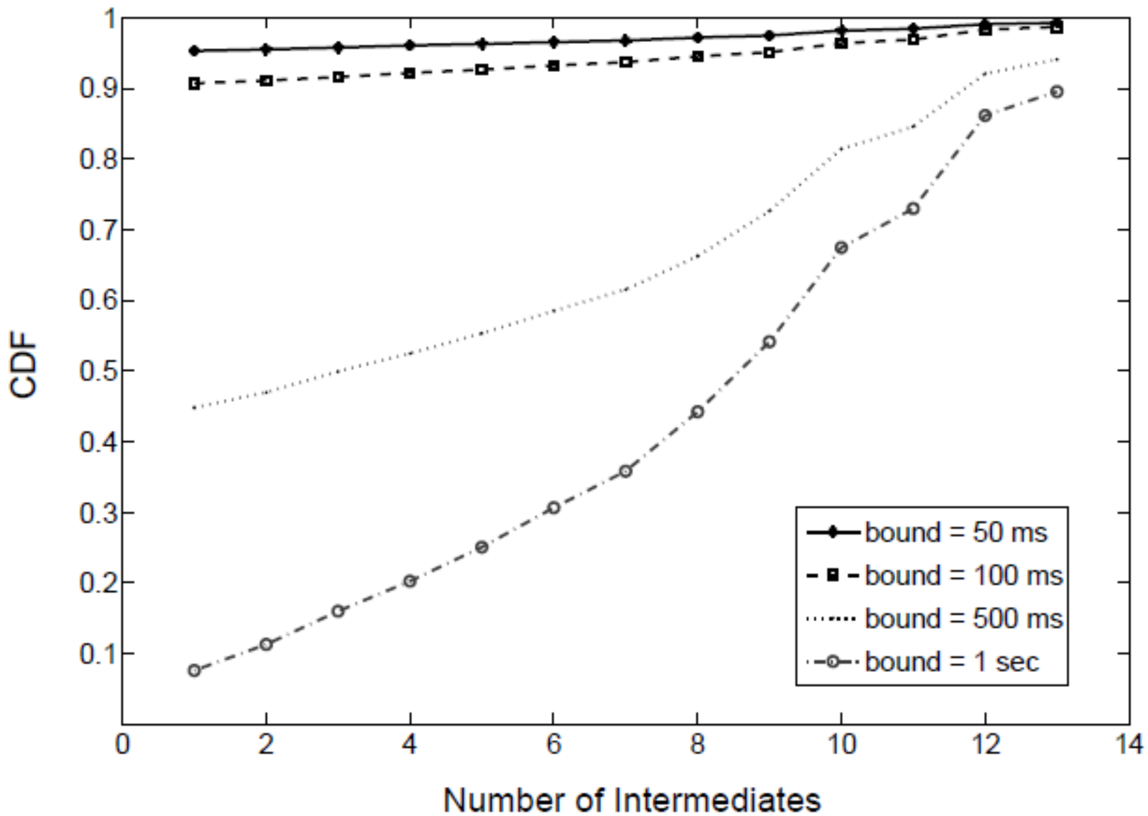


-Nodes probe a destination using IP-trace of a video clip
  - Cycle destinations and video-clips continuously for six days

- Destination *also* simultaneously probed via all other *N-2* nodes

- Alternate loss free paths with delay-bound < 500 ms are useful

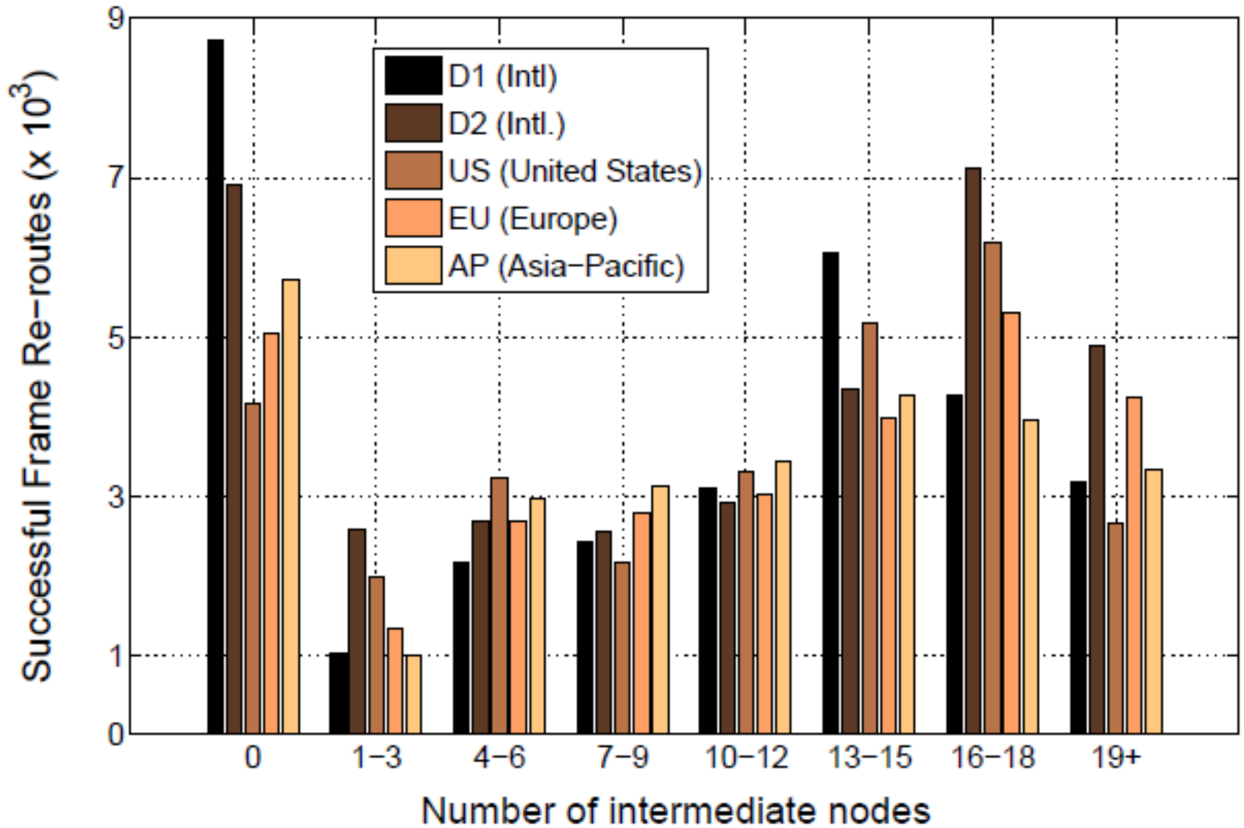
Suitability of Intermediaries



-Degradation on the default-IP path: number of useful intermediaries
- Confirms triangle inequality in the Internet

- Shown for different RTT bounds

Useful Intermediaries



- Useful intermediaries across all five datasets

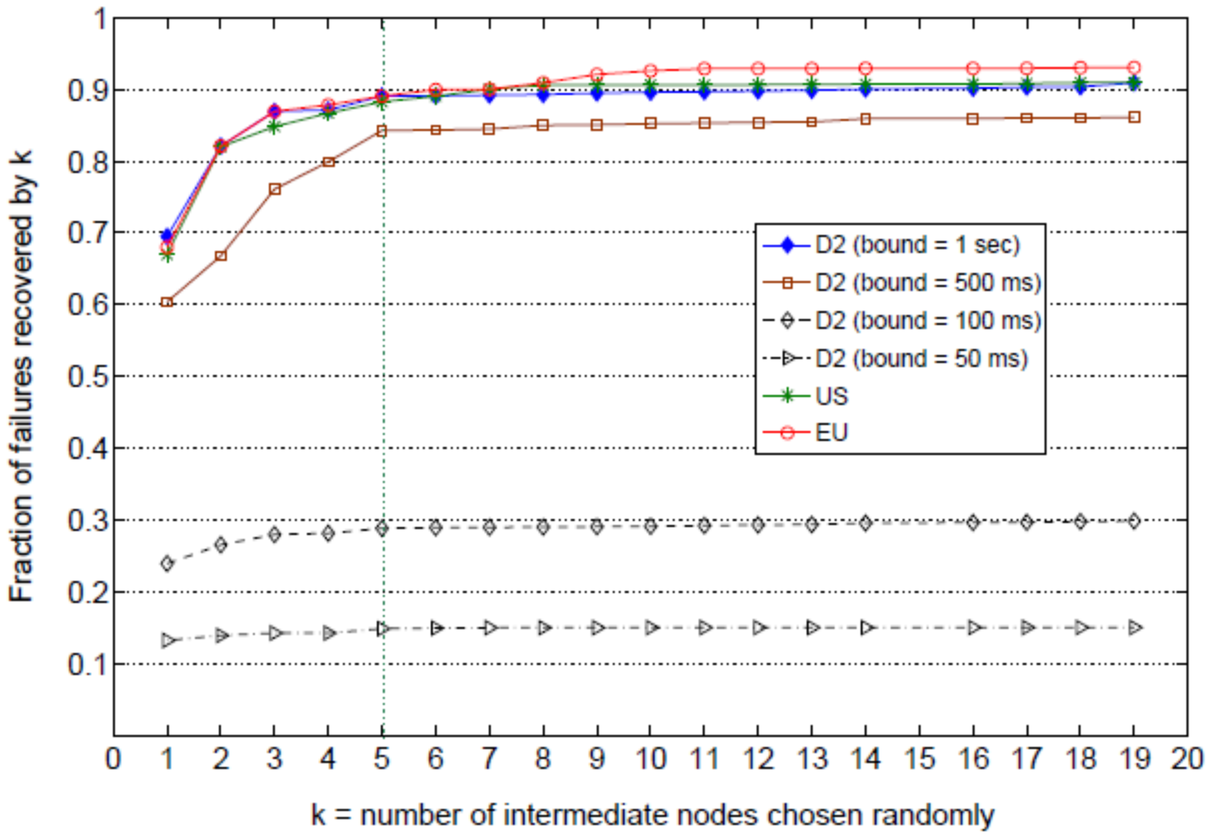
Random-*k* path selection

-Results confirm triangle inequality
    - Internet route selection based on many factors

- How can a node select suitable intermediaries *without* path quality information?
    - Enable large scale overlays

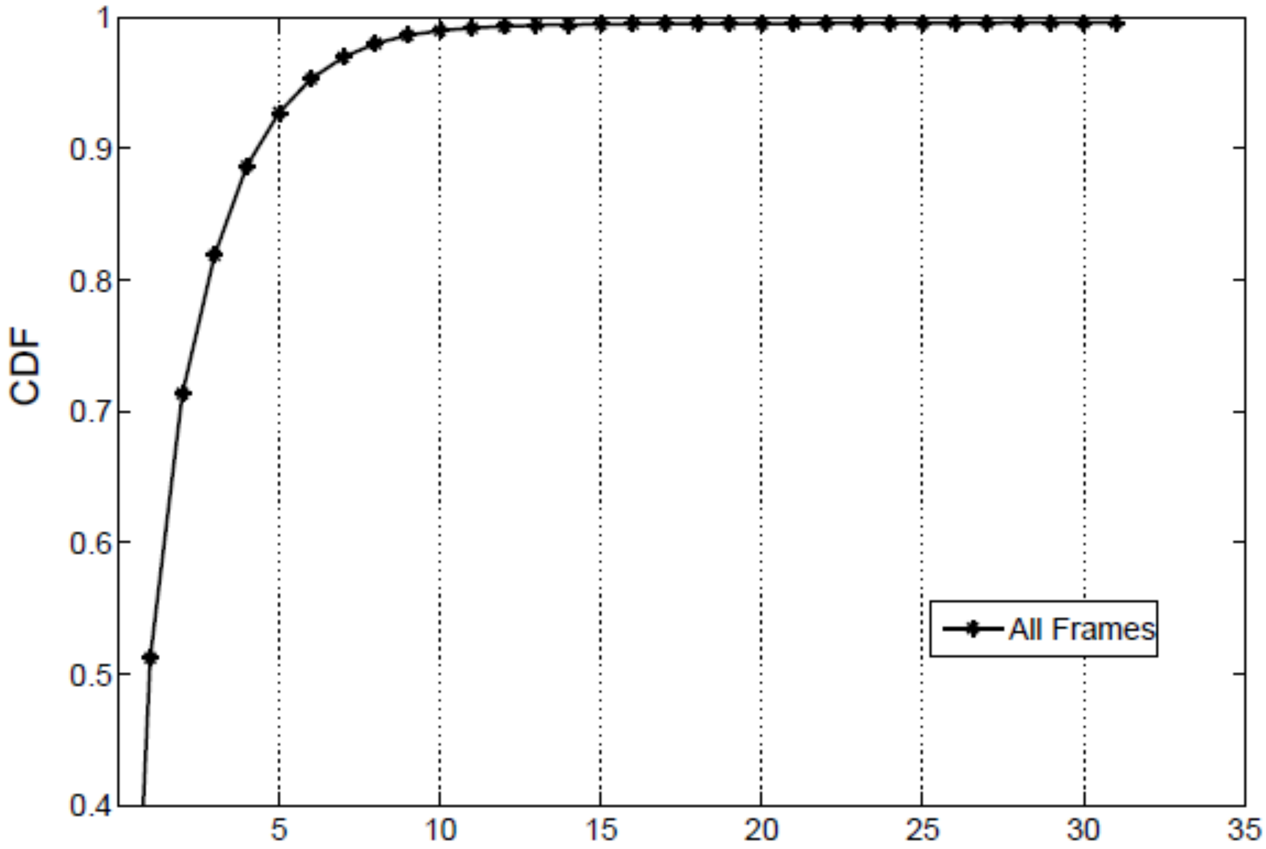
- Akin to randomized load allocation, we experiment with a random path selection strategy
    - Choose a random subset of nodes; called random-*k*
    - Try to work around outages; loss free and bound < 500 ms
    - Is there a suitable value of *k* that can route around outages?

Measurement free path selection



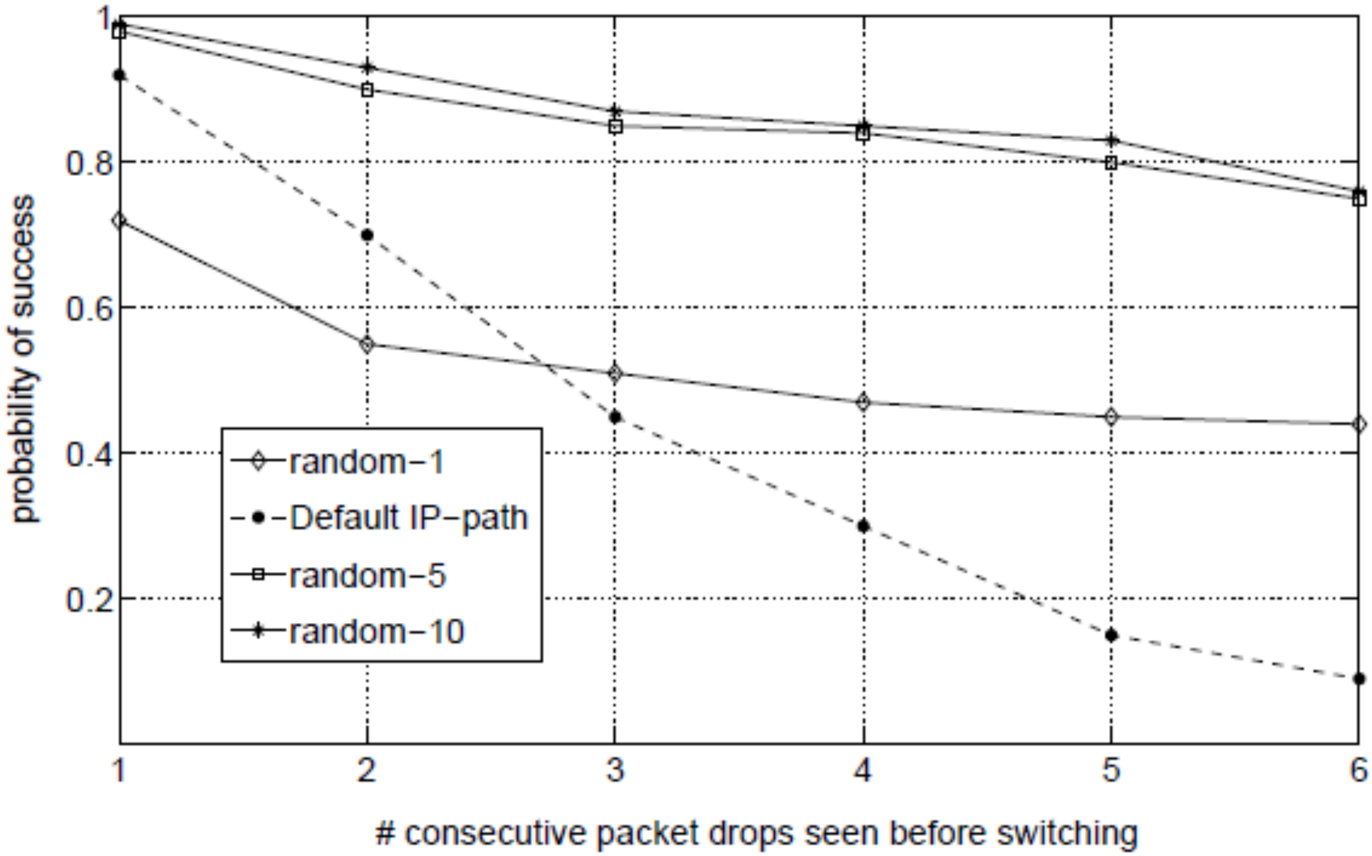
- *K = 5* provides a reasonable tradeoff

Frames impacted during outages



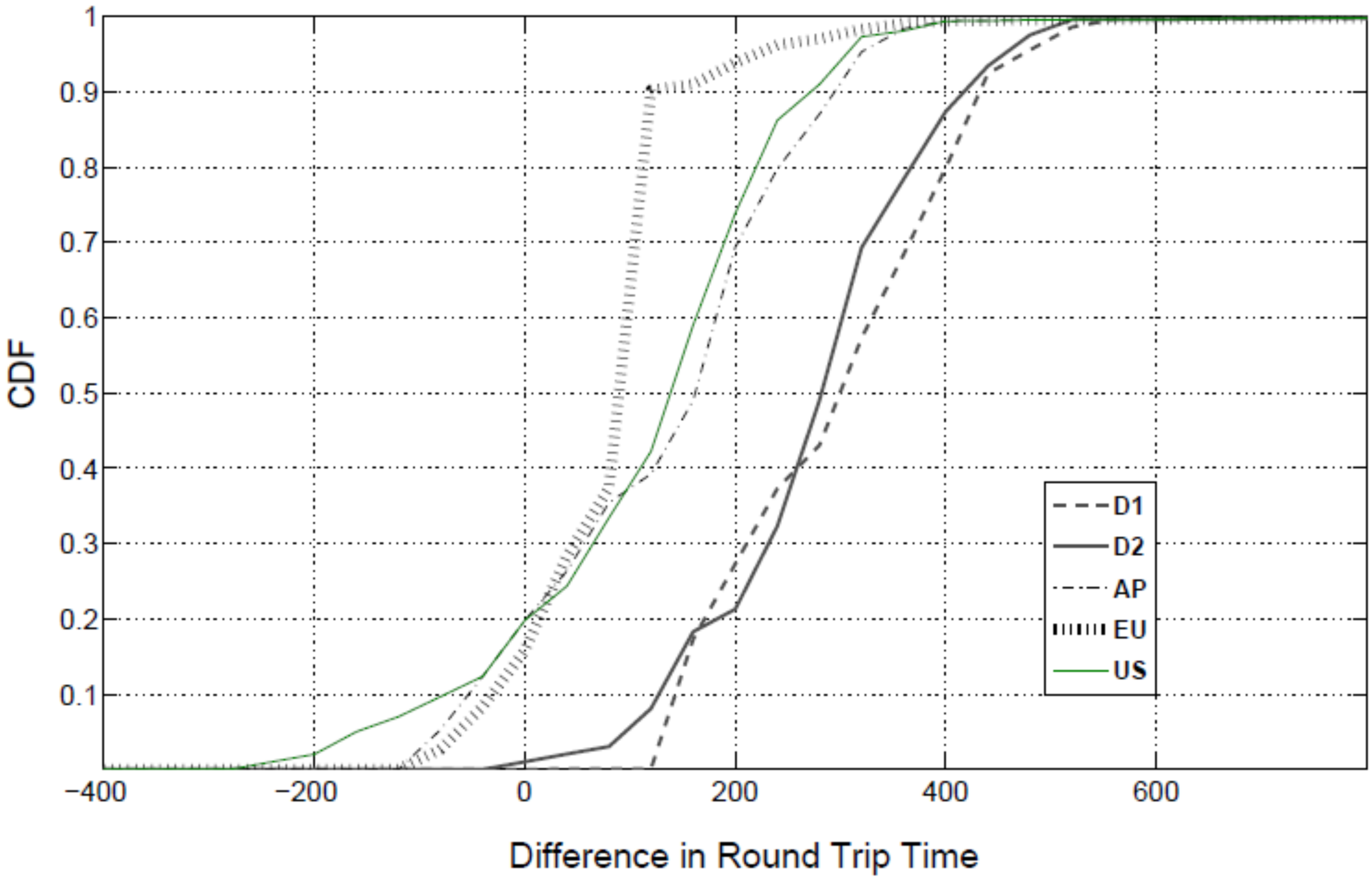
- Worst case: A single packet loss can degrade perceptual quality

Benefits of switching early



- Probability that the next frame is intact following loss

Preserving Interactivity



- Difference in RTT of random-5 and default-IP path

SIFR: Source Initiated Frame Restoration

-Based on random-*k* path recovery, we design and implement a system (SIFR)

- Destination reports an outage when key frame corrupt

- Source retries subsequent frames using *k* randomly chosen intermediaries

- Deployed SIFR on three source nodes, one each in US, EU and AP

- Compared against default-IP at three co-located nodes

- Ran experiment for little more than 48 hours

SIFR v/s IP from 3-node pairs

Performance Metric	SIFR	Default **IP-path**
total # of GOP degradations	303	779
# of degradation “episodes”	251	293
Mean # of corrupt GOP per episode	1.167	2.65
% of times episodes were limited to one GOP	96%	82%
Mean time to restore quality	< 1 sec	5.23 secs

- Episode: #of GOPs to receiving an intact GOP
- SIFR preserves about 61% of subsequent GOPs that default-IP could not
- Improves episode time by 55%, reroutes quickly

SIFR benefits are perceptual

- SIFR is better able to restore perceptual degradations
- *Left:* Default IP-path
- *Right:* SIFR redirection

Conclusions

-We presented large scale Internet path measurements
  - effects of Internet path selection on video-QoE
  - ways to improve video QoE

- First empirical measurement based characterization of Internet paths from a multimedia-quality standpoint

- Overhead free selection of alternate Internet paths

- We believe this technique has potential to build *large scale routing overlays* to alleviate many problems

-Future work shall focus on deploying large scale overlays based on random load allocation
  - Investigate latency reduction overlays
  - Investigate specific properties of random-*k*

Questions
-?