Positioning Relay Nodes in ISP Networks

Meeyoung Cha (KAIST)
Sue Moon (KAIST)
Chong-Dae Park (KAIST)
Aman Shaikh (AT&T Labs – Research)

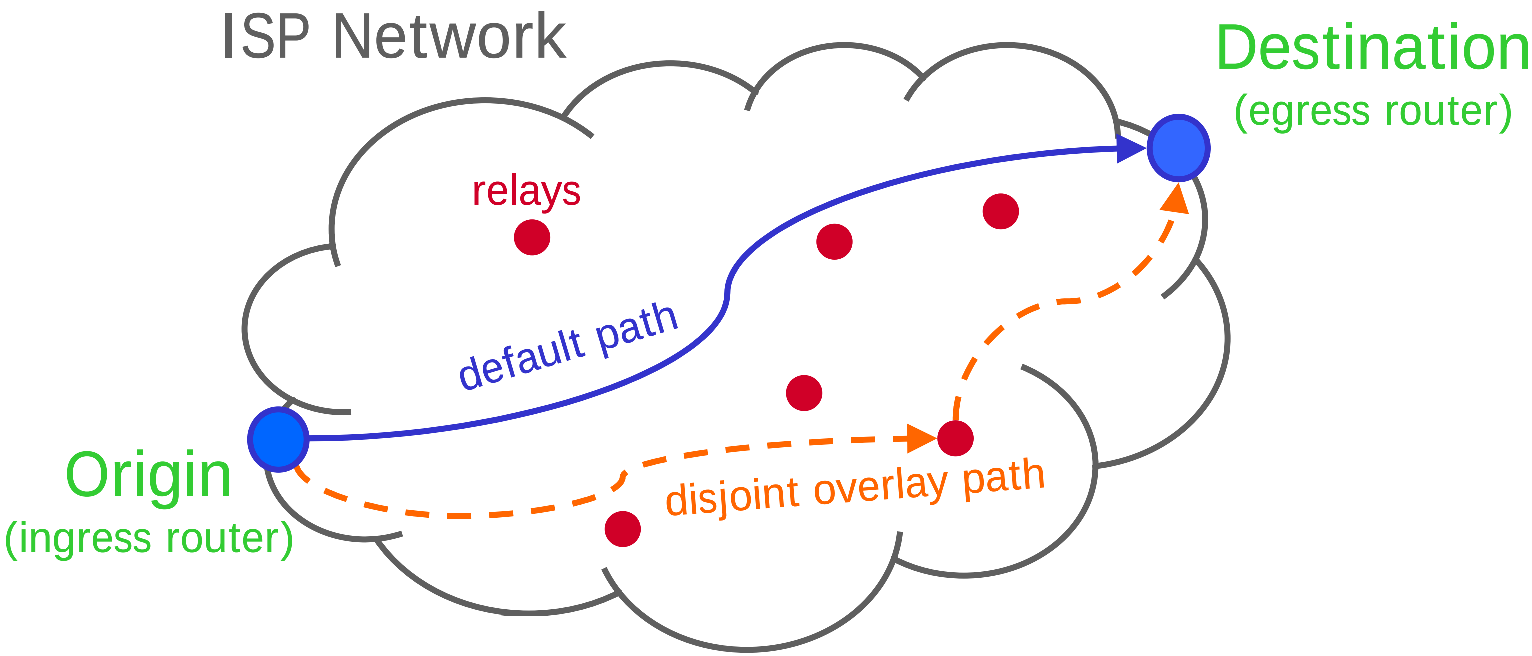
IEEE INFOCOM 2005 Poster Session

Routing Instability in the Internet

- Network-wide changes are frequent and may propagate slowly. During routing instability, persistent end-to-end connections experience packet delay, jitter, and loss.

- How to increase **reliability and robustness of mission-critical services** in the event of network failures?
  - Use "**Path Diversity**"
  - ex) overlay networks
    - RON [Anderson et al., SOSP 2001]
    - Detour [Savage et al., IEEE Micro 1999]

Path Diversity – Disjoint Overlay Path



Intuition: Disjoint overlay path gives maximum robustness against single link or router failures!

Objective of Our Work

- Previous work was focused on selecting good relay nodes under pre-deployed relay nodes.

- As an ISP, consider a problem of **optimal relay node positioning**; relaying packets could be value-added service.

Focus of this work is to find a **minimal set of relay nodes** that offer **as much path diversity as possible** to all OD pairs.

Under Assumptions:

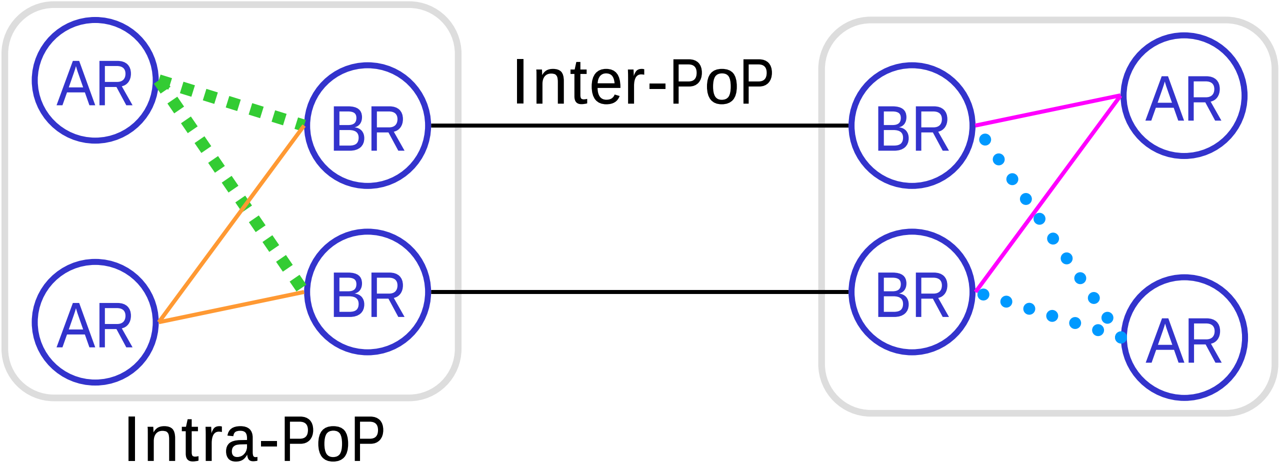
- Intra-domain routing [Shortest Path First (SPF) Routing]
- ISP network topology
- Disjoint overlay path uses only one relay

Practice of Path Diversity in a Typical ISP Network

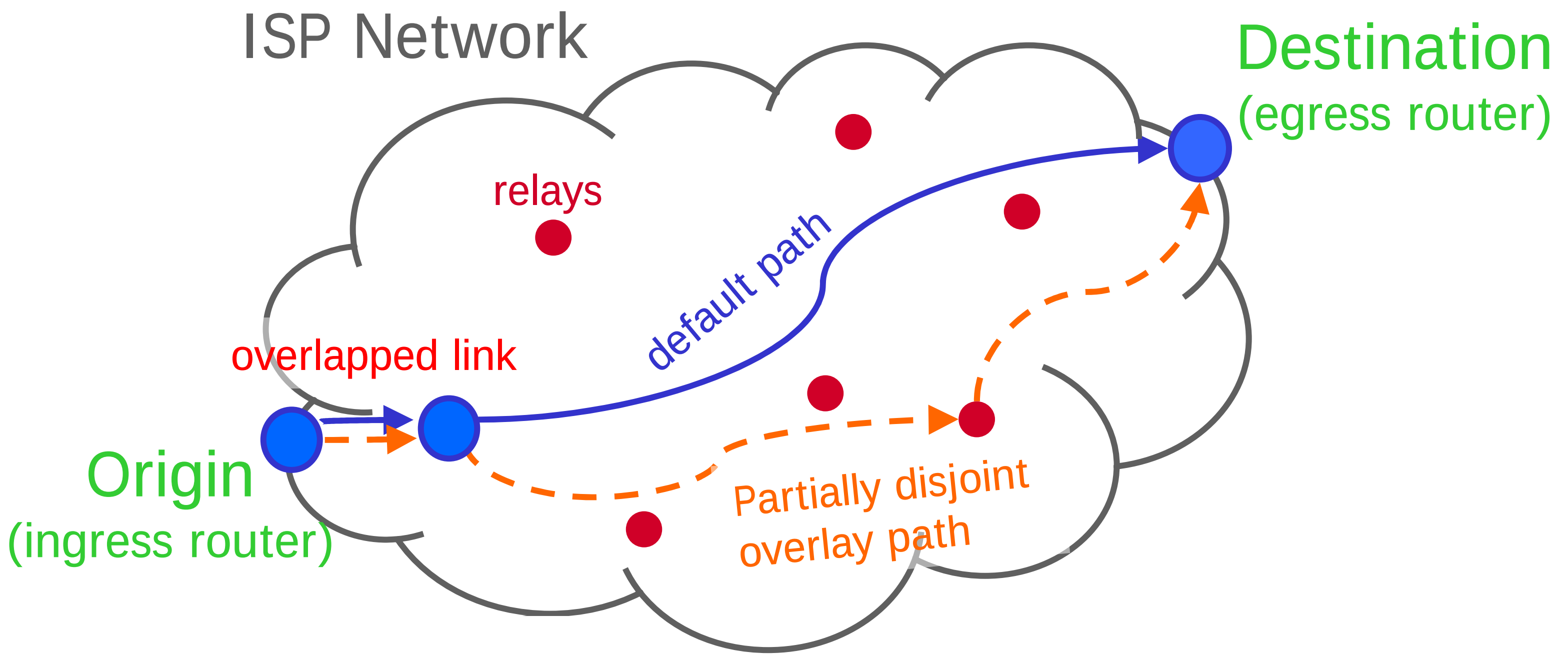
- Completely disjoint overlay paths are often not possible.

  ex) Equal Cost Multi-Paths (ECMPs)

  (AR: Access Router, BR: Border Router)



Partially Disjoint Overlay Path



When completely disjoint overlay paths are not available, we allow overlapped links.

Efficacy of disjoint paths

- Network is **resilient** as long as either the default or the overlay path is not affected by a failure

  → Disjoint paths are preferred

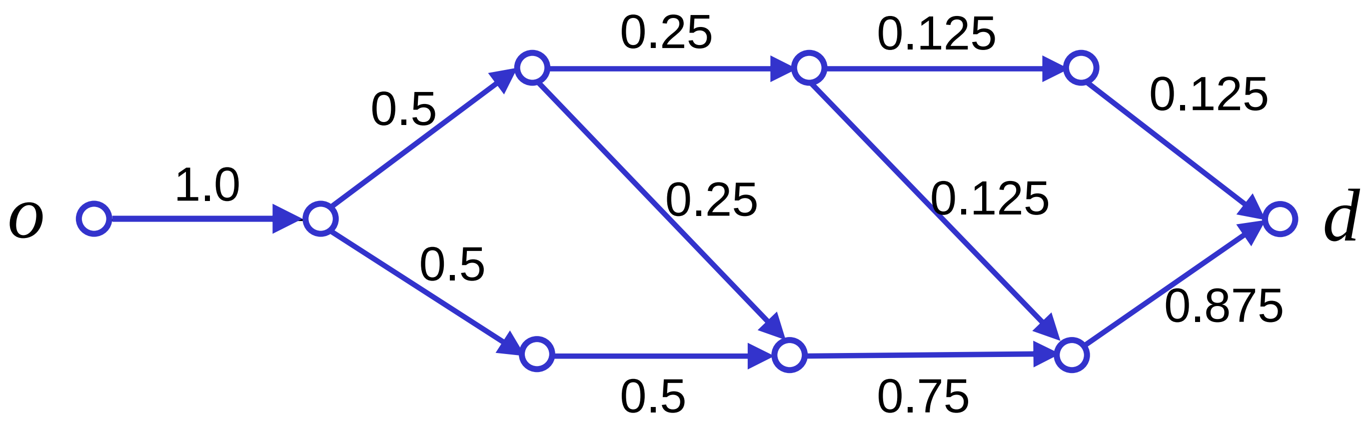
  → Overlapped links will diminish the efficacy of overlay paths

Path disjointness?

- depends on the number of overlapped links
- how do we quantify path disjointness?

Penalty for Overlapped Links

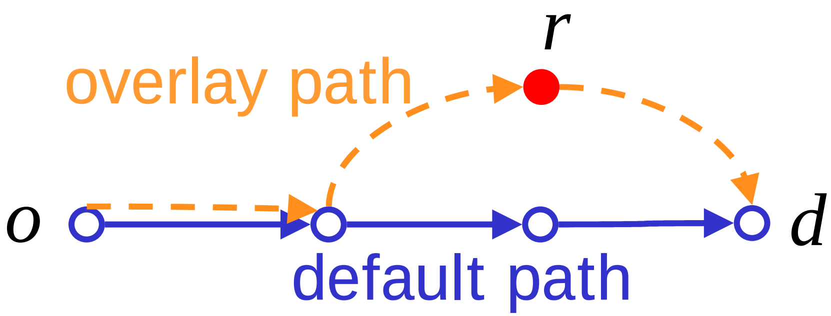
- Define $I_{o,d,l}$ (impact of a single link failure)
  - assume traffic is evenly split among shortest paths



- $I_{o,d,l}$ = Pr[$o \rightarrow d$ fails | link l fails]
  - fraction of traffic that traverse l for $o \rightarrow d$

Disjointness between two paths

- Define $K_{o,d}(r) = \sum_l I_{o,d,l} \, (I_{o,r,l} + I_{r,d,l})$
  - Path disjointness between $o \rightarrow d$ and $o \rightarrow r \rightarrow d$
  - $K_{o,d}(r)$ / $|E|$ =
    Pr[$o \rightarrow d$ & $o \rightarrow r \rightarrow d$ fails | a single link failure]



Selecting Relay Nodes for Overlay Path

- Based on the intuitive notion of penalty for partially disjoint overlay paths, we find relay nodes that incur the least amount of penalty.

- To evaluate our algorithm, we give preliminary results on how relay nodes selected by our algorithm increase network resiliency in a real network topology.

Evaluation Settings

- We use an **operational tier-1 ISP backbone** and the **real failures logs** that spans six-month.

Topology - 100 routers, 200 links, ECMP 53%

Event logs - June 1~Nov 30, 2003

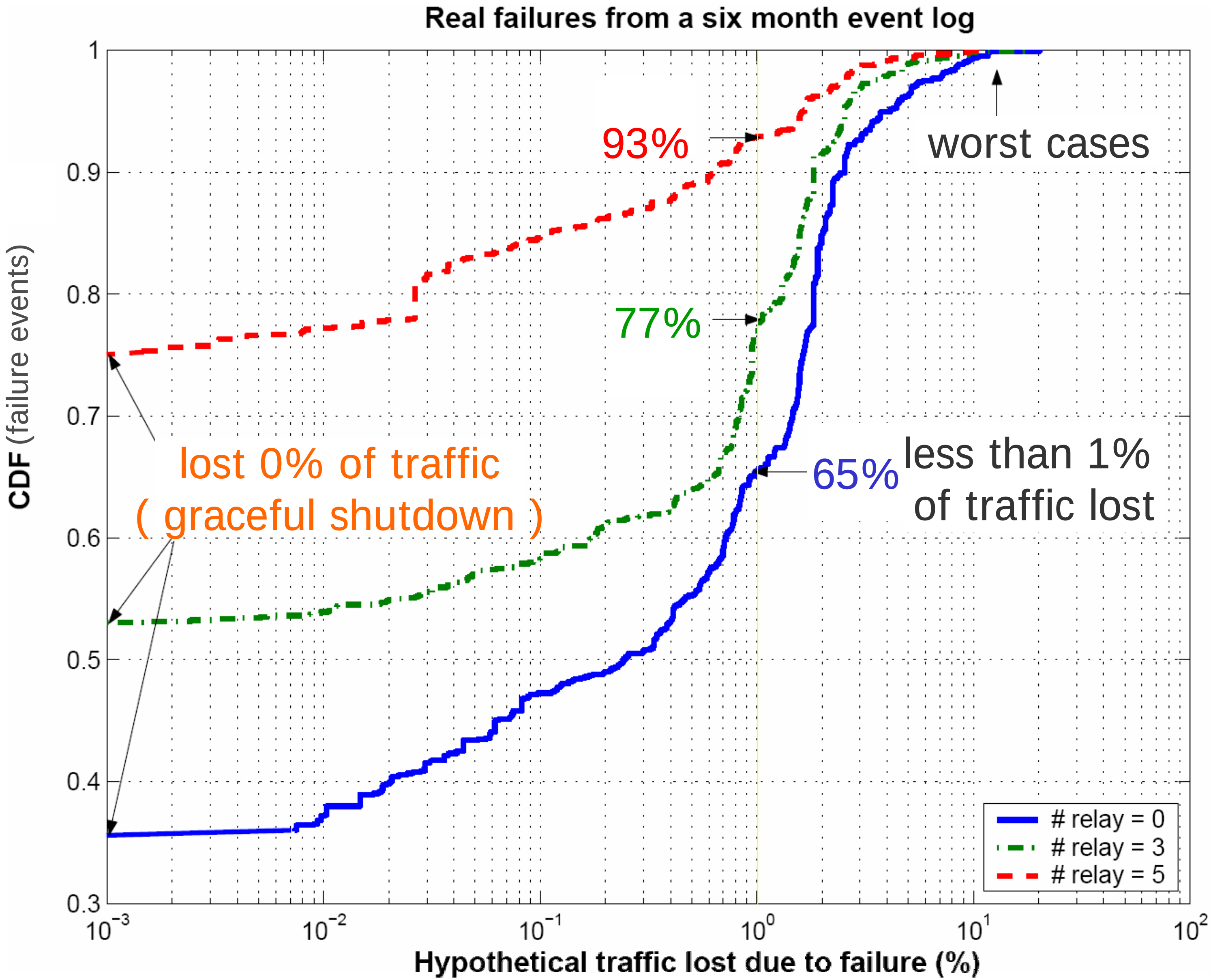
- only link and router down events considered

Hypothetical traffic matrix

- assumes equal amount of traffic between OD pairs

Assume rerouting is done instantaneously after events

Hypothetical Traffic Lost from Event Logs



Preliminary Results

- Network resilience to real failures increases as we increase the number of relay nodes.

  However, there certainly exists a saturation point.

- When five relay nodes are used,

  - **complete protection** against **75.3%** of failure events

  - for **92.8%** of failure events, **less than 1%** of hypothetical traffic is affected

- A small number of relay nodes is effective over the entire course of six months.

Conclusions

- Propose a simple greedy algorithm for **selecting the number and positions of relay nodes** in a network run by a single AS.
- When it is not possible to find completely disjoint paths, we allow **overlapped links** btwn two paths, and introduce the measure of penalty for the overlapped links.
- Evaluate the efficacy of our algorithm with an **operational tier-1 ISP** network.

Further Works

- Implementation Issues
  - relays on VoIP gateways
- Properties of relay nodes
  - topological insight
  - whether relays are selected on ARs or BRs
  - bandwidth / position / load-balancing of relays
  - how often should we reposition relays?
- Lower layer path diversity
  - how to incorporate fiber map into our algorithm?