Positioning Relay Nodes in ISP Networks

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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

ISP Network

Destination (egress router)

Origin (ingress router)

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)
When completely disjoint overlay paths are not available, we allow *overlapped links*.
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?
• Define $I_{o,d,l}$ (impact of a single link failure)
  - assume traffic is evenly split among shortest paths

  ![Diagram showing the impact of a single link failure]

• $I_{o,d,l} = \Pr[o \rightarrow d \text{ fails} | \text{ link } l \text{ fails}]$
  - 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 $o \rightarrow r \rightarrow d$
  - $K_{o,d}(r) / |E| = Pr[o \rightarrow d \& o \rightarrow r \rightarrow d \text{ fails} | \text{ a single link failure}]$
• 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

Real failures from a six month event log

- Lost 0% of traffic (graceful shutdown)
- 65% of traffic lost
- 77% less than 1% of traffic lost
- 93% worst cases
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 between 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?