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Geographic Properties of Internet Routing
Properties we study

- Can ISPs take geographic node failures?
  - Geographic Fault Tolerance
- Can we find sub-optimal peering among ISPs?
  - Hot-Potato / Cold-Potato Routing
- Multi-ISP routing properties
- Can help to find anomalous paths
  - Circuitousness of Geographic Paths
Outline

- Conclusions
- Geographic Fault Tolerance
- Routing across multiple ISPs
- Circuits
- Experimental Methodology
- GeoTrack and its properties
- What is a Geographic Path?
What is a Geographic Path?

- Geographic Path: Berkeley, San Francisco, Seattle, Pennauken, New York

- Example:
  BERK-BERK-7507, POS-calen2.net Berkeley+CA
  sl-bb10-sea-7.0.sprintlink.net Seattle+WA
  at-bb11-nj-0.0.appliedtheory.net New+York+NY
  acr1-loopback.Seattles2.net Seattle+WA
  208.172.83.118 unknown
  acr1-series2.0.0-SanFrancisco 실 San+Francisco+CA
  at-bb1-nj-0.0-OC3.appliedtheory.net New+York+NY

- Consider the tracert path to an end-host. The geographic path is the ordered list of unique geographic locations of the routers in the path.

- Geographic path does not cover the entire L2 path.
- Among 13 major ISPs, recognizability is 87%.
- Recognize 70% of net router labels (7842 out of 11296).
- Recognizability of routers
- US + 26 countries in Europe.

Coverage of the Tool

- Code pen in sl-002l-pen-2, sphintlink.net refers to Penmsaken+NI.

Example:

in its DNS name.

Recognize router's geographic location using codes that may be embedded.
This forms a large portion of the Geographic Path.

- Can recognize most of the routers when in transit between major ISPs.

Recognizability of Geographic Paths

![Graph showing the relationship between position in the path and percentage of routers recognized.](image-url)
ISPs topologies from CAIDA's Mapnet tool.

- Vern Paxson's traceroute dataset in 1995.
- Approximately 8000 traceroutes in total.

- **TVHosts**: 3100 clients at an online TV Program Guide.
- **EuroWeb**: 1092 web servers in Europe.
- **LibWeb**: 1205 public libraries in the US.
- **UnivHosts**: 267 universities in the US.

**Variety of Destination End-hosts**

- 20 geographically dispersed probe points (17 in US, 3 in Europe)

**Experimental Methodology**
- Number of components in the graph.
  - Geographic fault tolerance
  - Fraction of the path within the ISP.
  - Compute fraction of path in ISP
   - Multi-ISP routine

- Distance Ratio = Inherited distance / end2end Geographic distance
- Geographic distances in the path.
- Compute Inherited distance of a Geographic path as the sum of hop-hop
  - Circuitousness of Paths

Metrics
expeected to be smaller.

If source is close to well connected geographic location, distance ratio is

**Circuitousness:** Effect of Source Location
circuits. So many small ISPs are traversed in a path.

- There are many small (national) networks in Europe which makes routing

![Graph showing cumulative distribution of distance ratios between US-US and Europe-European networks.](image)
End2End paths are much more circuitious than intra-ISP paths.

**Distance Ratio vs Geographic Distance**
Path increase. Does this suggest sub-optimal peering?

The distance ratio seems to increase as the number of major ISPs in a

Multi-ISP routing
potato/cold-potato policies. Peering relationships may have a higher influence on routing than hot-cold potato/cold-potato policies.

Some other (i.e., Internet2) ISPs perform hot-potato routing while some major ISPs ( Sprintlink ) seem to perform hot-potato routing while Hot-Potato routing.
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- Can potentially detect suboptimal routing?

- Presence of Hot-potato/Cold-Potato routing in ISPs

  Geography helps in determining:

  - Circuits paths normally traverse multiple major ISPs.

  - Inter-ISP paths are less circuits paths Inter-ISP paths.

  - Network structure (small networks vs large ISPs).

- Source and Destination Location (proximity to networking hubs).

Circuitousness depends on:

Summary: Circuitousness, Multi-ISP Routing
Worst-case scenario: Nodes with high degree in the graph fail.

- Determine number of communicating pairs in the new topology.
- A component with \( n \) nodes has \( \frac{n(n-1)}{2} \) communicating pairs.
- Graph may be subdivided into components.

When node failure(s) occurs:

1. Nodes (including inter-node communication).
   - A connected graph has \( \frac{n(n-1)}{2} \) communicating pairs of geographic pairs.
2. Routers in one geographic location into one node.
   - Consider an ISP's topology with \( N \) geographic nodes. i.e. collapse all

Geographic Fault Tolerance
Even the combined topology of 9 ISPs has a skewed degree distribution. Many major ISPs have some nodes of very high degree making them vulnerable to failures. (New York, Chicago)
PSTNet has the best fault tolerance properties. Degree distribution of PSTNet is very balanced (very few leaves).

- PSTNet\(B_{\text{BBNP}}\) (60\% of the nodes are leaves).

\textbf{Worst case Failure Scenario}
In some cases it may not be economically viable to build fault tolerant topologies. For example, Ring topology normally have better geographic fault tolerance than ISPs based on star topology of 9 major ISPs. Many ISPs do not have a good fault tolerant structure. This is true even today.