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The Center for Education and Research in Information Assurance and Security
PURDUE UNIVERSITY

Multi-Path Overlay Routing to Improve Latency while Tolerating Intrusions

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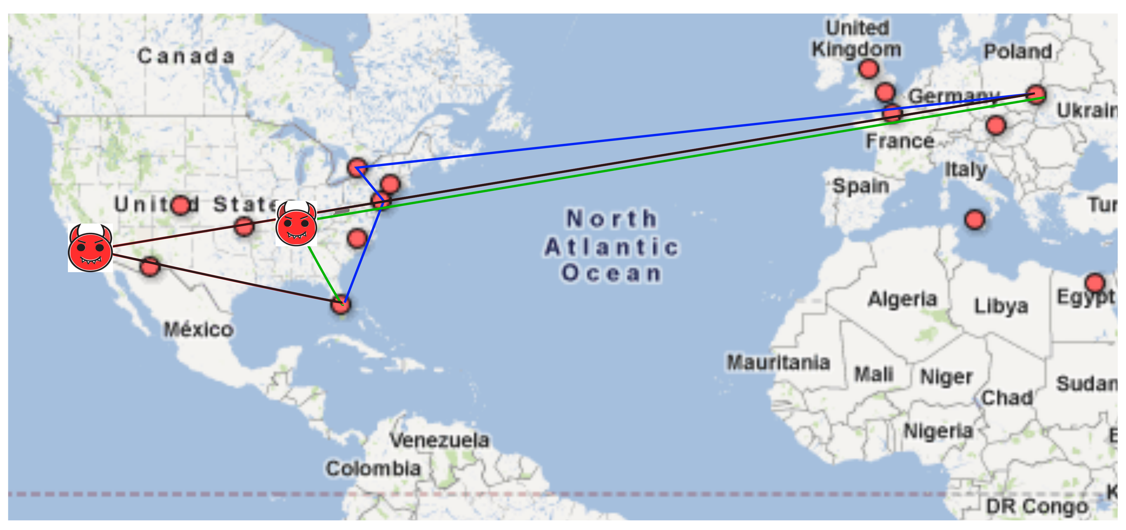
Problem

Many online services require better latency guarantees than offered by the common network infrastucture, and previous work [1] has shown this is achievable with overlay networks. We consider mission-critical network services which need to maintain these latency guarantees despite outages or intrusions of overlay nodes. Our work investigates the following:

- What is the routing algorithm in such a model?
- Can an overlay network with assumed outages and compromises still improve latency when compared to trivially using the network infrastructure?
- What is the overhead improvement when compared to the trivial flooding?
- How well does this work in the real-world?

Model



- Bounded number of compromised nodes
- Compromised nodes cannot interfere with legitimate to legitimate node connections
- Must ensure timely packet delivery

Multi-Path Routing Algorithm

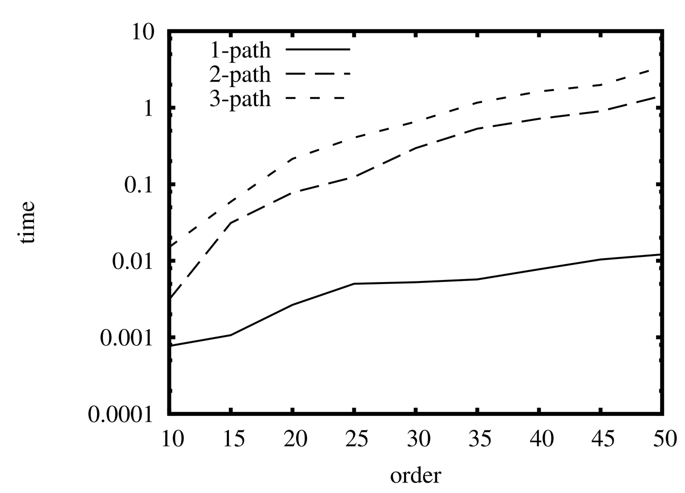
We express an overlay network as a graph with nodes N where edge weights $w_{i,j}$ are latencies. Given that f nodes can be compromised, find $f+1$ node-disjoint paths P which minimize the maximum path latency. A Mixed Integer Program can be formulated to solve this problem precisely:

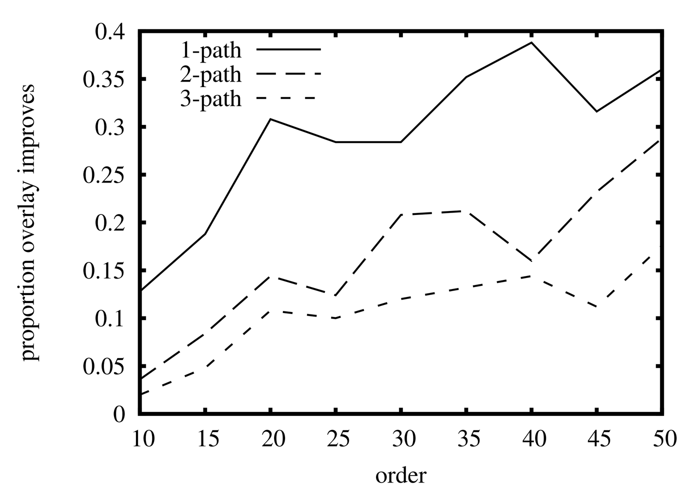
$$\begin{aligned}
\text{minimize} \quad & z \\
\text{subject to} \quad & \sum_j \sum_k x_{i,j,k} * w_{j,k} \le z, \; i \in P \\
& \sum_i \sum_j x_{i,j,k} \le 1, \; k \in (N - t) \\
& \sum_k x_{i,j,k} - \sum_k x_{i,k,j} = \begin{cases} 1 & j = s \\ -1 & j = t \\ 0 & \text{else} \end{cases}, \\
& i \in P, \; j \in N \\
& x_{i,j,k} \in \{0,1\}, \; i \in P, \; j \in N, \; k \in N
\end{aligned}$$

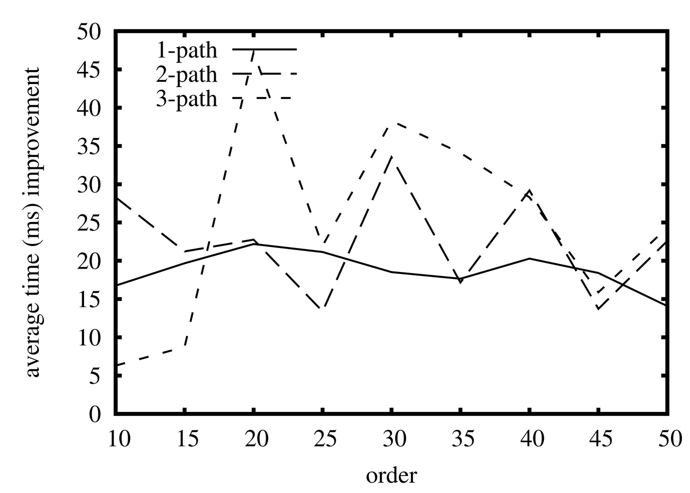
Experiment

Leverage King dataset which has median latencies between 1700 WAN nodes. Perform experiments for varying network size and number of paths as follows:

1. Pick random subset as graph
2. Fill in edge weights (complete graph)
3. Select random source and destination
4. Run Mixed Integer Program to find best paths







Future Work

Consider graphs with bounded number of neighbors. Consider how to construct the graph with low *fault diameter* [2]. Deploy systems on PlanetLab to learn about overhead involved with user-space routing as well as dynamically changing latencies.

References

[1] Yair Amir and Claudiu Danilov *Reliable Communication in Overlay Networks*, DSN (2003)

[2] M. Krishnamoorthy and B. Krishnamurthy *Fault Diameter of Interconnection Networks*, Computers and Mathematics with Applications (1987)

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