CYBER SECURITY DIVISION
2013 PRINCIPAL INVESTIGATORS'

Deploying Efficient Internet Topology Primitives

Naval Postgraduate School
Robert Beverly

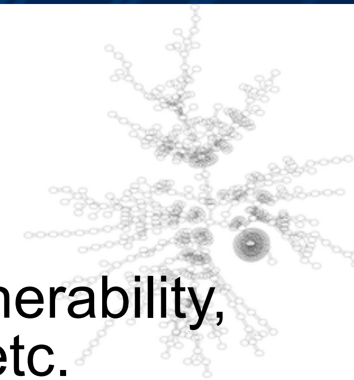
September 18, 2013

Homeland Security
Science and Technology

Team Profile

- **Naval Postgraduate School**:
  - US Navy's Research University
  - Located in Monterey, CA
  - 1500 students (all 5 services, civilians, foreign military)
- Our team:
  - **PI**: Robert Beverly
  - **Faculty**: Geoffrey Xie (NPS CS), Ralucca Gera (NPS Math), Arthur Berger (Akamai)
  - **Students**: Guillermo Baltra, Billy Brinkmeyer, Daryl Lee, Sam Trassare

Customer Need



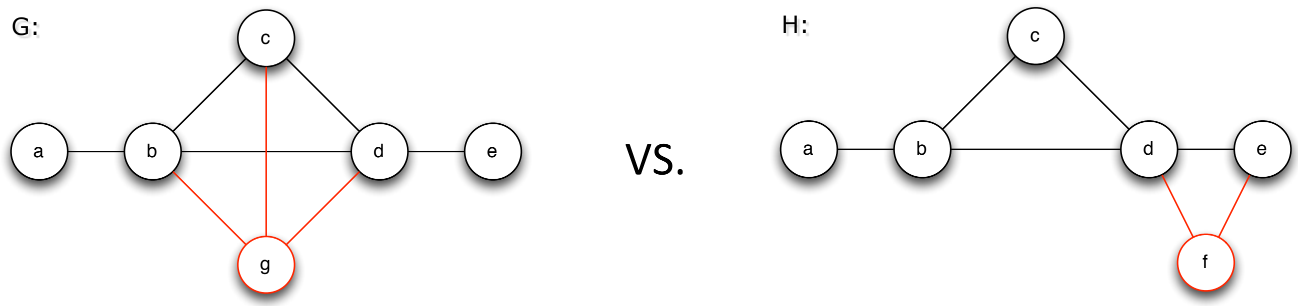
- **Internet-scale Topology Mapping**
- Need:
  - Topology of Internet remains poorly understood
  - Critical infrastructure protection: robustness, vulnerability, correlated failures, IPv4/IPv6 interdependence, etc.
  - DHS BAA: "*…identify infrastructure components in greatest need of protection*."
  - Researchers: modeling, prototyping new protocols, clean-slate designs, Internet evolution, etc.
- Production systems, e.g. Ark, iPlane:
  - Require O(weeks) to map
  - Induce significant load
  - Can miss short-lived events (which may be of *most* interest)

Approach Summary

- Started with theory primitives we proposed in [BBX10]
- Key Insights:
  - Utilize available <u>external knowledge</u>
  - Maintain state over <u>prior rounds</u> of probing
  - Adaptively sample to <u>discover subnet structure</u>
  - Maximize probing efficiency and information gain:
    - Which destinations to probe
    - How/where to perform the probe
- Implement in production on CAIDA's Archipelago (Ark)
- Gather performance metrics

A Performance Metric

- Hard: how to evaluate "quality" of inferred topologies?
- Developed *edge/vertex symmetric difference (esd/vsd)* metric:
  - Intuitive (0-100%) difference between two topologies
  - Fast, scalable

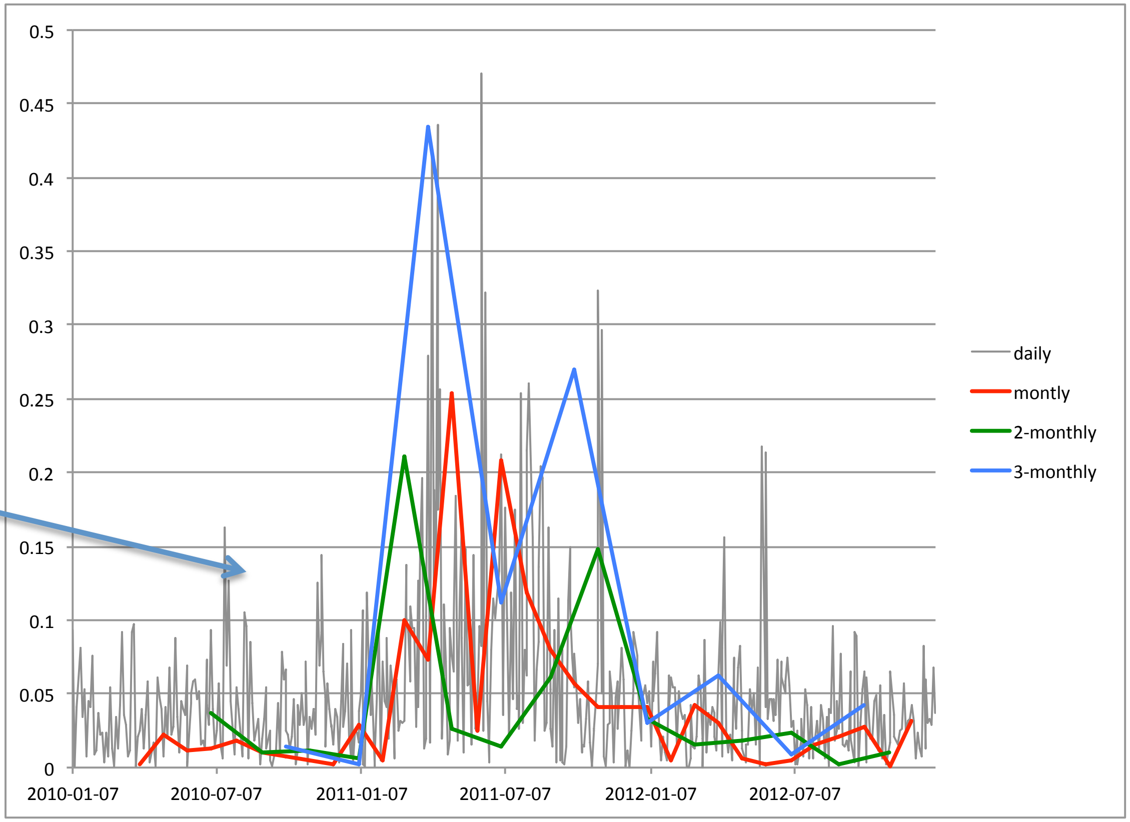


$$vsd(G,H) = \frac{|V(G) \setminus V(H)| + |V(H) \setminus V(G)|}{|V(G)| + |V(H)|} = \frac{1+1}{6+6} = 16.7\%$$

Edge Symmetric Difference

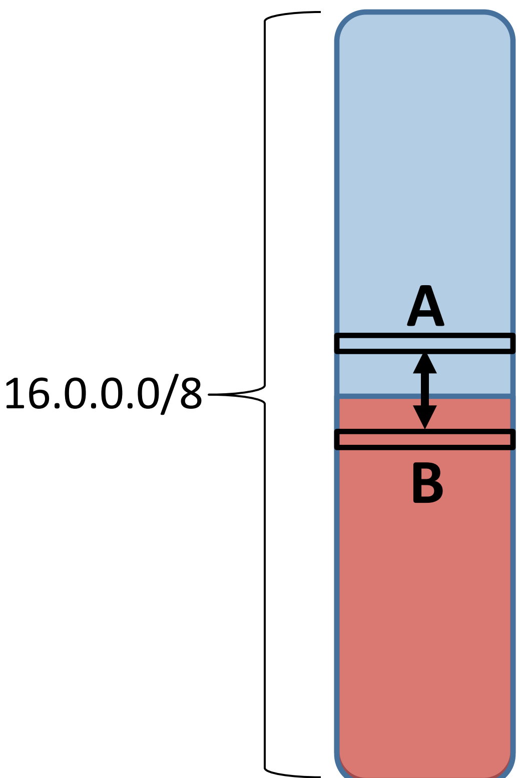
- Example using VSD, applied to archived topology data:

Temporal analysis of Egyptian ASes in Ark (2010-2013). VSD reveals onset of Egyptian revolution, and instability during.



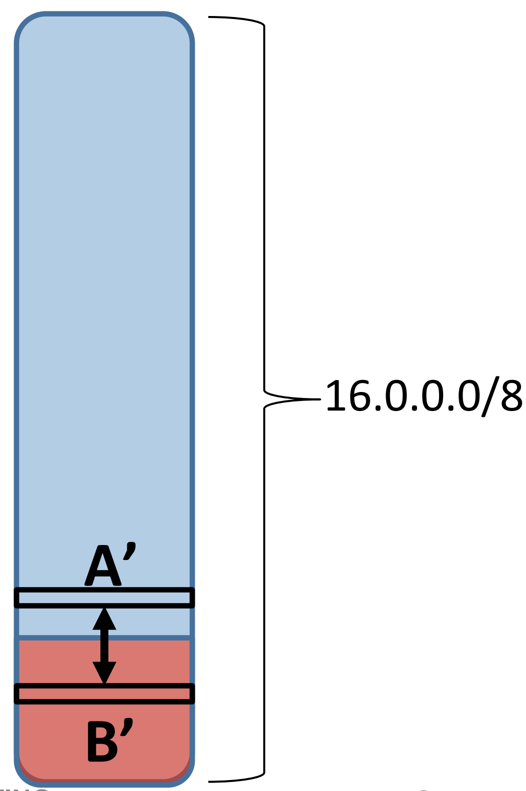
Utilize External Knowledge

- System input is set of global BGP prefixes (e.g. routeviews)
- Use knowledge of how networks are commonly provisioned and subnetted:



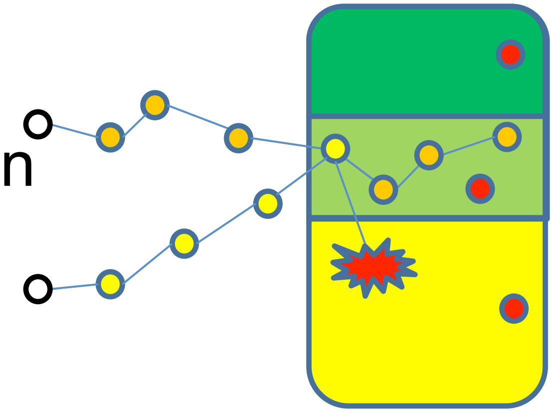
Easier to believe A and B in different subnets

Even though same “distance” apart. Use Least Common Prefix [BBX10]: find destinations with best probability of being in different subnets



Adaptive Probing

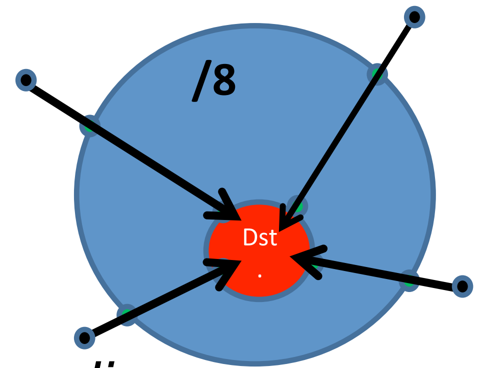
- Binary search each prefix, prune leaves that do not returning new topology
- Maintain set of interfaces discovered within the AS advertising the target prefix
- If new interfaces discovered by a probe, subdivide prefix and probe sub-prefix



- Design based on real-world challenges implementing primitive in [BBX10]:
  - No edit distance (distorted by load balancing)
  - Not pair-wise, no longer memoryless
  - Permits different vantage point for each probe, thus enabling integration with vantage point spreading

Maintain State

- We find 50% of prefixes probed by only ~10 monitors
- Thus, the choice of vantage point matters



- Developed and implemented *Ingress Point Spreading*:
  - Examine the set of ingresses into the target network discovered during prior rounds of probing
  - Rank order vantage points per target network to exploit ingress diversity
  - Expansion to "notional ingresses" permits any number of vantage points to be rank ordered intelligently
  - Prevents premature termination of adaptive sampling algorithm

Benefits

- Probing 50,000 randomly chosen BGP prefixes
- Compared to state-of-the-art Ark system
- More topology with half the load and time

Metric	RSI+IPS	Ark
Vertices	520,105	465,788
Edges	1,034,228	934,326
Probes	2,073,988	4,042,521
Ingresses	38,787	31,110
Time	18h 33m	53h 48m

Current Status

- Implemented primitives on Ark:
  - Worked with CAIDA to debug, refine Ark interface
  - Integration into cohesive system
  - Operational experience gathering real topologies (amid load balancing, etc) using CAIDA's topo-on-demand
- Have met year 1 milestones and deliverables
- Topology publication output:
  - **PAM2013**: "*IPv6 Alias Resolution via Induced fragmentation*"
  - **IMC2013**: "*Speedtrap: Internet-scale IPv6 Alias Resolution*"
  - **IMC2013**: "*Internet Nameserver IPv4 and IPv6 Address Relationships*"
  - **MILCOM2013**: "A Technique for Network Topology Deception"

Next Steps

- Probe whole Internet (rather than 50K subset)
- Begin multi-cycle probing using combined primitives
- Better quantify load savings and running time
- Begin gathering, analyzing, and reducing topologies to router and AS-level
- Tech transfer:
  - Working closely with CAIDA and Akamai
  - CAIDA will deploy an implementation of our primitives, beginning with IPv6 (to lower risk)
  - Planned activity for years 2 and 3

Contact Information

- Center for Measurement and Analysis of Network Data @NPS: http://www.cmand.org
- Contact:

Robert Beverly

Assistant Professor

http://rbeverly.net/research

rbeverly@nps.edu

831-656-2132