StrobeLight: Lightweight Availability Mapping and Anomaly Detection

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INTERNETS
Serious Business.
At any given moment, how can we tell which enterprise machines are online and network-reachable?
Who Could Give Us Availability Data?

- Best case: Zeus
- If we’re lucky: the distributed system itself
  - Limited scope?
  - Doesn’t scale?
  - Need to modify hosts/routers?
Our Solution: StrobeLight

• Persistent enterprise-level monitoring
  – Track availability of 200K+ hosts
• Network-wide sweep every 30 seconds
  – Fast enough for near real-time analysis
  – Archive results for use by other services
• Doesn’t require modification to:
  – End hosts
  – Core routing infrastructure
How Would We Use This Data?

• Improve system performance
  – DHTs, Farsite: select the best storage hosts
  – Multicast trees: build more robust topologies
  – BOINC: perform smarter task allocation

• Detect system-level anomalies
  – Misconfigured routers
  – IP hijacking attacks
Outline

• Design and Implementation
• Availability Fingerprints
• Detecting IP Hijacks Using Fingerprints
• Related Work
• Conclusions
Design Goals

• Keep it simple, stupid
  – Don’t modify end hosts
  – Don’t change routing core

• Don’t be annoying
  – Don’t impact real flows

• Collect high-resolution data
  – Per-host statistics
  – Fine temporal granularity
There Were Non-goals™

• Infinite scaling: overkill in enterprise setting
  – Scaling target: hundred of thousands of hosts
  – Small number of administrative domains
  – Centralized solution might be okay
• Total address disambiguation: hard, unnecessary
  – NATs, DHCP, firewalls decouple hosts, IPs
  – We’re content to measure IP reachability
The Winning Design: StrobeLight

- DNS Servers
- Discover hosts
- Archive data
- Corporate Data Storage
- Ping
- Transfer data for analysis
- Issue alerts
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Availability Fingerprint

• Instantaneous snapshot of subnet availability
  – Bit vector: \( b_h = 1 \) iff host \( h \) responded to probe
• Similarity metric: \# of equivalent bit positions
  – Normalize to the range \([-1,1]\)
• What does fingerprint similarity look like . . .
  – Within a single subnet across time?
  – Between different subnets at a given moment?
Self-similarity: 15 minute intervals (256-host subnets)
Instantaneous Cross-subnet Similarity
Cross-subnet similarity vs. Time

Cool

Uncool

Delta similarity

Time (units of 6 hours)
Ghosts Were Not To Blame

(a) Host availability in 157.55.*.*

(b) Host availability in 10.*.*.*
One Use For StrobeLight

YOU'RE DOING IT WRONG
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IP Hijacking

- Internet: a collection of autonomous systems
- BGP protocol stitches ASes together
  - ASes announce prefix ownership, path lengths
  - No authentication of announcements!
- Hijack attack: disrupt routing to target prefix
  - Announce ownership of/short route to prefix
  - Some routers may not be affected (location matters)
IP Hijacking

1) Blackhole attack: drop all traffic
2) Imposture attack: impersonate target prefix
3) Interception attack: inspect/modify traffic

• First two should cause fingerprint anomalies!
Enterprise Network
Enterprise Network

\[ f_t \sim f_{t-1} \]

\[ f_t \neq f_{t-1} \]
Does WAN Distort Our Probes?
Does WAN Distort Our Probes?
Spectrum Agility Hijacks

• Short-lived manipulation of BGP state
  – Hijack /8 prefix
  – Send spam from random IP addresses
  – Withdraw BGP advertisement a few minutes later

• Assume attacker subnet has random fingerprint
Spectrum Agility Hijacks

• Simulation setup
  – Slide window through MSR trace
  – For each subnet x, test two similarities
Spectrum Agility Hijacks

- Simulation setup
  - Slide window through MSR trace
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<td>$f_{x,t-1}$</td>
<td>$f_{x,t}$</td>
<td>$f_{x,t+1}$</td>
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True negative: $\text{sim}(f_{x,t}, f_{x,t-1}) \geq c$
False positive: $\text{sim}(f_{x,t}, f_{x,t-1}) < c$
Spectrum Agility Hijacks

- Simulation setup
  - Slide window through MSR trace
  - For each subnet $x$, test two similarities

**Attack**

No attack

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<th>$f_{x,t-2}$</th>
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<th>$f_{khan}$</th>
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True positive: $\text{sim}(f_{khan}, f_{x,t-1}) < c$
False negative: $\text{sim}(f_{khan}, f_{x,t-1}) \geq c$
Detecting Spectrum Attacks: $c=0.78$

DNS failure: StrobeLight thinks hosts have died
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Availability Monitoring

- **Academic network path monitors**
  - CoMon, iPlane, RON
  - Don’t scale to enterprise/don’t track per-host stats

- **Commercial monitoring tools**
  - Pro: Richer set of statistics
  - Cons: More difficult to deploy, slower refresh
Detecting IP Hijacking

• Modify BGP/push crypto into routing core

• Passive monitoring of routing state
  – Find anomalies in RouteViews, IRR

• Data plane fingerprints (Hu and Mao 2006)
  – Monitor live BGP for suspicious updates
  – Scan target prefix with nmap, IP ID probes
  – Raise alarm if different views are inconsistent
Conclusion

• StrobeLight: enterprise-level availability monitor
  – End hosts/routers unchanged
  – Real-time feeds, archival data

• Example of StrobeLight client: Hijack detector
  – Uses availability fingerprints to find routing anomalies
  – Anomaly detection is fast and accurate
  – Don’t need to modify BGP/push crypto into routers
Thanks!