Quantifying Violations of Destination-based Forwarding on the Internet

Tobias Flach, Ethan Katz-Bassett, and Ramesh Govindan
University of Southern California
November 14, 2012
Destination-based Routing

Routing based on destination only

<table>
<thead>
<tr>
<th>Destination</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
</tr>
</tbody>
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Destination-based Routing

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Destination: A

1

2
Relying on Destination-based Forwarding

- **iPlane**
  - Information Plane for Distributed Services
  - [IMC 2006] [OSDI 2006] [NSDI 2009]

- **Doubletree**
  - Algorithm for Large-Scale Topology Discovery
  - [PAM 2005] [IEEE Comm Journal 2006]

- **Netdiff**
  - [NSDI 2008]

- **Reverse Traceroute**
  - [NSDI 2010]
Reverse Traceroute

Reverse path stitched together by combining segments with common hops to the same destination
Reverse Traceroute

Reverse path stitched together by combining segments with common hops to the same destination
Reverse Traceroute

Reverse path stitched together by combining segments with common hops to the same destination.
MPLS Router violates Destination-based Routing

Default routing entry for non-production traffic (traffic without an MPLS label)
MPLS Router violates Destination-based Routing

Reverse Traceroute can produce a reverse path which differs significantly from the ground truth

UT Arlington

LEARN

THEnet

Grandecom

U Auckland (New Zealand)

Src

Dst
### Violation Causes

<table>
<thead>
<tr>
<th>Load balancing</th>
<th>Destination and flow identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPLS tunneling</td>
<td>MPLS label only</td>
</tr>
<tr>
<td>Preferred routes for some customers</td>
<td>Source (and destination) address only</td>
</tr>
<tr>
<td>(source-based)</td>
<td></td>
</tr>
<tr>
<td>Other routing policies</td>
<td>Any header field combination</td>
</tr>
</tbody>
</table>
Contributions

Methodology for detecting destination-based forwarding violations

Analysis of violations observed in active measurements
Measurement Methodology

Modify the point of injection to elicit violations of destination-based routing
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Violation Causes

- Load balancing
- MPLS tunneling
- Preferred routes for some customers (source-based)
- Other routing policies
- Destination and flow identifier
- MPLS label only
- Source (and destination) address only
- Any header field combination
MPLS Tunnels

Explicit MPLS tunnels

MPLS tunnels with default routing

Dst 1

Dst 2

Dst 3
MPLS Tunnels

Explicit MPLS tunnels

MPLS tunnels with default routing

All injected probes regardless of destination) use the non-regular path (orange)
MPLS Tunnels

Explicit MPLS tunnels

MPLS tunnels with default routing
Results Summary

262,034 traces recorded
39,699 IP addresses targeted
3,777 ASes visited

28.9% of the IP addresses cause violations
1.3% cause paths forking to different ASes
## Violation Types in Targeted Nodes

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency (all forks)</th>
<th>Frequency (forking to different ASes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load balancing</td>
<td>16.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Explicit MPLS tunnel</td>
<td>0.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Default routing</td>
<td>0.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Unclassified</td>
<td>6.9%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Non-violating / invalid</td>
<td>76.3%</td>
<td>98.0%</td>
</tr>
</tbody>
</table>
Conclusion

- More than 25% of the targeted IPs route via multiple paths to a single destination
- Packets with the same destination are sometimes routed via different ASes
- Impact on precision
  - Possible prediction of wrong paths
  - e.g. Reverse Traceroute, iPlane
- Impact on recall
  - Missing links during topology discovery
  - e.g. Doubletree
- Our techniques can be used to increase precision and recall at the cost of additional probing overhead
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