vrfinder: Finding Outbound Addresses in Traceroute

Alex Marder, Matthew Luckie, Bradley Huffaker, kc claffy
Overview

• What are outbound addresses?
  • Layer 3 Virtual Private Networks (L3VPNs)
  • Impact on topology inference

• Methodology:
  • Finding outbound addresses
  • Challenges – forwarding loops, /31 and /127 subnets

• Results
  • Evaluation against ground truth
  • Modified bdrmapIT
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Traceroute Response Types
Traceroute Response Types: Inbound
Traceroute Response Types: Off-Path
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Layer 3 Virtual Private Network
L3VPN: Default Forwarding
L3VPN: Default Forwarding
L3VPN: Virtual Forwarding

Service Provider (SP)
L3VPN: Virtual Forwarding
Impact on Traceroute Analysis

162.252.70.138
IP2AS: Internet2

72.14.209.107
IP2AS: Google

72.14.209.106
IP2AS: Google

Real Topology

Internet2

Google

i_1
R_1

R_2
i_2

R_3
i_3
Impact on Traceroute Analysis

Incorrect Inferred Topology
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Inferring Outbound Addresses
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![Diagram of network flows with IP addresses labeled]
Inferring Outbound Addresses

Path A: inbound addresses

192.0.2.2
192.0.2.9
192.0.2.10
192.0.2.2.14
Inferring Outbound Addresses

Path A: inbound addresses
- 192.0.2.2
- 192.0.2.5
- 192.0.2.9
- 192.0.2.13
- 192.0.2.21
- 192.0.2.25

Path B: off-path address
- 192.0.2.2
- 192.0.2.10
- 192.0.2.14
- 192.0.2.17
- 192.0.2.21
Inferring Outbound Addresses

Path A: inbound addresses
192.0.2.2 192.0.2.9 192.0.2.21 192.0.2.25
Path B: off-path address
192.0.2.2 192.0.2.10 192.0.2.12/30 192.0.2.21
Path C: outbound address
192.0.2.2 192.0.2.14 192.0.2.21
Challenges

• Inefficient routing at IXPs

• Unresponsive routers

• Forwarding loops

• Two address subnets - /31 and /127
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Challenges: Loops

Path D: forwarding loop, repeated address
Challenges: Loops

Path D: forwarding loop, repeated address

Path E: forwarding loop, no repeated address
Challenges: Loops

Path E: forwarding loop, no repeated address

Traceroute Test: target $i_6$
Challenges

• Inefficient routing at IXPs

• Unresponsive routers

• Forwarding loops

• Two address subnets - /31 and /127
Challenge: /31 and /127 Subnets

Path F: /31 look like outbound
Challenge: /31 and /127 Subnets

Path F: /31 look like outbound

192.0.2.4  192.0.2.5  192.0.2.6  192.0.2.7
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Experiments

• IPv4 and IPv6 traceroutes from January 2020

• Inferred outbound addresses
  • 5.8% in IPv4
  • 1.7% in IPv6
Validation Against Internet2 and REANNZ

Internet2
- Default forwarding connects members
- L3VPN connects members to commercial peers

REANNZ
- Default forwarding supports MPLS
- All members connected via L3VPN

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<thead>
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Improvements for AS Operator Accuracy

**IPv4**

- Internet2 VPN: 90% bdrmapIT, 95% bdrmapIT + vrfinder
- REANNZ VPN: 80% bdrmapIT, 85% bdrmapIT + vrfinder
- Internet2 DFN: 95% bdrmapIT, 100% bdrmapIT + vrfinder
- Internet2 Neighbor: 90% bdrmapIT, 95% bdrmapIT + vrfinder
- REANNZ Neighbor: 80% bdrmapIT, 85% bdrmapIT + vrfinder
- PeeringDB: 90% bdrmapIT, 95% bdrmapIT + vrfinder
- Regex: 80% bdrmapIT, 85% bdrmapIT + vrfinder

**IPv6**

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Improvements for AS Operator Accuracy

IPv4

IPv6
Improvements for AS Operator Accuracy

IPv4

IPv6
Conclusion

• Outbound addresses complicate traceroute interpretation

• vrfinder infers outbound addresses in traceroute

• High PPV and TPR

• Vrfinder improves AS operator inferences