Real Time Network Policy Checking Using Header Space Analysis

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with

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Network debugging is hard!

• Forwarding state is hard to analyze!
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• Forwarding state is hard to analyze!
  1. Distributed across multiple tables and boxes.
  2. Written to network by multiple independent writers (different protocols, network admins)
  3. Presented in different formats by vendors.
  4. Not directly observable or controllable.

• Not constructed in a way that lends itself well to checking and verification.
Can host a talk to host b?

Is there any forwarding loop in the network?
Steam-based Checking
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Prevent errors before they hit network. Report a violation as soon as it happens.
Outline

• Motivations.

• NetPlumber: Real time policy checking tool.
  – How it works?
  – How to check policy?
  – How to parallelize?

• Evaluation on Google WAN.

• Conclusions.
NetPlumber

• The System we build for real time policy checking is called NetPlumber.

Logically centralized location to observe the state changes.

SNMP Trap
NetPlumber

- The System we build for real time policy checking is called NetPlumber.
  - Creates a dependency graph of all forwarding rules in the network and uses it to verify policy.
  - Nodes: forwarding rules in the network.
  - Directed Edges: next hop dependency of rules.
NetPlumber – Nodes and Edges
NetPlumber – Intra table dependency
NetPlumber – Computing Reachability
NetPlumber – Computing Reachability

1) Create directed edges
NetPlumber – Computing Reachability

1) Create directed edges
2) Route flows
3) Update intra-table dependency
NetPlumber – Checking Policy

Source Node

Policy: Packets go through RED box.
NetPlumber – Checking Policy

Source Node

Policy: packets go through RED box.
Checking Policy with NetPlumber

Policy: Guests can not access Server S.

∀f : f.path ～![^ (p = G₁ | p = G₂).]*
Checking Policy with NetPlumber

Policy: http traffic from client C to server S doesn’t go through more than 4 hops.
Checking Policy with NetPlumber

Policy: traffic from client C to server S should go through middle box M.

\[ \forall f \quad f.path \sim [^\wedge (p = C)] \quad : \quad f.path \sim[^\wedge .*(t = M)] \]
Why the dependency graph helps

• Incremental update.
  – Only have to trace through dependency sub-graph affected by an update.

• Flexible policy expression.
  – Probe and source nodes are flexible to place and configure.

• Parallelization.
  – Can partition dependency graph into clusters to minimize inter-cluster dependences.
Distributed NetPlumber
Dependency Graph Clustering
Outline

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• NetPlumber: Real time policy checking tool
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• Conclusions.
Experiment On Google WAN

- Google Inter-datacenter WAN.
  - Largest deployed SDN, running OpenFlow.
  - ~143,000 OF rules.
Experiment On Google WAN

• Policy check: all 52 edge switches can talk to each other.
• More than 2500 pairwise reachability check.
• Used two snapshots taken 6 weeks apart.
• Used the first snapshot to create initial NetPlumber state and used the diff as a sequential update.
Experiment On Google WAN

<table>
<thead>
<tr>
<th>#instances:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>median (ms)</td>
<td>0.77</td>
<td>0.35</td>
<td>0.23</td>
<td>0.2</td>
<td>0.185</td>
<td>0.180</td>
</tr>
<tr>
<td>mean (ms)</td>
<td>5.74</td>
<td>1.81</td>
<td>1.52</td>
<td>1.44</td>
<td>1.39</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Benchmarking Experiment

- For a single pairwise reachability check.

<table>
<thead>
<tr>
<th>#Network:</th>
<th>Google</th>
<th>Stanford</th>
<th>Internet 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Time</td>
<td>mean</td>
<td>median</td>
<td>mean</td>
</tr>
<tr>
<td>Add Rule (ms)</td>
<td>0.28</td>
<td>0.23</td>
<td>0.2</td>
</tr>
<tr>
<td>Add Link (ms)</td>
<td>1510</td>
<td>1370</td>
<td>3020</td>
</tr>
</tbody>
</table>
Conclusions

• Designed a protocol-independent system for real time network policy checking.

• Key component: dependency graph of forwarding rule, capturing all flow paths.
  – Incremental update.
  – Flexible policy expressions.
  – Parallelization by clustering.
Thank You!