Detecting Unsafe BGP Policies in a Flexible World

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ICNP

October 31, 2012
Balance Safety and Flexibility in Policy Based Routing

Expressiveness

ISPs innovate in policies as customer needs evolve

Safety

The protocol always converges to a unique routing solution

Autonomy

ISPs configure their network without global coordination
Preferred routing path for the Large ISP is in blue.

Gao and Rexford. Stable Internet Routing Without Global Coordination. SIGMETRICS 2000.
Relaxing(?) Safety: Prefer Peer to Avoid Specific AS

Preferred routing path for the Large ISP is in blue.
Relaxing Autonomy: Backup Policy Requires Coordination

Notify that this is a backup route.

Respect the Backup Service provided by another ISP.

Gao and Rexford. Stable Internet Routing Without Global Coordination. SIGMETRICS 2000.
Griffin and Huston. BGP Wedgies. RFC 4264.
The Stable Paths Problem (SPP)

- Provides: a *sufficient condition for safety* (acyclicity of dispute digraph)

- Requires:
  - knowledge of all potential routing paths
    *i.e.* all paths permitted by the policies of each router
  - strict ordering of the potentially available paths of each router

The Stable Paths Problem (SPP)

- Provides: a sufficient condition for safety (acyclicity of dispute digraph)

- Requires:
  - knowledge of all potential routing paths
    - i.e. all paths permitted by the policies of each router
      - Need for router configuration files, which ISPs consider proprietary.
      - In the worst case, path enumeration is an intractable problem.
  - strict ordering of the potentially available paths of each router
    - Requires a lot about the internals of an ISP, like IGP distances.
    - Depends on vendor specific details (e.g. tie break).
    - Including MED is computationally expensive, if not infeasible.
Extended SPP

- Provides: a sufficient condition for safety

- Requires:
  - knowledge of all potential routing paths
    *i.e.* all paths permitted by the policies of each router
  - strict ordering of the potentially available paths of each router

Enumerate All Paths Among Some ISPs Only
A small number of ISPs share their configurations with trusted third party.

Execute the BGP Decision Process Steps as Needed
Allow a router to equally prefer two paths, even if they do not share the next-hop.
Extended SPP

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**Enumerate All Paths Among Some ISPs Only**

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**Execute the BGP Decision Process Steps as Needed**

Allow a router to equally prefer two paths, even if they do not share the next-hop.
Contributions

- We define a new data structure, the Multipath Digraph ($\mathcal{MD}$).
- We prove the relationship $\mathcal{MD}$ has with the Paths Digraph\(^1,2\) ($\mathcal{PD}$).
- We provide a methodology for ensuring BGP safety
  - assuming nothing about the policies ISPs use
  - assuming nothing about the Internet graph structure (hierarchical/flat)
  - requiring no change to BGP
  - detecting not only instability but also multiple stable states
  - relaxing SPP requirements so that router configuration information is used only as needed
  - pointing out safety risks when paths are only partially known

Strict SPP Example

Network Topology

Node 0 | Destination
---|---
\{p_1, p_2\} | \(p_1, p_2\) equally preferred
\{p_1\} | \(p_1\) preferred over \(p_2\)
Strict SPP Example

Network Topology
Strict SPP Example

Network Topology
Strict SPP Example

Network Topology
Network Topology
Strict SPP Example

Network Topology

MD
Strict SPP Example

Network Topology

MD
$MD$ has Cycle, $PD$ is Acyclic

$PD$

$MD$
The Only Refinement That Has a Cycle

Both \( PD \) and \( MD \) will be:

Refinement: specification where every router has its paths strictly ordered
A Methodology for Safety (I)

MD: Multipath Digraph
PD: Paths Digraph

$\text{n} = 1 \rightarrow \text{Execute BGP Decision Process Step n. Create MD.}$

- Is MD Acyclic?
  - Yes: ALL Refinements are Guaranteed to be Safe.
  - No: Is PD Acyclic?
    - Yes: $\text{n}++$
    - No: NO Refinement is Guaranteed to be Safe.
A Methodology for Safety (II)

1. Execute BGP Decision Process Step n. Create MD.

2. Is MD Acyclic?
   - Yes: ALL Refinements are Guaranteed to be Safe.
   - No: Is PD Acyclic?
     - Yes: Configure the Network for a Safe Refinement as Directed by MD.
     - No: NO Refinement is Guaranteed to be Safe.
Example

Specification of ASes with Node 6 as Destination

Nodes 1, 4: prefer peer routes equally to customer

Sessions 7 → 4, 4 → 3, 3 → 2: announce peer routes (plus customer)
MD Has No Cycle

\( \{156, 1476, 123456, 123476\} \)

\( \{3456, 3476\} \) -> \( \{32156, 321476\} \) -> \( \{156, 1476, 123456, 123476\} \)

\( \{23456, 23476\} \) -> \( \{2156, 21476\} \)

\( \{456, 476\} \) -> \( 4156 \) -> \( \{32156, 321476\} \)

\( \{3456, 3476\} \) -> \( \{32156, 321476\} \)

\( \{56\} \) -> \( \{5476, 5123476\} \)

\( \{76\} \) -> \( \{7456, 74156\} \)
$\mathcal{MD}$ with Partial Information

Group $\mathcal{K}$: Nodes 1, 3, 4

Known configurations

Group $\mathcal{U}$: Nodes 2, 5, 7

Unknown configurations
Conclusion

- ISPs can implement a richer set of BGP policies without sacrificing safety and determining themselves the level of autonomy.
- The complexity of the SPP safety analysis can be reduced by partially executing the BGP decision process without losing accuracy.
- Operators receive feedback even when paths are only partially known.
- We plan to implement a tool that evaluates the proposed approach. See Poster Session.
Questions?

Thank you

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Relationship of Cycles in $MD$ and $PD$
Double Backup Wedgie (I)

{321, 341, 351}  {41, 4321, 4351}

{251, 2351, 2341}  21

Specification

MD
Double Backup Wedgie (II)

**PD**

**MD**