# An Expectation-Based Approach to Policy-Based Security of the Border Gateway Protocol

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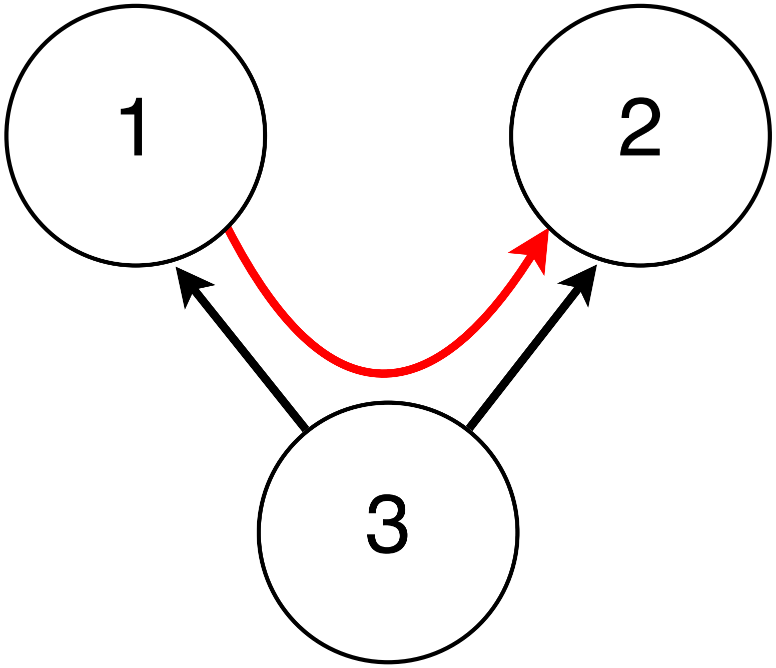
# The Problem

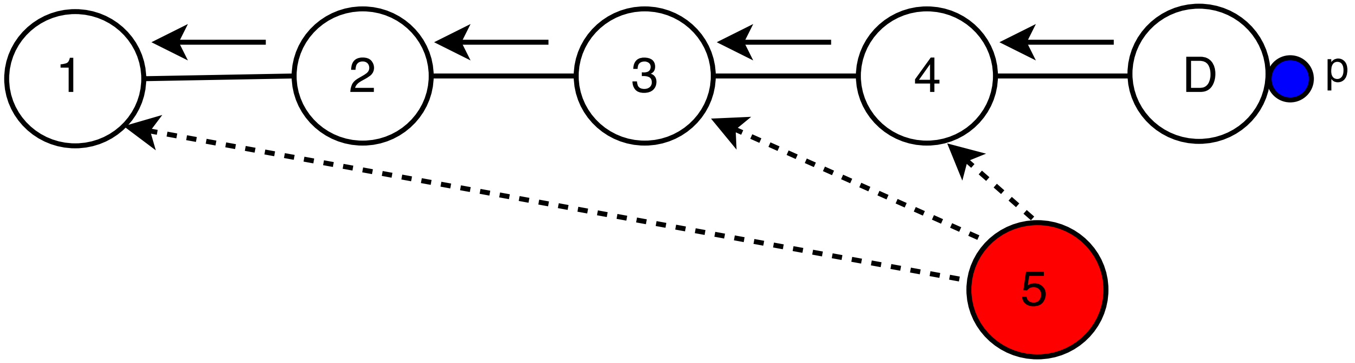
- The Border Gateway Protocol (BGP) is the *de facto* standard inter-domain routing protocol on the Internet
- Most BGP security solutions focus on **topology-based** security
    - origin authentication, path integrity
- They seldom consider policy-based security, esp. whether a path conforms to routing policies of ASes *en route* or not

# A Route Leak Example

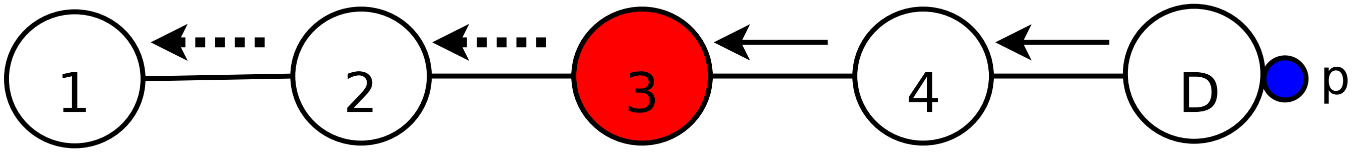


AS3 is a customer AS of AS1 and AS2, and it leaks to AS1 its route to AS2. AS1 thus learns a leaked route (in red) that AS1 should not use.

# Another Example



A topology-based security solution can defend against an attacker (node 5) impersonating the origin of prefix *p* or lying about its path to *p*.



A topology-based security solution *cannot* prevent an attacker (node 3) from leaking a route and obtaining traffic toward a victim prefix.

# Policy-based Security for BGP

- BGP is a policy-based routing protocol
- BGP security in the policy dimension is a significant concern
- Besides conventional routing policies, ASes should define and enforce policies w.r.t. the legitimacy of routes, such as
    - whether or not an AS can be included on a particular route
- Every AS can define its own policy at its discretion

# Our Approach

- A policy-based security solution called Expectation Exchange and Enforcement, or **E3**
- E3 exchanges and enforces routing policies between ASes
  - A newly advertised route must meet policy expectations of ASes
  - In the previous example, node 4 can tell node 2 that it does not expect to receive traffic from node 2 via node 3
- E3 runs alongside topology-based BGP security solutions (e.g., BGPSEC)

# What is an Expectation?

- *Expector*: an AS that produces an expectation
- *Expectee*: an AS that enforces an expectation
- *Subject*: an AS that is specified in an expectation and directly affected by the expectation
- A set of *IF-THEN* rules (conditions and actions)

# Types

- Unilateral Expectations: an expector's own expectation about a subject without consulting the subject
- Contractual Expectations: an expector and its subject constructs a contractual expectation
- Active Expectations: expectations that are actively enforced
  - Always associated with a contractual expectation

# Exchange of Expectations

- *Query mode*: a BGP router queries specific ASes to learn their expectations
- *Notification mode*: a BGP router notifies potential expectees of new expectations

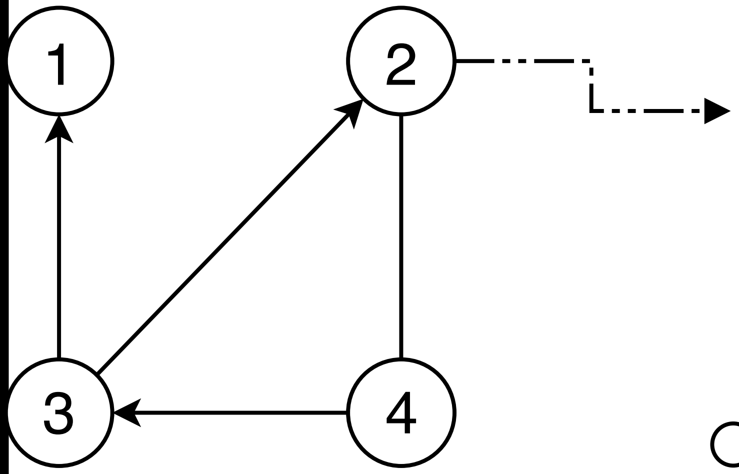
# Enforcement of Expectations

- BGP updates must be checked against expectations to ensure routing policy compliance, with two main tasks:

- Checking a BGP update against active expectations
  - Check every IF-THEN rule
  - If the condition of a rule (IF part) is met, take the action (THEN part)

- Checking an active expectation against its associated contractual expectation
  - All of the conditions in the active expectation must be a subset of the conditions in the contractual expectation
  - The action of the active expectation must be the same as the action of the contractual expectation

# An Example of Expectation Enforcement



AS2’s active expectations:

| Expector | Subject | Rule |
|---|---|---|
| 1 | 3 | RouteContainsLink(1,3) -> Discard |
| 4 | 3 | RouteContainsLink(3,4) -> LocalPref=200 |

○⟶○ The left AS is a customer, the right AS is a provider.

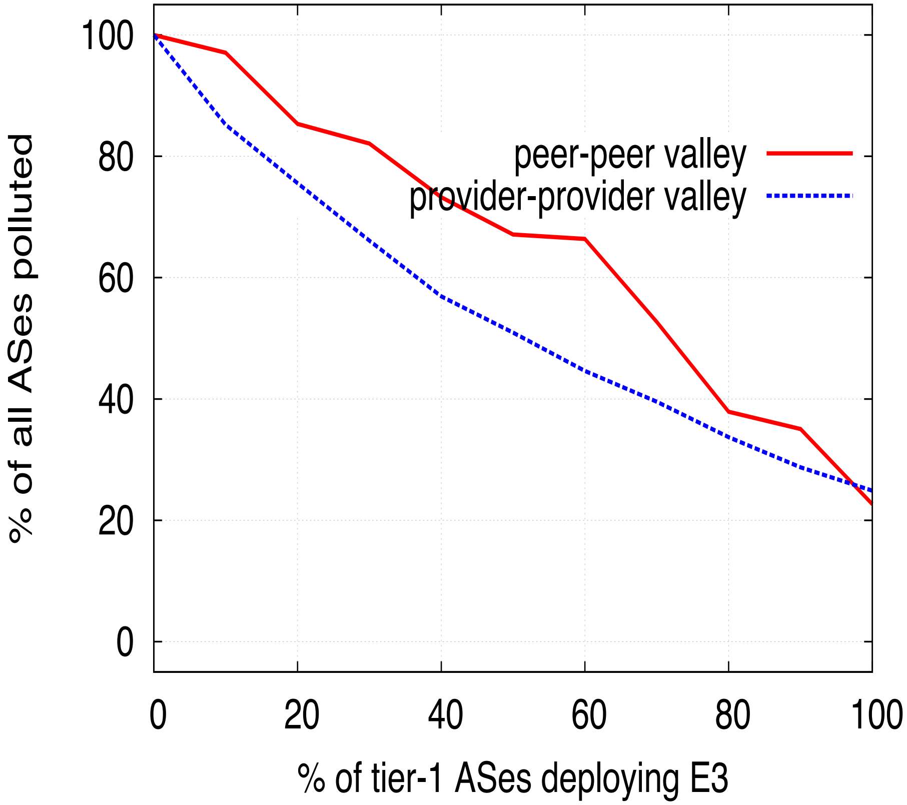
○—○ The two ASes are peers to each other.

# Evaluation Methodology

- We measure when E3 is deployed, how much ASes would still accept routes violating routing policies
- This study chooses one specific policy that requires routes to be valley-free
  - I.e., for any AS along the route, either its previous hop, or its next hop, or both are customers of the AS in question
  - Other policies can also be evaluated
- We classify ASes according to their AS rank
  - We classify the first 100 as tier 1 and the next 900 as tier 2

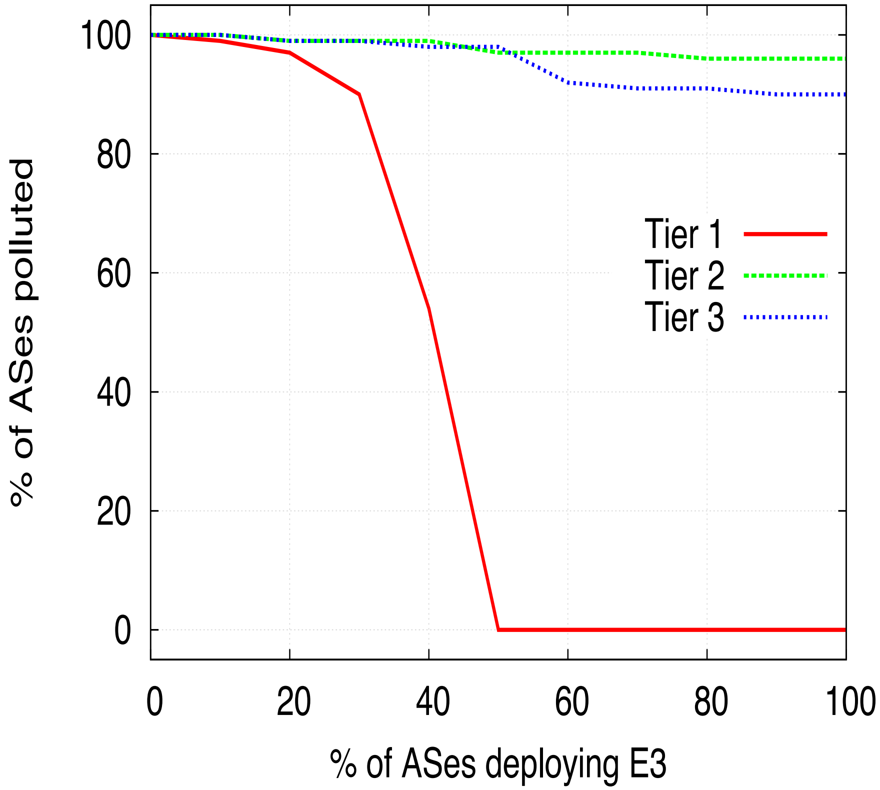
# Simulation: % of ASes Polluted with Invalid Routes

- When 100% tier-1 ASes deploys E3, nearly 80% of ASes originally polluted are then protected from invalid valley routes
- Only deploying E3 at certain tier-1 ASes won't be very effective
- A route-leaking BGP update does not always traverse an E3-enabled tier-1 AS
- More opportunities for provider-provider valley routes to be prevented.



# Case Study: 2012 Canada Route Leak Event

- On August 8, 2012, Canadian ISP Dery Telecom Inc (AS 46618) leaked all its routes acquired from one of its provider VideoTron (AS 5769) to its another provider Bell (AS 577)
- Affected 107,409 prefixes from 14,391 different ASes across the Internet
- Deploying E3 on tier-1 ASes has the best effectiveness



# Deployment Considerations

- Probably not easy to have a high percentage of tier-1 ASes to deploy E3
- Our analysis shows that the route leaks usually have bottleneck ASes that determine the propagation scope (which are not always tier-1 ASes)
- Deploying E3 on these bottleneck ASes can be most effective
  - Identifying them would be key to the success of E3

# Implementation Considerations

- E3 can be implemented on every BGP router (thus in-band expectations via BGP updates), or
- A dedicated server at every AS (thus out-of-band channels for ASes to communicate expectations)
- Expectation, in its current form, is an abstract concept, and could be formatted using Routing Policy Specification Language (or something similar)

# Conclusions

- Topologically valid BGP routes may be still illegitimate and violate routing policies
- We address policy-based BGP security, which has been largely overlooked
- We introduce E3 as a BGP extension for expressing and enforcing policies across ASes, thus to prevent policy-violating routes from propagating further

# Questions?

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