The PEERING testbed: Internet Routing Experiments for the Cloud Era

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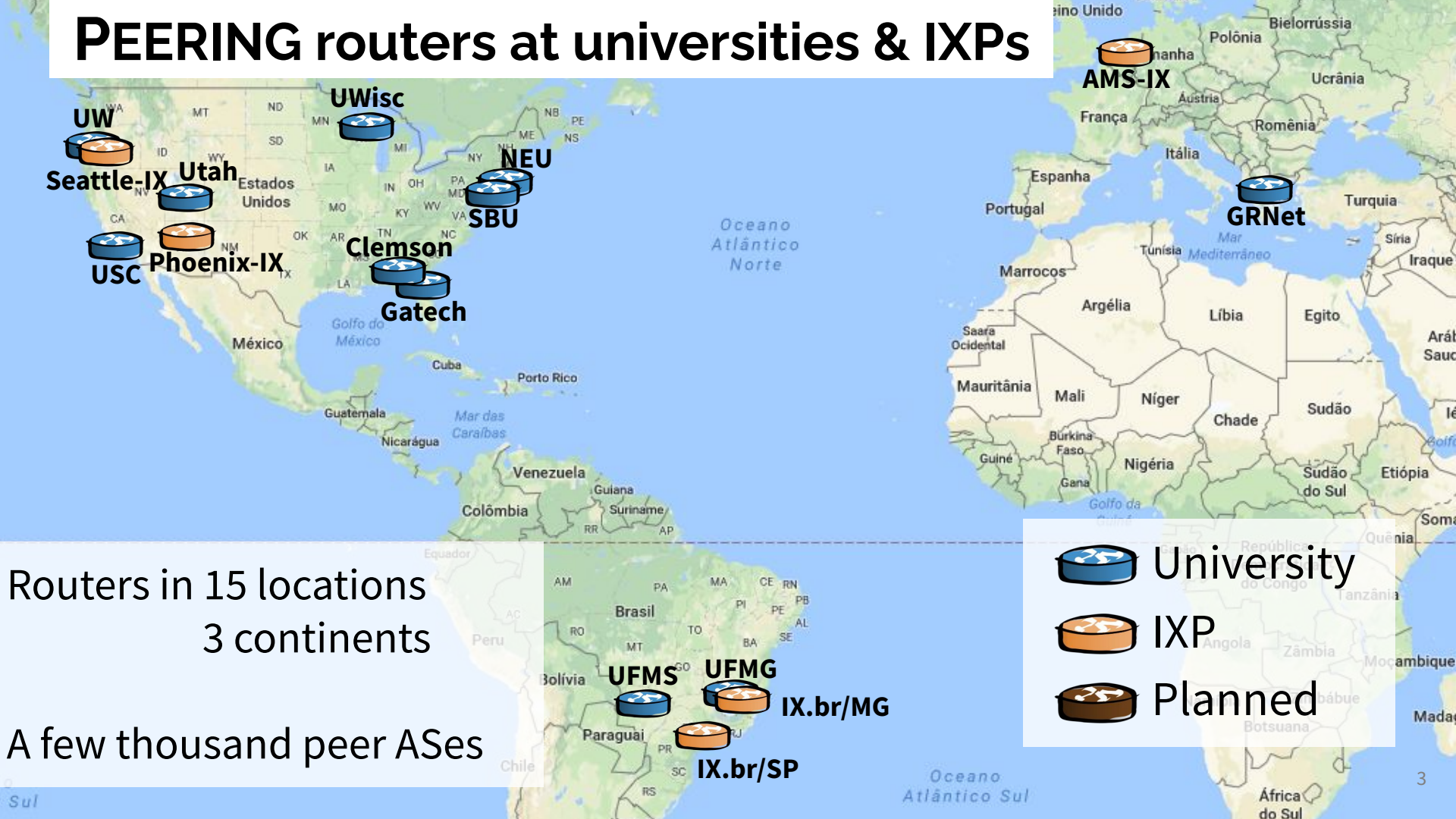
What is PEERING?

- A network (aka autonomous system/AS) with routers around the world & BGP connections to 1000s of commercial networks

PEERING routers at universities & IXPs

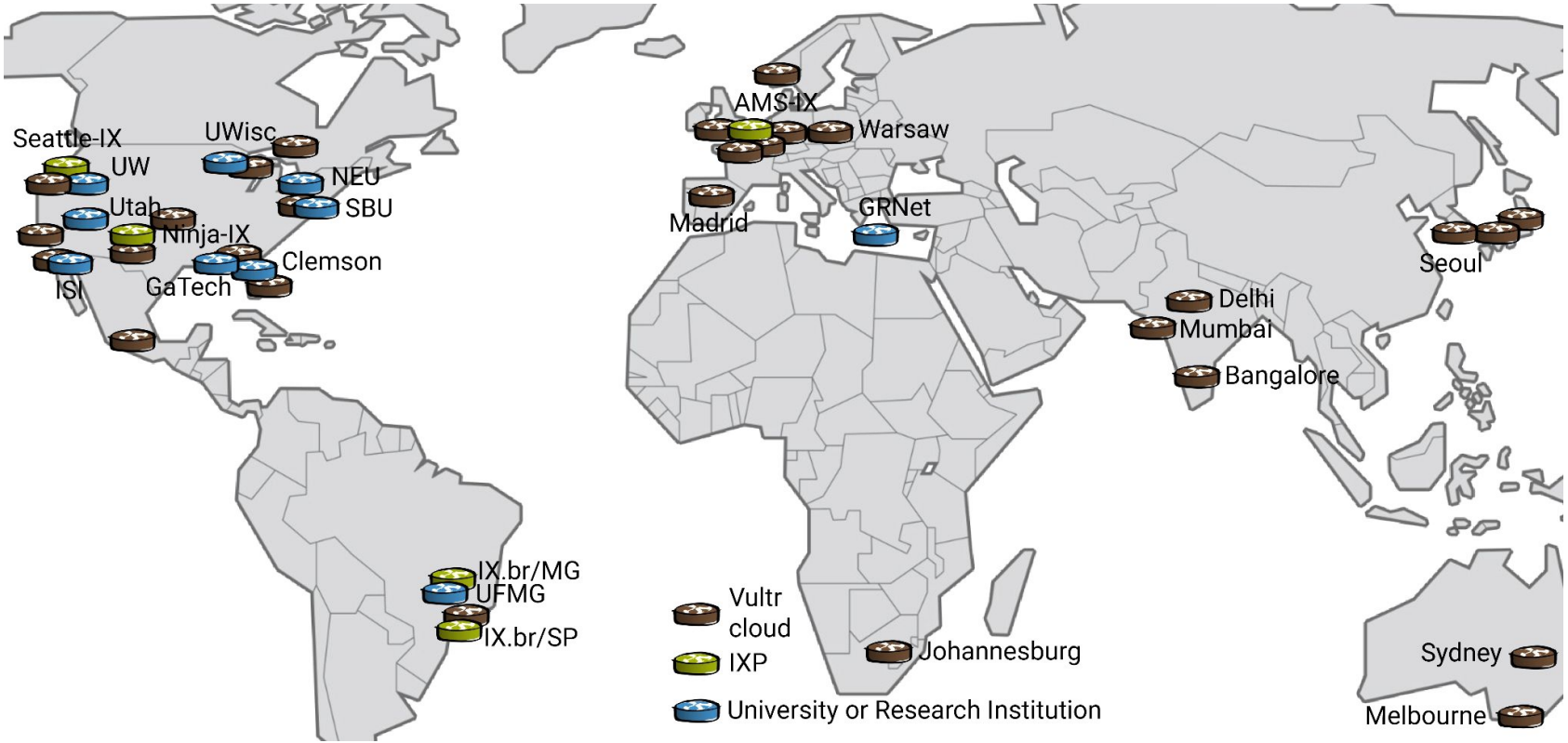


Routers in 15 locations
3 continents

A few thousand peer ASes

University
IXP
Planned

PEERING sites - Deployed on Vultr data centers



PEERING sites - Deployed at Cloudflare PoPs

What is PEERING?

- A network (aka autonomous system/AS) with routers around the world & BGP connections to 1000s of commercial networks
- Experiments have (almost) full control of control & data planes:
  - Control BGP announcements to influence how other networks route towards experiment
  - Select outgoing routes towards Internet destinations
  - Exchange traffic with Internet destinations
- Open to the research community
  - Propose experiment at: https://peering.ee.columbia.edu/

PEERING site capabilities

	# sites	# neighbor ASes	exchange traffic	control BGP announcements	select outgoing routes
universities	10	~10	Y	Y	Y
IXPs	5	~1500	Y	Y	Y
Vultr	32	~6000	Y	Y	N
Cloudflare	335	~13,000	Y	N	N

Why did we build the PEERING testbed?

1. BGP contributes to many of the Internet's **fundamental problems**

   BGP's design results in:

   - Security vulnerabilities such as hijacking and spoofing
   - Poor performance due to circuitous routes
   - Transient outages due to delayed convergence
   - Persistent outages due to protocol interactions
   - ... (the list goes on…)

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1. BGP contributes to many of the Internet's **fundamental problems**
2. **Limited existing tools** for BGP research

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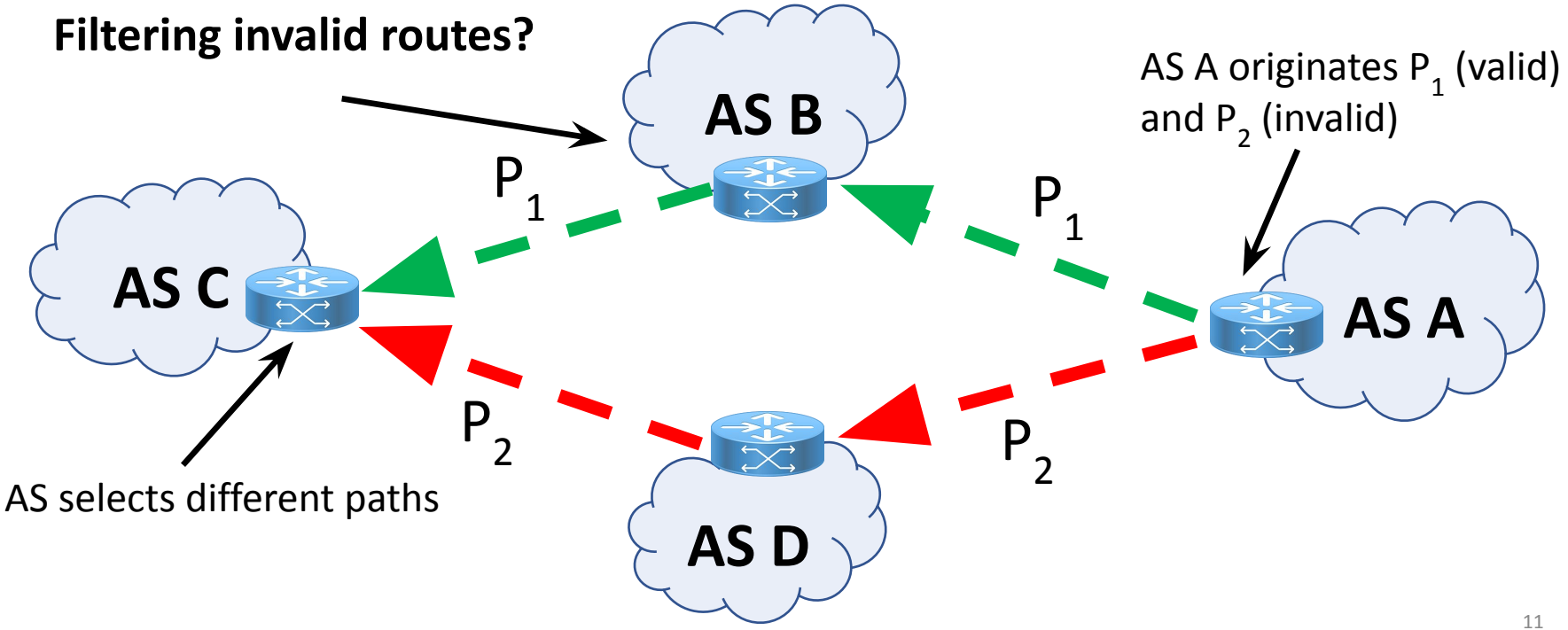
Example use case:

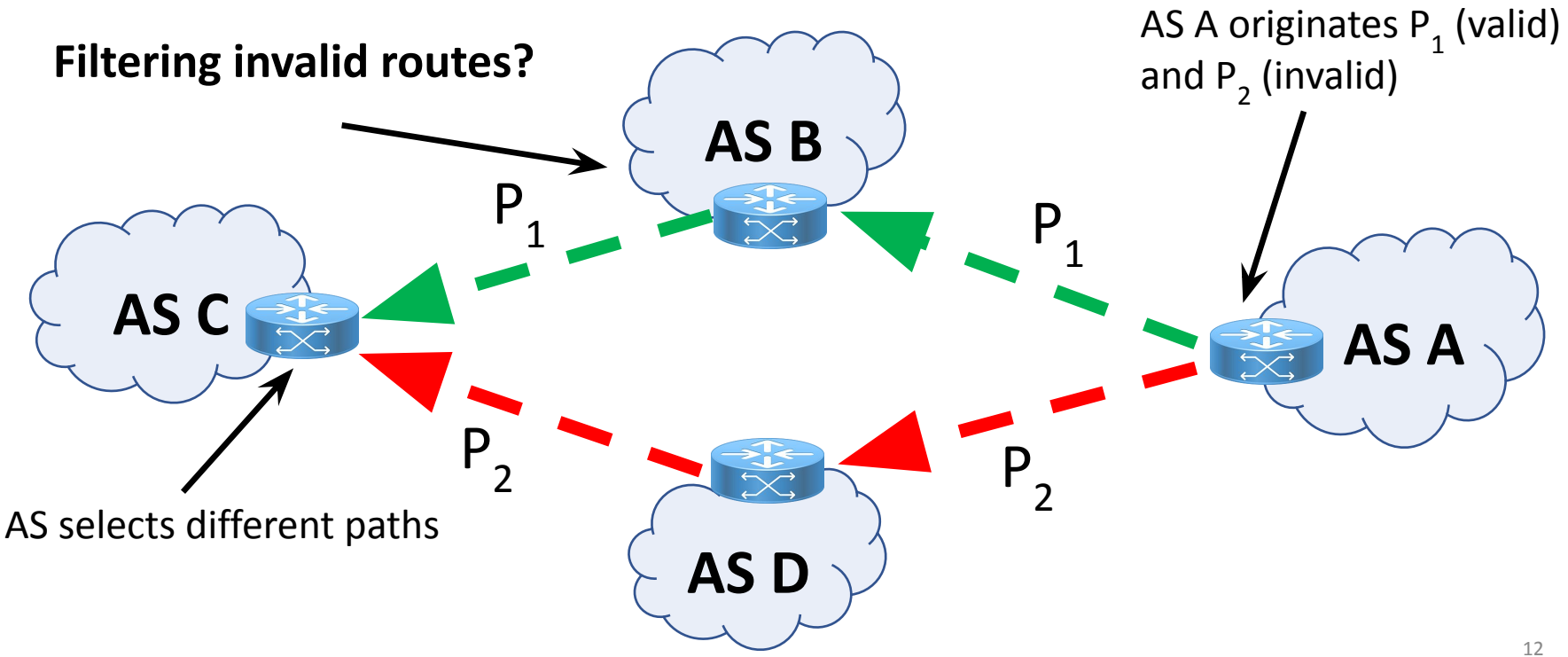
Can we identify ASes that filter [RPKI] invalid routes... **without PEERING?**

1. Find cases when an AS announces both a valid prefix and an invalid prefix
2. Identify vantage points that use different routes to the two prefixes



Problem: The experiment is uncontrolled

1. AS A could be announcing P1 differently from P2
2. And/or AS C could choose different routes for reasons unrelated to RPKI



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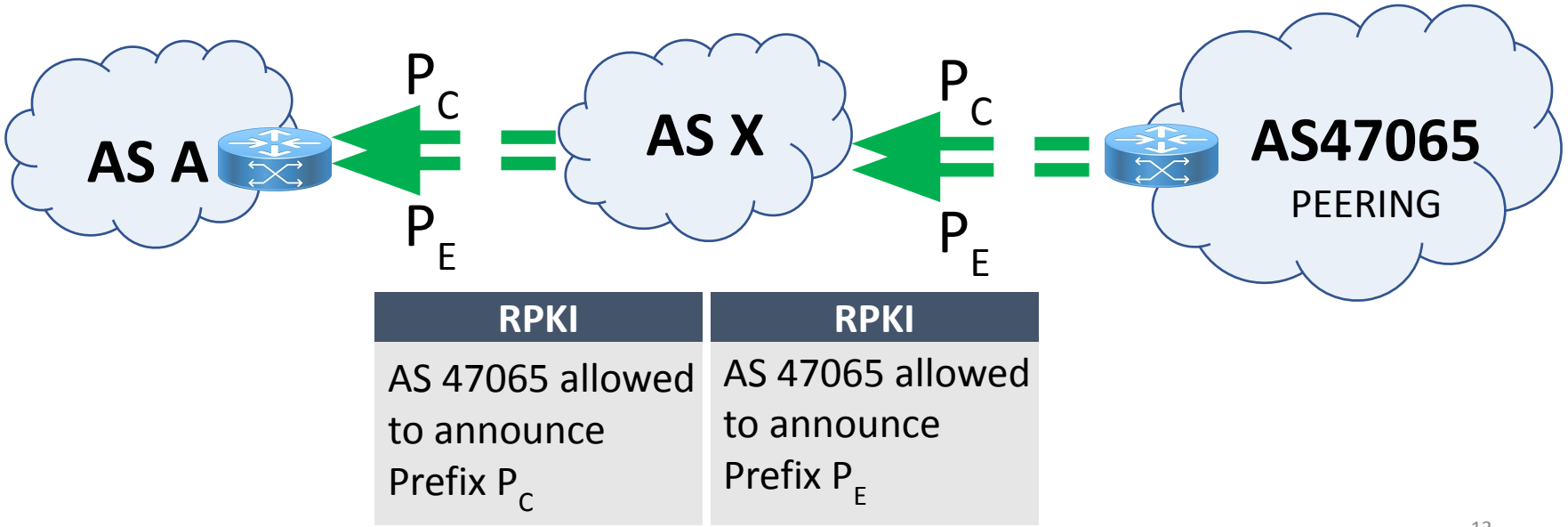
Controlled experiment: Jointly manipulate route announcements and RPKI validity, observe impact.



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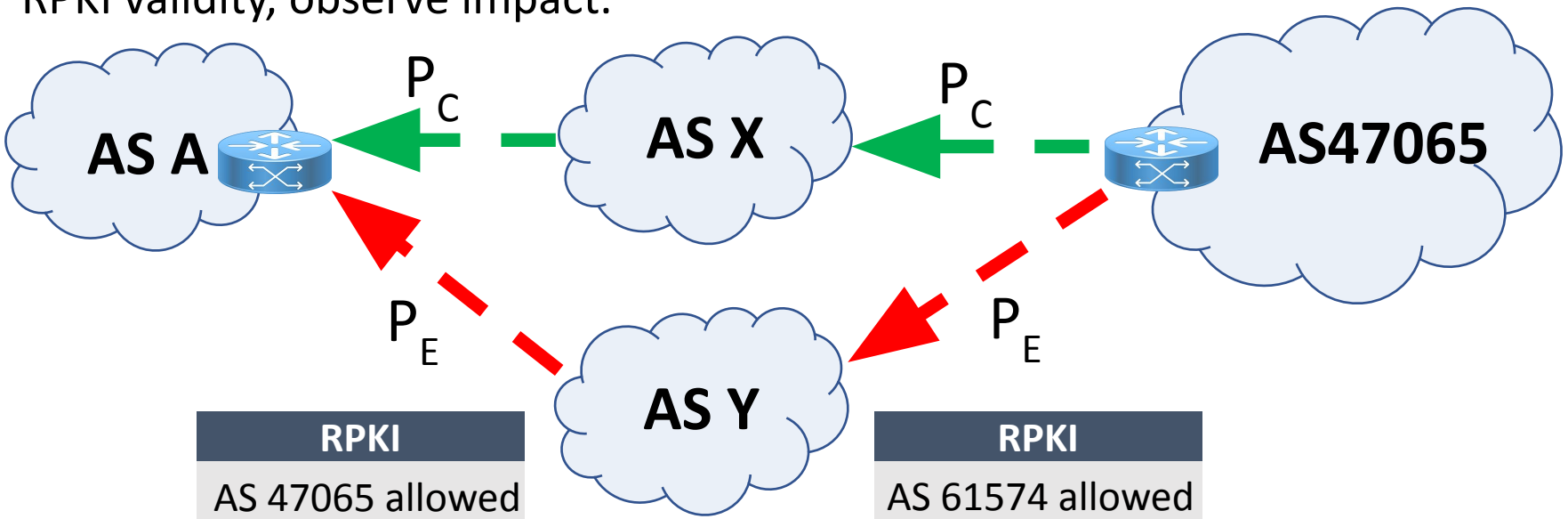

Use cases of the PEERING testbed

PEERING used for experiments in 50+ publications with total of 3500+ citations

SIGCOMM papers using the PEERING testbed

2023: PAINTER: Ingress Traffic Engineering & Routing for Enterprise Cloud Networks
2022: Continuous In-Network Round-Trip Time Monitoring
2018: Internet Anycast: Performance, Problems and Potential
2017: Bootstrapping evolvability for inter-domain routing with D-BGP
2017: Engineering Egress with Edge Fabric: Steering Oceans of Content to the World
2016: ARTEMIS: Real-Time Detection and Automatic Mitigation for BGP Prefix Hijacking
2014: (ARROW) One Tunnel is (Often) Enough
2014: SDX: A Software Defined Internet Exchange
2013: PoiRoot: Investigating the Root Cause of Interdomain Path Changes
2012: LIFEGUARD: Practical Repair of Persistent Route Failures

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Common reasons experiments use PEERING:

1. Controlled experiments: control aspects of routing as a means to conduct controlled experiments or systematically generate ground truth data.
2. In-the-wild demonstrations, especially of TE systems and of attacks/defenses.
3. Measurements of hidden routes: BGP routes are only measurable if they are used, providing limited visibility into backup routes, route diversity, routing policies, or the underlying topology. PEERING can manipulate which routes are available.

Data collection

- Looking Glass on PEERING routers so experimenters can view routes
  - Especially useful for debugging your own experiments to check your own experiments
- Traceroutes:
  - 48 teams of 400 RIPE Atlas probes run traceroute to PEERING prefixes every 20 minutes
  - Can configure exact source probes and destination PEERING prefixes/addresses
- Route monitoring
  - Monitor route visibility of PEERING announcements from RIPE RIS
  - https://github.com/PEERINGTestbed/peeringmon_exporter
- TODO: Feed routes to RouteViews/RIS/Gill
  - Announcements that experiments make
  - Routes we learn from the Internet

Challenges with operating PEERING

- Requires dealing with lots of issues, most of which are individually small (maintaining testbed, dealing with ASes, supporting researchers)
  - How to fund?
  - How to staff?
- Deploying new sites (especially physical sites) can be a headache
  - We are an unusual network to deal with: our needs & means are low
  - Universities make it hard to pay recurring hosting costs
- Many moving parts, relationships with many ASes
  - Requires goodwill of operator community

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