Stalloris: RPKI Downgrade Attack

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Team

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  - Network Security Researcher
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Cybersecurity Analytics and Defences departement

- Network Security
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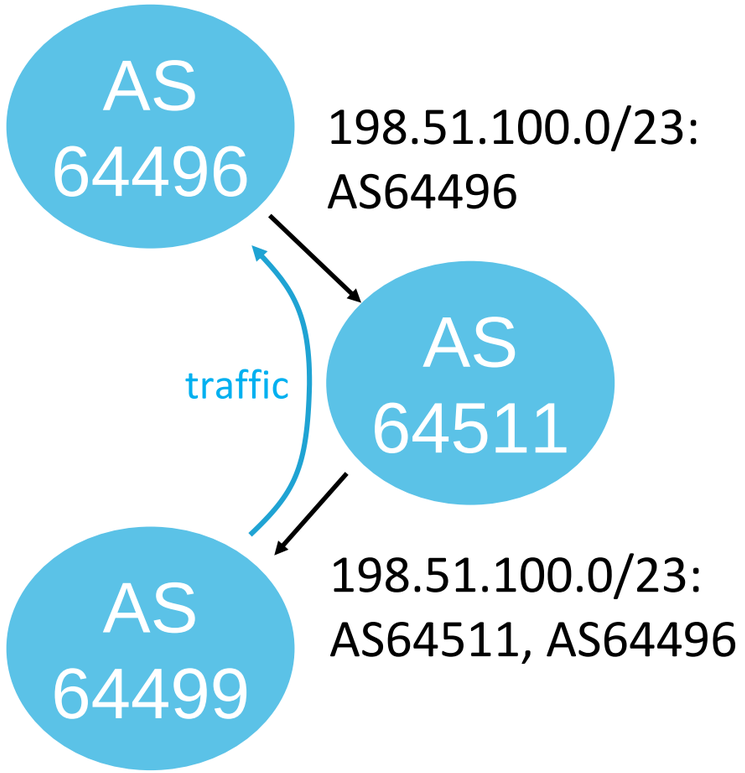
Outline

- BGP & BGP Security
- Ressource Public Key Infrastructure (RPKI)
- Downgrade attack against RPKI
- Feasability
- Mitigations

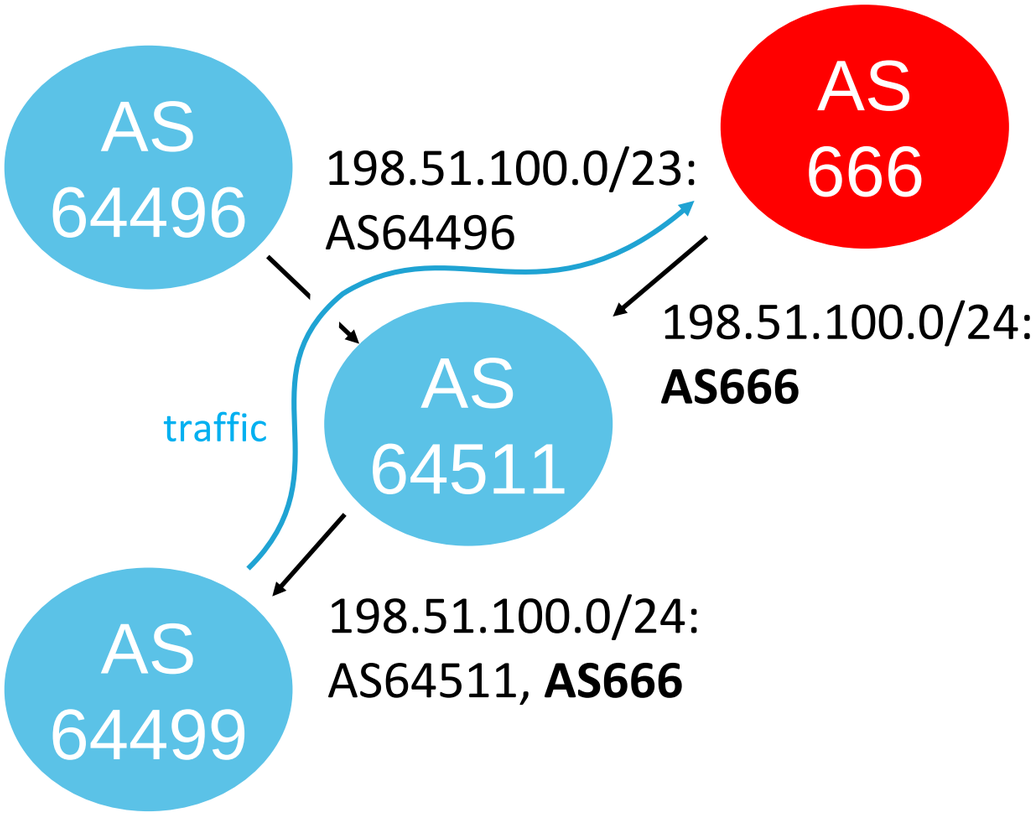
BGP

- Routing system of the Internet
- Networks (ASes) announce the IP prefixes they have
- Neighbors forward these announcements
- Everyone knows where to send traffic



BGP Hijacks

- No built-in security
- Just announce a prefix you do not own, be MitM, profit?

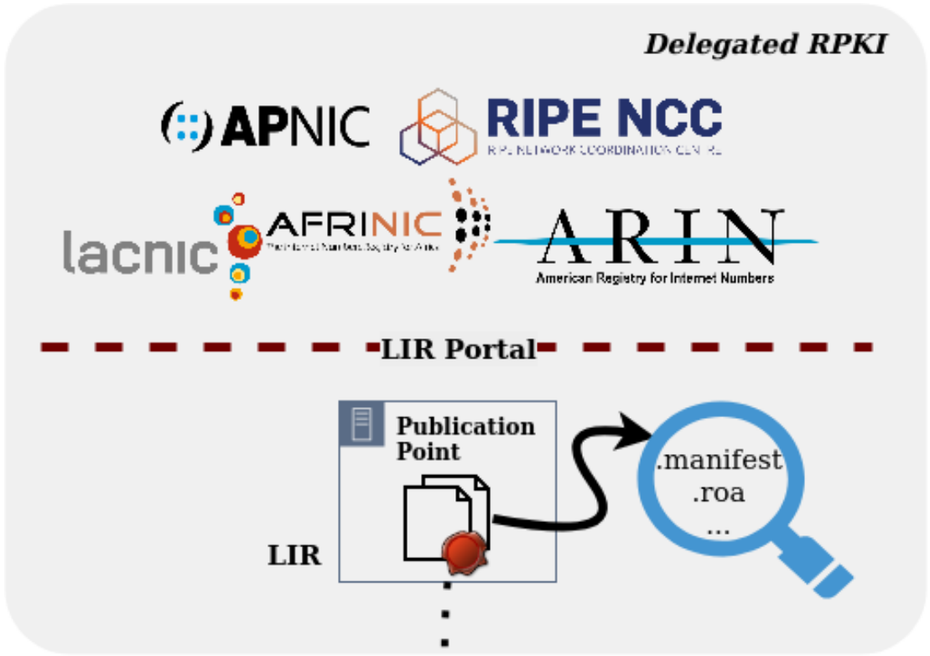


RPKI

- Systematic approach to BGP Security
- Certificates: Address block -> ASN
  - Called Route Origin Authorization (ROA)
- Root of Trust: RIRs
  - Because RIRs allocate address blocks!
- Kind of like getting your TLS cert from the registry

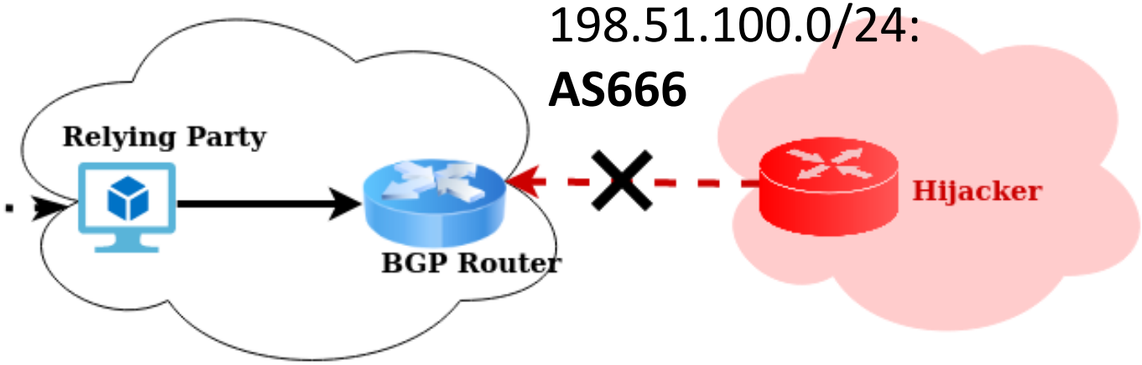
```
{
    "asn": "AS64496",
    "prefix": "198.51.100.0/24",
    "maxLength": 24,
    "ta": "RIPE",
}
```

Route Origin Validation

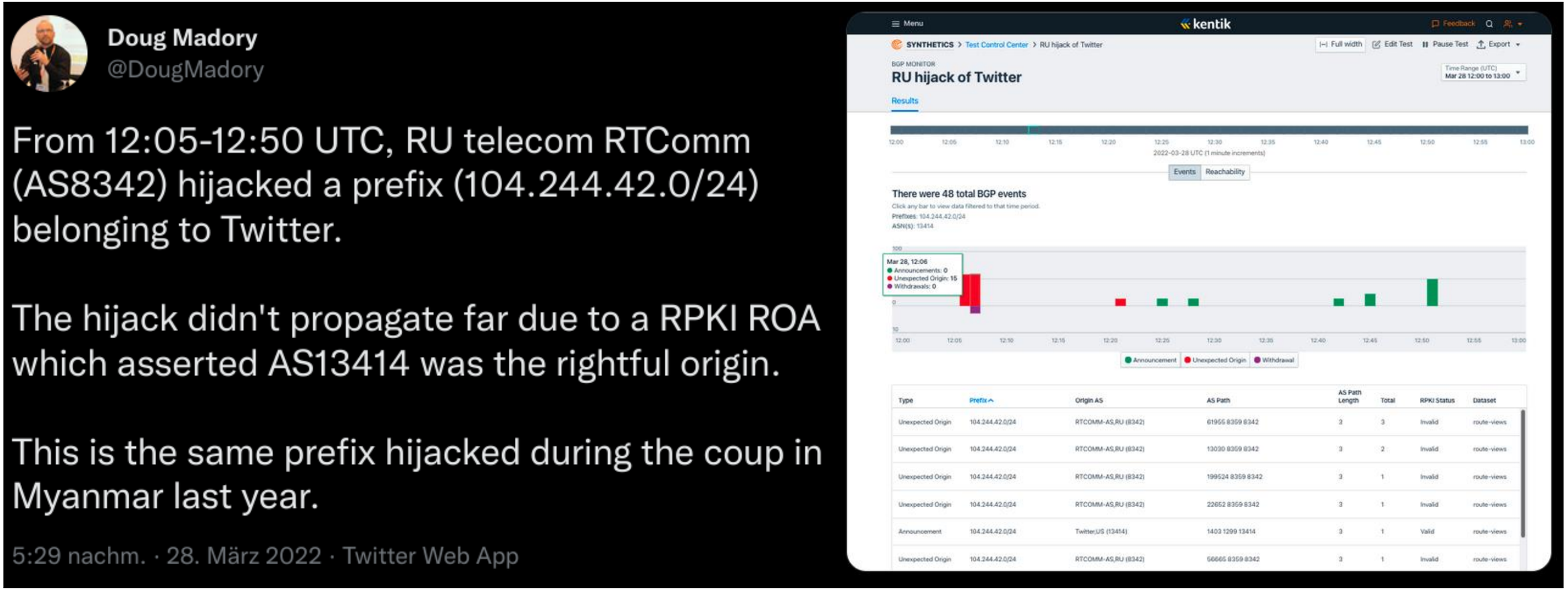


- Now everyone has ROAs
  - (actually only 34.2%)
- How to check them?
  - Put them into BGP?
  - Third-party system!

ROA:
AS64496 owns
198.51.100.0/24



RPKI works!



Attacking RPKI

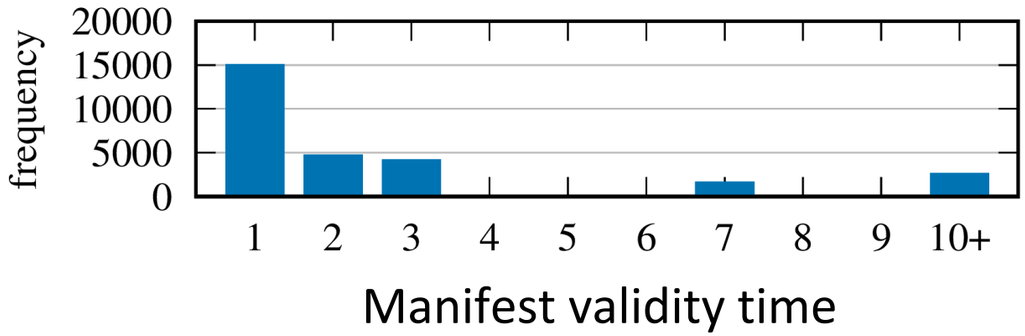
- Integrity?
  - Create Malicious ROA? Breaking crypto is hard.
  - Fool the CAs? CAs are run by RIRs.
- Availability!
  - RPKI is a third party system to BGP
  - What if RPKI stops working?

Making RPKI stop working

- Relying Parties (RPs) need to download ROAs from Publication Points (PPs)
  - If download fails, RPs will not have ROAs and assume RPKI has not been deployed
- Plan:
  - Break communication with PP
  - RPs cannot fetch information
  - RPKI turned off (RPKI state unknown)
  - Start BGP hijack

RP cache and manifests

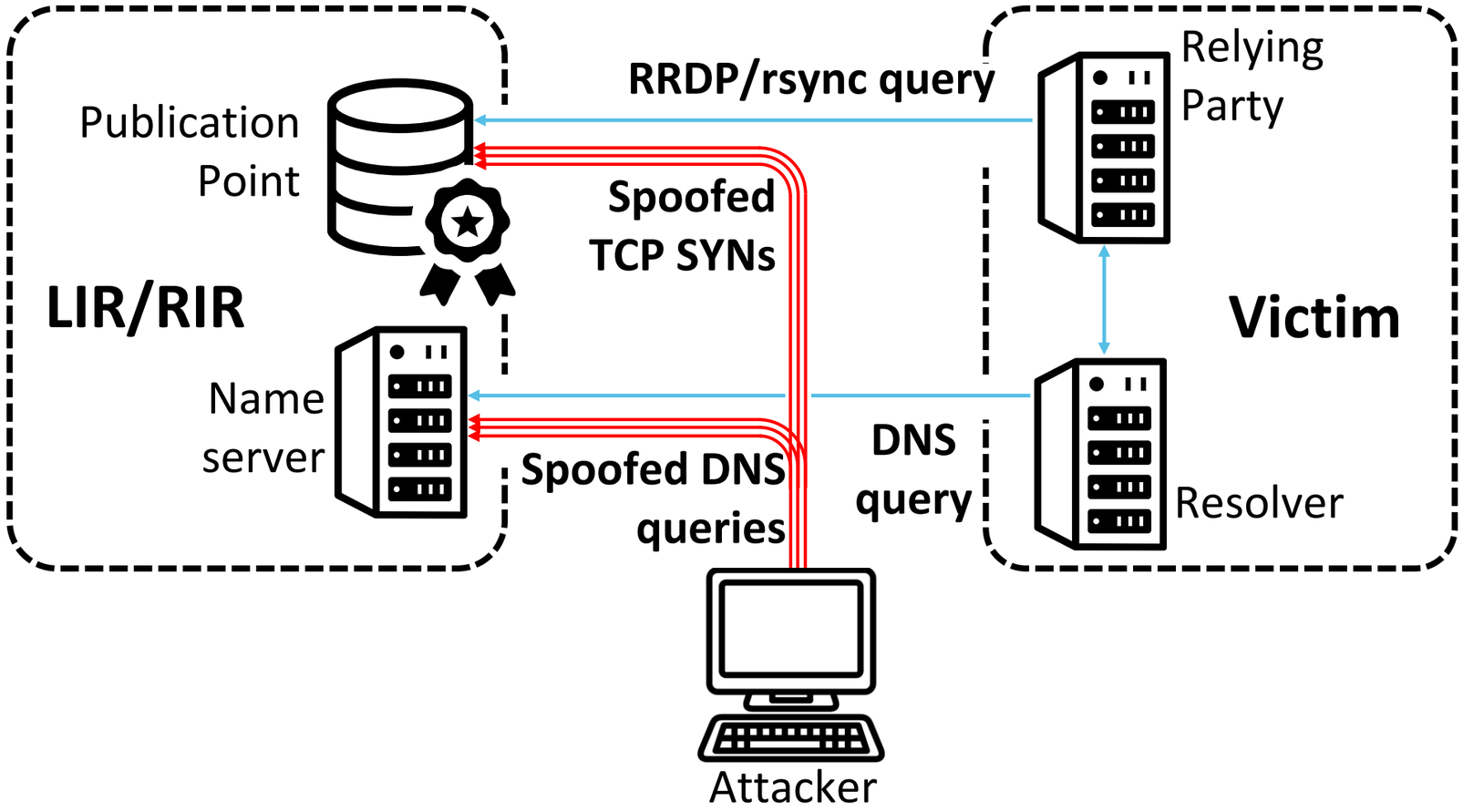
- RPs cache old data until expiry
  - ROAs expire pretty slowly (1 year)
- Manifests
  - Essentially a signed index
  - Designed to prevent replay attacks
  - ROAs not listed in manifest get removed
  - **Short expiry time! (1 day)**
    - Effectively only 6 hours of attack time because of deterministic re-generation



Breaking communication

Low-rate attack:

- Exploit rate-limiting on PP/NS
- Send spoofed requests
- Victim gets blocked
- After 6 hours: ROAs removed from cache due to expired manifest



Rate-limiting in RPKI

Tested rate-limiting in PPs

- DNS RRL & TCP Syn rate-limiting
- Typically implemented to prevent DoS

Results

- 47% of PPs do it (limit < 10,000 pkt/s)
- Affects 60% of RPKI-protected IPv4 space
- 3% of IPv4 are protected by PPs with very low (<60 pkt/s) rate-limit

		total addresses	% of assigned address space	% of ROA-protected
has ROA	v4	64 * /8	34.2 %	100.0 %
	v6	322 * /24	40.0 %	100.0 %
vulnerable (all)	v4	39 * /8	20.4 %	59.6 %
	v6	122 * /24	15.2 %	37.9 %
vulnerable (low ratelimit)	v4	2 * /8	1.1 %	3.1 %
	v6	10 * /24	1.3 %	3.2 %

Feasability (1)

So 60% of Ipv4 can be attacked?

Example:

- Rate-limit is 1,000 pkt/s,
  attacker sends 10,000 pkt/s
- Connection success is ~ 10%
- But RPs will **retry**

Feasability (2)

(Scenario)	$n_{attempts}$	t_{attack}	t_{sleep}	$n_{retries}$
(1)	24	old manifest 6 *hours*	unbound (blocked) 900 *s*	unbound (blocked) 1
(2)	864	fresh manifest 1 *day*	routinator (normal) 600 *s*	bind9 / linux tcp 6
(3)	23040	long-valid manifest 2 *days*	RIPE NCC validator 120 *s*	unbound normal 16

Simulation using different scenarios

- Feasible for low rate-limits (< 60 pkt/s), higher ones are challenging due to retries in 6 hours

We have to try harder

- RPKI allows ***delegation***
  - LIRs can run their own Publication Point
  - ***Attackers*** can run their own Publication Point
  - and RPs have to contact ***them***
  - *Can we exploit this to break the RP?* 🤔

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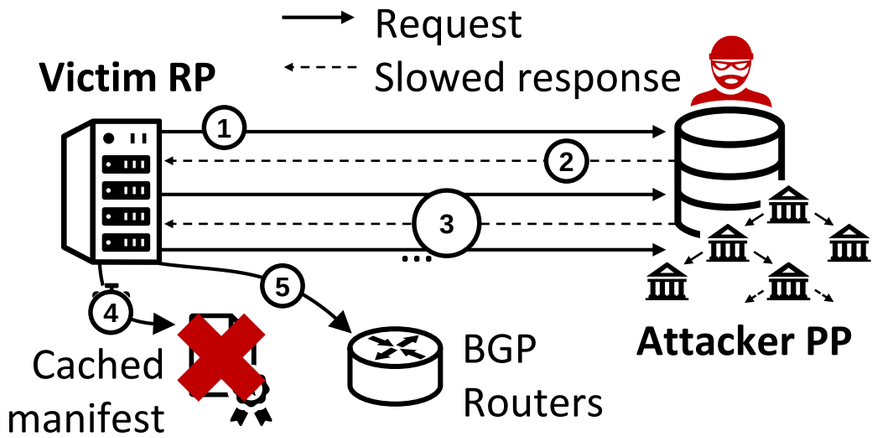
- Attacker becomes malicious Publication Point
- Sends responses as slow as possible
- Hinders RP from doing many retries

Simulation shows this makes attack feasible for high rate-limits and less-favorable scenarios

- Becoming a PP also helps time the attack with spoofed queries



Wrapping up

- Third-party system allows attacks on availability
- Rate-limiting can be exploited to block legitimate requests from off-path
- Short manifest validity makes attacks feasible
- Attackers can become PPs and prevent RPs from doing their work

Recommendations

- Publication points
  - Avoid low rate limits: Limiting to 60 pkt/s/IP is very easy to spoof
  - Longer manifest validities, e.g., 1 week
  - Randomize when manifests are re-generated
  - More robust deployment/redundancy
- Relying parties
  - Monitor connection failures
  - Limit processing time/PP and limit tree size under one PP

Thank You!

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