ATHENE
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Stealth BGP Hijacks with uRPF Filtering

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6. Limitations, Challenges, and Countermeasures
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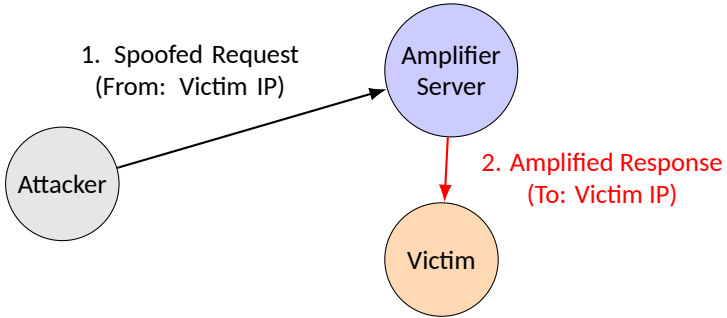
Introduction

- **IP spoofing remains a major security threat**
  - Used in Denial of Service, reflection/amplification, and bypass attacks
- **Unicast Reverse Path Forwarding (uRPF) is a primary mechanism to defend against IP spoofing**
  - Validates source IP addresses in incoming packets based on routing tables
- **But: uRPF is not robust, can be exploited by adversaries to carry out DoS attacks**
  - Exploitable via BGP prefix hijacks
- **Our contribution: SBA-uRPF attack model**
  - Adversaries utilize prefix hijacks to influence the uRPF behavior to block legitimate traffic
- **Impact:** Potential to disrupt thousands of networks

Background: IP Spoofing

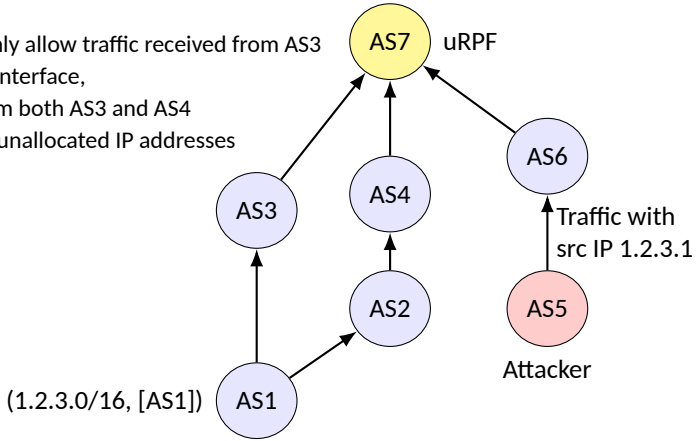
Example: DoS Amplification Attack

- The source address is specified in the IP layer header of packets to identify the origin
- But, the IP protocol lacks built-in authentication mechanisms
- Attackers can manipulate packets to appear as if they originated from another source, a technique referred to as IP spoofing



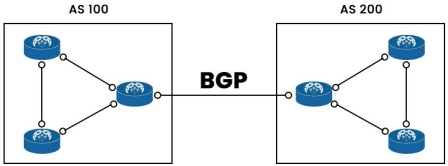
Background: Unicast Reverse Path Forwarding (uRPF)

- uRPF verifies incoming packet source via routing (forwarding) tables; checks if it can forward packets to the source through the interface
- Three common modes
  - Strict: same interface, only allow traffic received from AS3
  - Feasible-path: available interface, allow traffic received from both AS3 and AS4
  - Loose: against bogon or unallocated IP addresses



Background: Border Gateway Protocol (BGP)

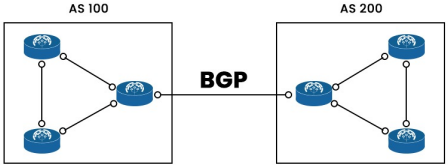
- BGP routers exchange reachability information across Autonomous Systems (ASes) using BGP;
  E.g., AS100 announces a route for its prefix 1.2.3.0/24 to AS200: (1.2.3.0/24, [AS100])
- BGP relationships: BGP customers (pay providers for traffic transfer), peers (exchange traffic for free), and providers (provide transfer service for customers)



https://www.pynetlabs.com/bgp-in-computer-networks/

Background: Border Gateway Protocol (BGP)

- Valley-free routing policy: An AS is not allowed to forward routes learned from its provider or peer to another provider or peer
- Route preference: Upon receiving BGP routes for the same prefix, routers select the best one for forwarding; e.g., based on Local preference: customers > peers > providers
- Routing loop prevention: ASes will discard a BGP announcement if they detect their own AS numbers in the AS path



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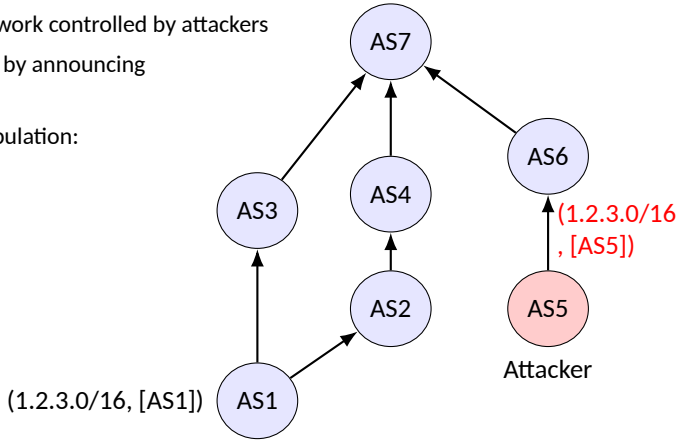
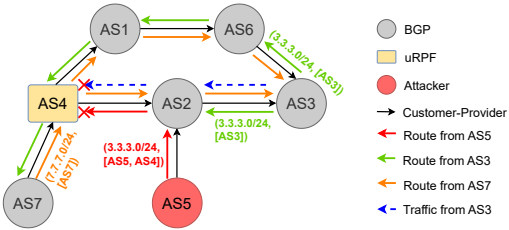
Background: Prefix Hijacks

- Prefix hijacks occur when an AS originates a BGP route for a prefix that belongs to another AS
- Redirecting the traffic to the network controlled by attackers
- E.g., AS5 launches a prefix hijack by announcing the prefix owned by AS1
- Prefix hijacks with AS path manipulation: (1.2.3.0/16, [AS5, AS1])



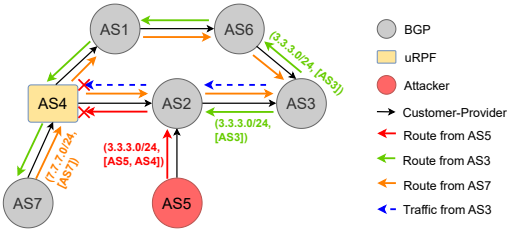
Novel Attack Model: SBA-uRPF

- **S**tealthy **B**GP **a**ttack abusing **uRPF**
- AS4 deploys uRPF; an attacker within network AS5 originates a BGP route for the prefix 3.3.3.0/24, which belongs to AS3, and appends AS4 to the end of the AS path
- AS5 is a customer of AS2, while AS3 is a provider or a peer of AS2
- Based on local preference, AS2 selects and forwards the route from AS5 to AS4
- However, AS4 drops this route to avoid routing loops
- Packets with source IP addresses within the prefix 3.3.3.0/24 can not be accepted on the interface connected to AS2
- We refer to AS2 as the “bridging network”



Novel Attack Model: SBA-uRPF

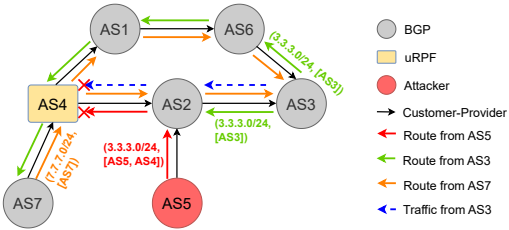
- **S**tealthy **B**GP **a**ttack abuses **uRPF**
- AS7 is a customer of AS4 and orignates a route for its prefix 7.7.7.0/24
- Two potential paths to AS3: [AS4, AS2, AS3] and [AS4, AS1, AS6, AS3]
- Since AS3 is AS2's provider or peer, to enable the route forwarding to AS3, AS4 must be a customer of AS2 (valley-free policy)
- AS3 selects the best route [AS2, AS4, AS7] to forward the traffic with a source IP from 3.3.3.0/24 to AS7
- As a result, the traffic is discarded by uRPF within AS4



Novel Attack Model: SBA-uRPF

The attack possesses the following major properties:

- **Targeted:** specifically tailored to each uRPF-enabled network (by triggering routing loop prevention)
- **Stealthy:** hidden from the uRPF-enabled network as well as its downstream customer networks (such as AS4 and AS7)
- **DoS:** leads to Denial-of-Service (DoS) by causing legitimate traffic drops



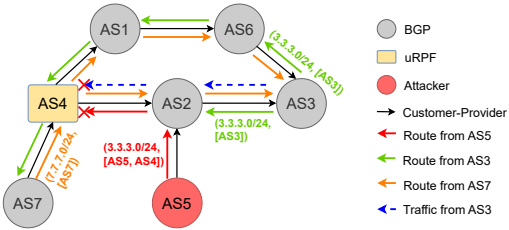
Evaluation Methodology

- We identify uRPF-enabled networks that are vulnerable to SBA-uRPF attacks.
- We assess the vulnerability using a simulator built upon CAIDA AS topology data, including 77K ASes (65K stub or multihomed, 12K transit, and 19 tier-1 networks)
- We assume that all of ASes deploy uRPF on the simulator to conduct a theoretical evaluation

Evaluation

Steps to Identify a Vulnerable uRPF-Enabled Network:

- Select a uRPF-enabled network to evaluate (e.g., AS4)
- For each of its providers, check if it can act as a bridging network (e.g., AS2):
  - Has a customer exploitable by attackers
  - Has a provider or peer that could be a victim
- Simulate a route announcement from the uRPF network (e.g., 4.4.4.0/24)
- Check if any potential victim sees the best route via the bridging network
- If such a bridging network exists, the uRPF network is vulnerable to SBA-uRPF



Results

Our analysis is based on a simulation with universal uRPF deployment assumption. The main results are:

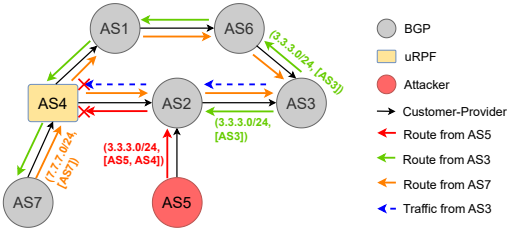
- 99.3% (76,953) of networks across the Internet could be vulnerable to SBA-uRPF attacks
- Vulnerable transit networks exhibit larger numbers of attack scenarios (different pairs of attacker and victim networks), resulting in a total of 1.7M potential attacks
- In the worst-case scenario, up to 59K networks (76.3%) could be affected
- No Tier-1 networks are vulnerable (no providers act as bridging networks)

	Tier-1	Transit	Edge
Vulnerable	0	12,045	64,908
Attacks	0	1,781,854	818,355
Impact (mean)	0	1,141	1
Impact (maximum)	0	59,115	1

Table: Simulation statistics across different types of networks.

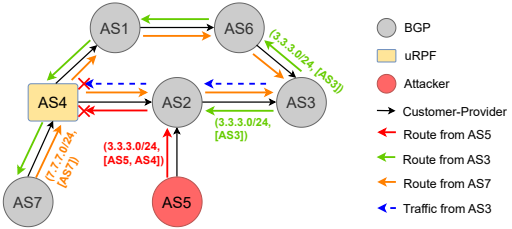
Limitations and Challenges

- **Theoretical analysis:** Assumes universal uRPF deployment
- **Upper bound:** Real networks use complex policies; they may use BGP communities to adjust local preferences and control route export behavior; SBA-uRPF may not apply to these cases
- **Traffic load:** Attackers receive unwanted redirected traffic
- **Reduced stealth:** Hijacks may be detected by global BGP monitoring systems



Countermeasures

- ASes such as AS2 deploy mechanisms that defend against AS path manipulation, e.g., BGPsec: path validation prevents AS path manipulation), ASPA (AS Provider Authorization): validates provider-customer relationships
- AS2 deploys Route Origin Validation (ROV) to filter out bogus routes



Conclusions

- We introduce a new attack model that exploits prefix hijacks to manipulate uRPF behavior to cause the dropping of legitimate traffic
- SBA-uRPF attacks remain undetectable to affected networks; can cause long-term service disruption; can target critical Internet infrastructure such as DNS, NTP, web servers
- Our theoretical evaluation shows that 99.3% of networks are vulnerable to SBA-uRPF, with a potential maximum impact affecting over 76.3% of networks
- Finally, our findings reveal a troubling paradox: in the case of uRPF, protection can be turned into a weapon by attackers.

Questions?

Thank you for your attention!