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The bridge to possible

IPv6 Security in the Local Area with First Hop Security (FHS)

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@evyncke

BRKENT-3002

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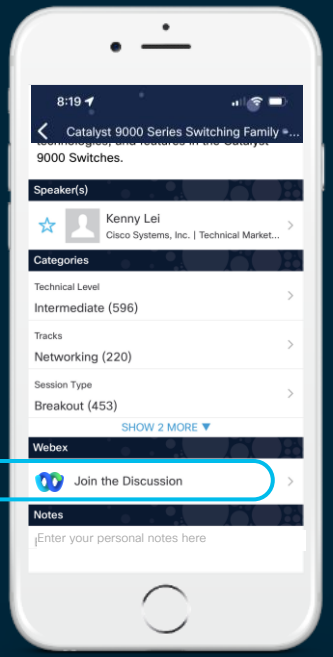

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Agenda

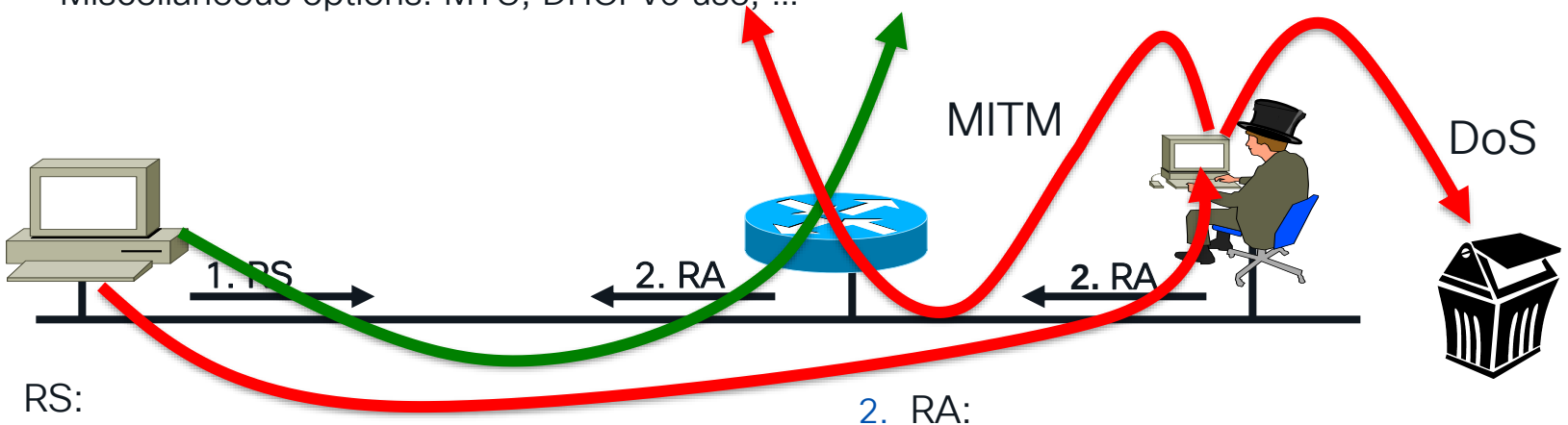
- Integrity of Routing and Addressing
- Integrity of *<MAC, IPv6>* Addresses Bindings
- Address Availability
- More Information on First Hop Security (FHS)
- IPv6 Security Beyond Local Area
- Summary

Integrity of Routing and Addressing

StateLess Address Auto Configuration SLAAC: Rogue Router Advertisement

- Router Advertisements (RA) contains:
  - Prefix to be used by hosts
  - Data-link layer address of the router
  - Miscellaneous options: MTU, DHCPv6 use, …

RA w/o Any Authentication Gives Exactly Same Level of Security as DHCPv4 (None)

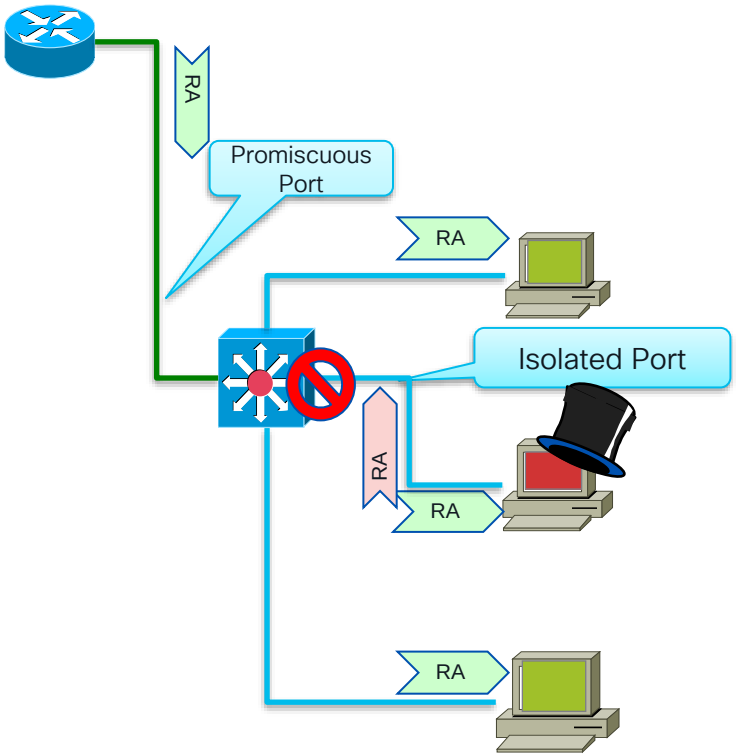


1. RS:
   - Data = Query: please send RA

2. RA:
   - Data= options, prefix, lifetime, A+M+O flags

Mitigating Rogue RA: Host Isolation

- Prevent Node-Node Layer-2 communication by using:
  - Private VLANs (PVLAN) where nodes (isolated port) can only contact the official router (promiscuous port)
  - WLAN in 'AP Isolation Mode'
  - 1 VLAN per host (SP access network with Broadband Network Gateway)
- Link-local multicast (RA, DHCP request, etc.) sent only to the local official router: no harm
  - Side effect: breaks Duplicate Address Detection (DAD)



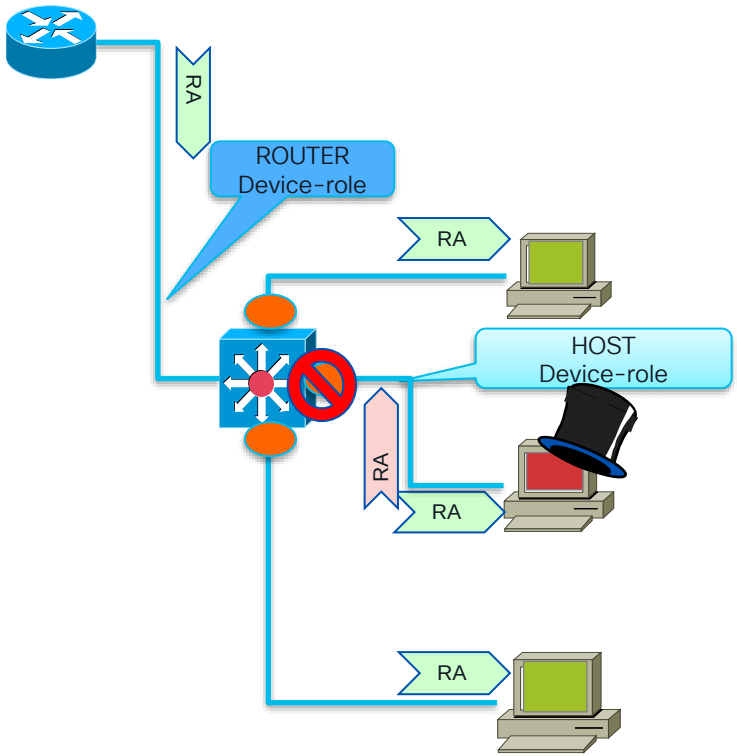
First Hop Security: RAguard since 2010 (RFC 6105)

- **Port ACL**
  blocks all ICMPv6 RA from hosts

```
interface FastEthernet0/2
  ipv6 traffic-filter ACCESS_PORT in
  access-group mode prefer port
```

- **RAguard**

```
ipv6 nd raguard policy HOST
 device-role host
ipv6 nd raguard policy ROUTER
 device-role router
vlan configuration 1
 ipv6 nd raguard attach-policy HOST
interface Ethernet0/0
 ipv6 nd raguard attach-policy ROUTER
```



General principles on FHS command interface

- Each FH feature provides commands to attach policies to targets: global, VLAN, port

```
vlan configuration 100
  ipv6 nd raguard attach-policy host
  device-tracking
interface Ethernet 0/0
  ipv6 nd raguard attach-policy router
```

- Packets are processed by the lowest-level matching policy **for each feature**
  1. Two RA guard policies are configured: policy "**host**" and device-tracking on VLAN 100, policy "**router**" on interface Ethernet 0/0 (part of VLAN 100)
  2. Packets received on Ethernet 0/0 are processed by policy "**router**" AND by policy device-tracking "**default**"
  3. Packets received on any other port of VLAN 100 are processed by policy "**host**" AND by policy device-tracking "**default**"

Configuration examples

Step1: Configure policies	Step2: Attach policies to target	
	Vlan	Port
`ipv6 nd raguard policy HOST` `  device-role host`	`vlan configuration 100-200` `  ipv6 nd raguard attach-policy HOST`	
`ipv6 nd raguard policy ROUTER` `  device-role router`		`interface Ethernet0/0` `  ipv6 nd raguard attach-policy ROUTER`

`device-tracking policy NODE`
`  tracking enable`
`  limit address-count 10`
`  security-level guard`
	`vlan configuration 100,101`
	`  ipv6 snooping attach-policy NODE`	

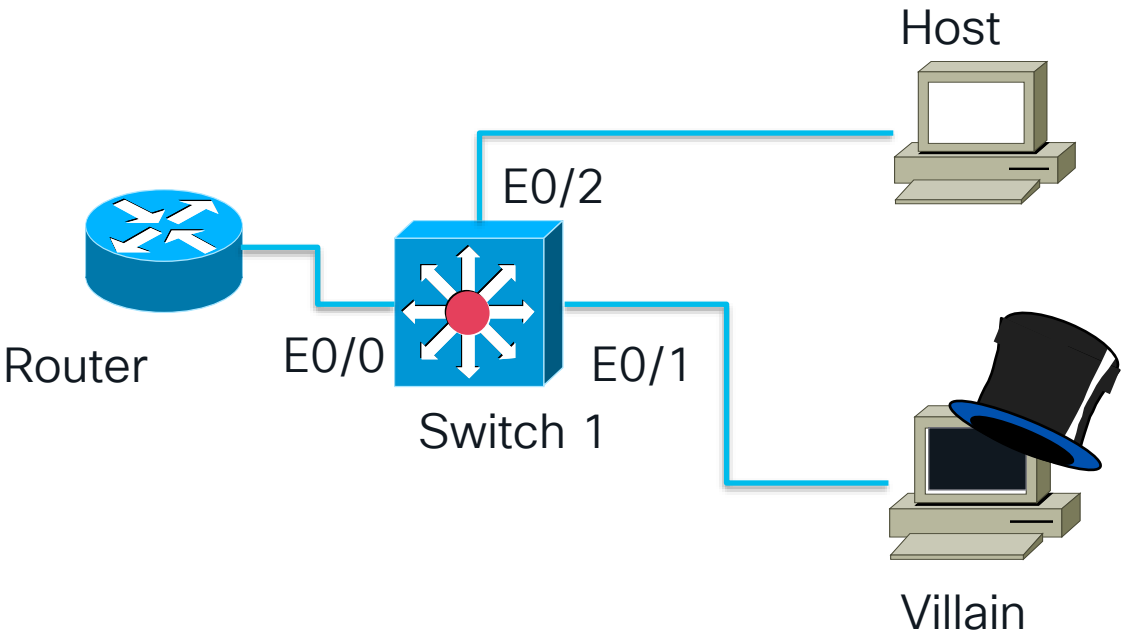
`device-tracking policy SERVER`
`  trusted-port`
`  tracking disable`
`  security-level glean`
		`interface Ethernet1/0`
		`  device-tracking attach-policy SERVER`

Older CLI for NDP snooping was '`ipv6 snooping`' it is now '`device-tracking`'

Device Roles

- For RA-guard, devices can have different roles
  - Host (default): can only receive RA from valid routers, no RS will be received
  - Router: can receive RS and send RA
  - Monitor: receive valid and rogue RA and all RS
  - Switch: RA are trusted and flooded to synchronize states
- For device-tracking, device can have different roles
  - Node (default):
    - Received ND are inspected (= gleaned)
    - Only valid ND are sent
  - Switch:
    - all valid ND are flooded to port to synchronize states
    - received ND from port are trusted

RA-Guard Demo Topology



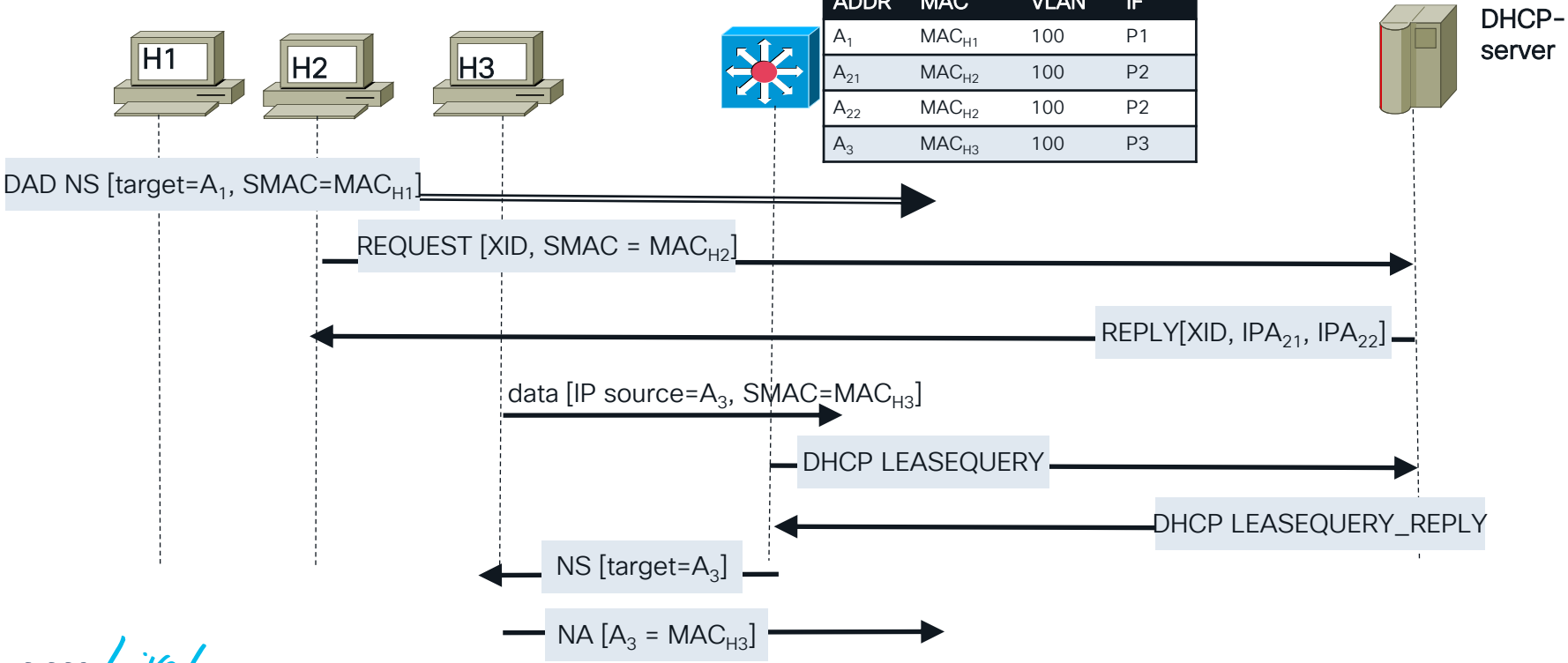
https://youtu.be/1kwCaY4H9Tw (4min 24 sec)

Integrity of MAC-IPv6 Addresses Bindings

Discover Endpoint Addresses *(no animation)*

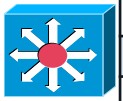
Binding table

ADDR	MAC	VLAN	IF
A_1	MAC_{H1}	100	P1
A_{21}	MAC_{H2}	100	P2
A_{22}	MAC_{H2}	100	P2
A_3	MAC_{H3}	100	P3

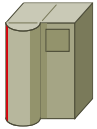


Discover Endpoint Addresses: Preference

Binding table



ADDR	MAC	VLAN	IF	Preference
A_1	MAC_{H1}	100	P1	X
A_{21}	MAC_{H2}	100	P2	Y
A_{22}	MAC_{H2}	100	P2	Y
A_3	MAC_{H3}	100	P3	Z

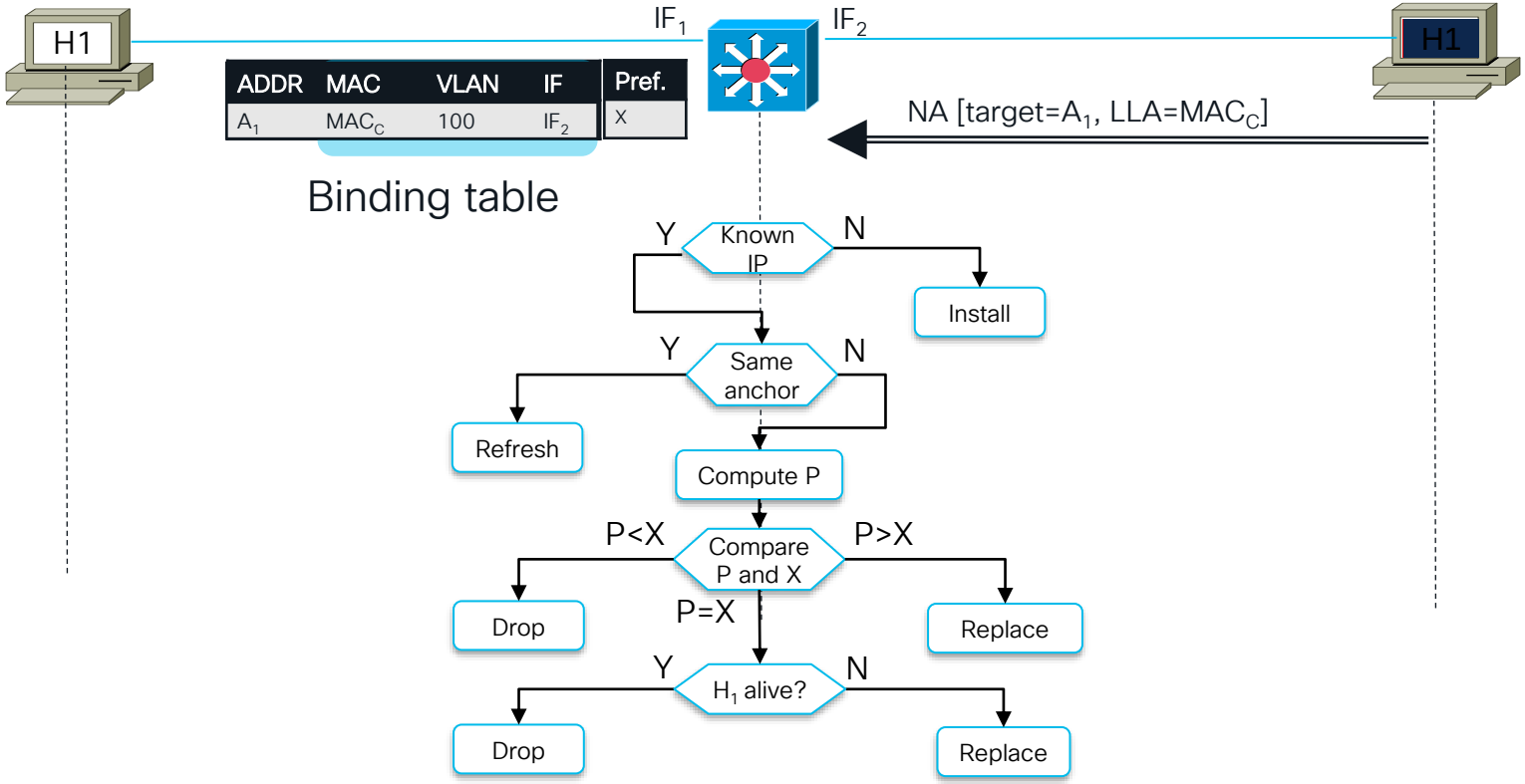


DHCP-server

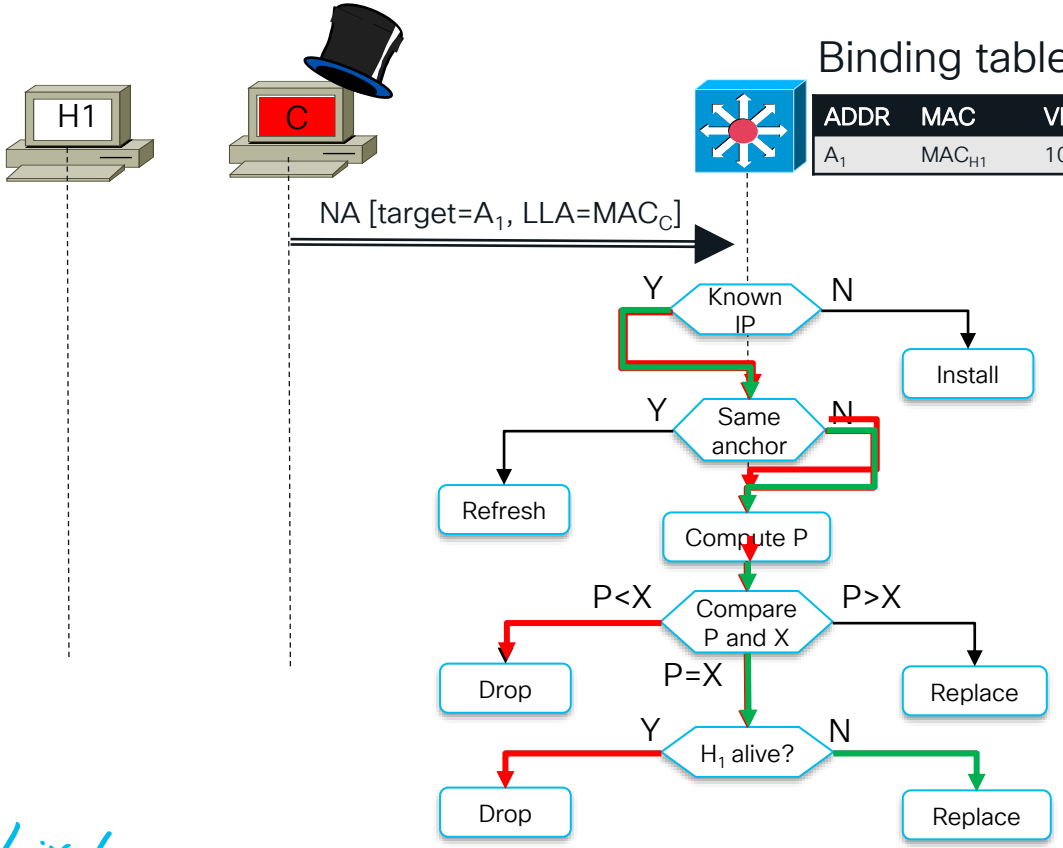
Each entry has a preference based on:

- Configuration: server, node
- Learning method: static, DHCP, DAD, ...
- Credentials: 802.1X

Enforce/Validate Endpoint Addresses



Enforce/Validate Endpoint Addresses



IP theft, equal trust

IP theft, thief less trusted

IP move

Configuration Example

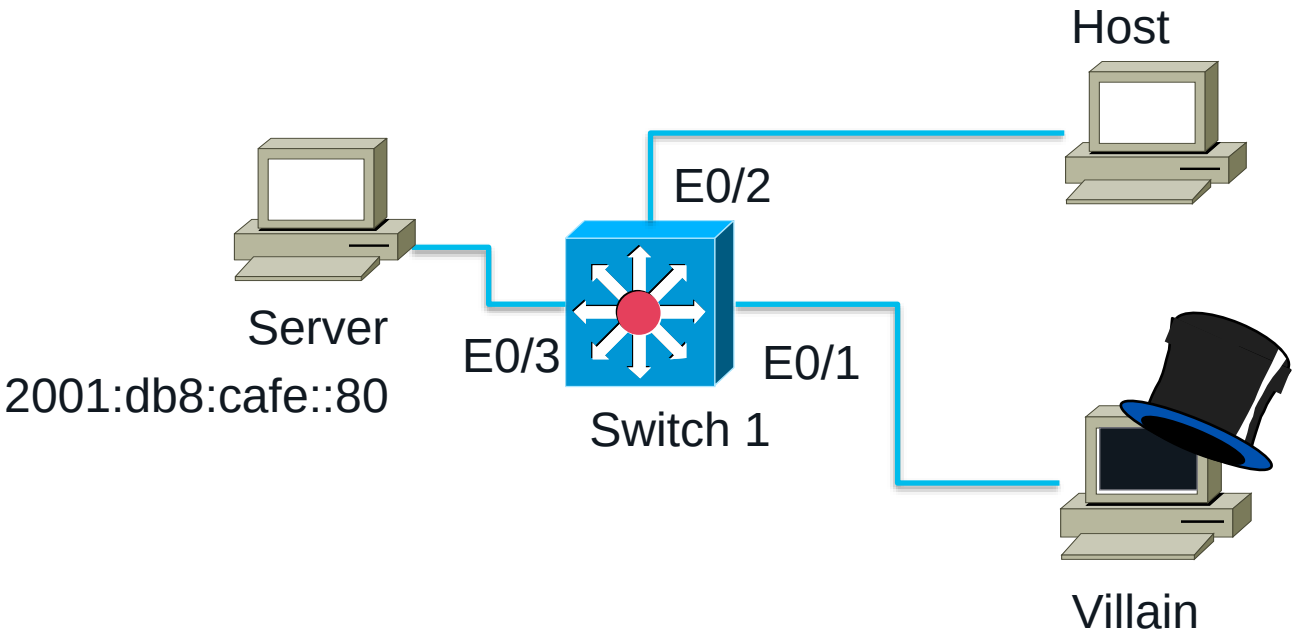
```
device-tracking policy NODE
      tracking enable
      limit address-count 10
      security-level inspect
device-tracking policy SERVER
      trusted-port
      tracking disable
      security-level glean
```

```
vlan configuration 1
    device-tracking attach-policy NODE

interface Ethernet0/3
   device-tracking attach-policy SERVER
```

Security level:

- **glean**: only build the binding table
- **inspect**: as glean + drop wrong NA
- **guard**: as inspect + drop RA & DHCP server messages

Device-Binding Demo Topology



https://youtu.be/REL1AmqnFFc (5 min 17 sec)

Address Availability

Denial of Address Initialization

host

attacker

router

Computes A = {P, HOSTID}

RA

ICMP Type = 134
Destination = ALL-NODES
Options = Prefix P

ICMP type = 135 (Neighbor Solicitation)
Source = UNSPEC, Destination = SOL $_{A,}$ target = A
Query = Does anybody use A already?

NS-DAD, target=A

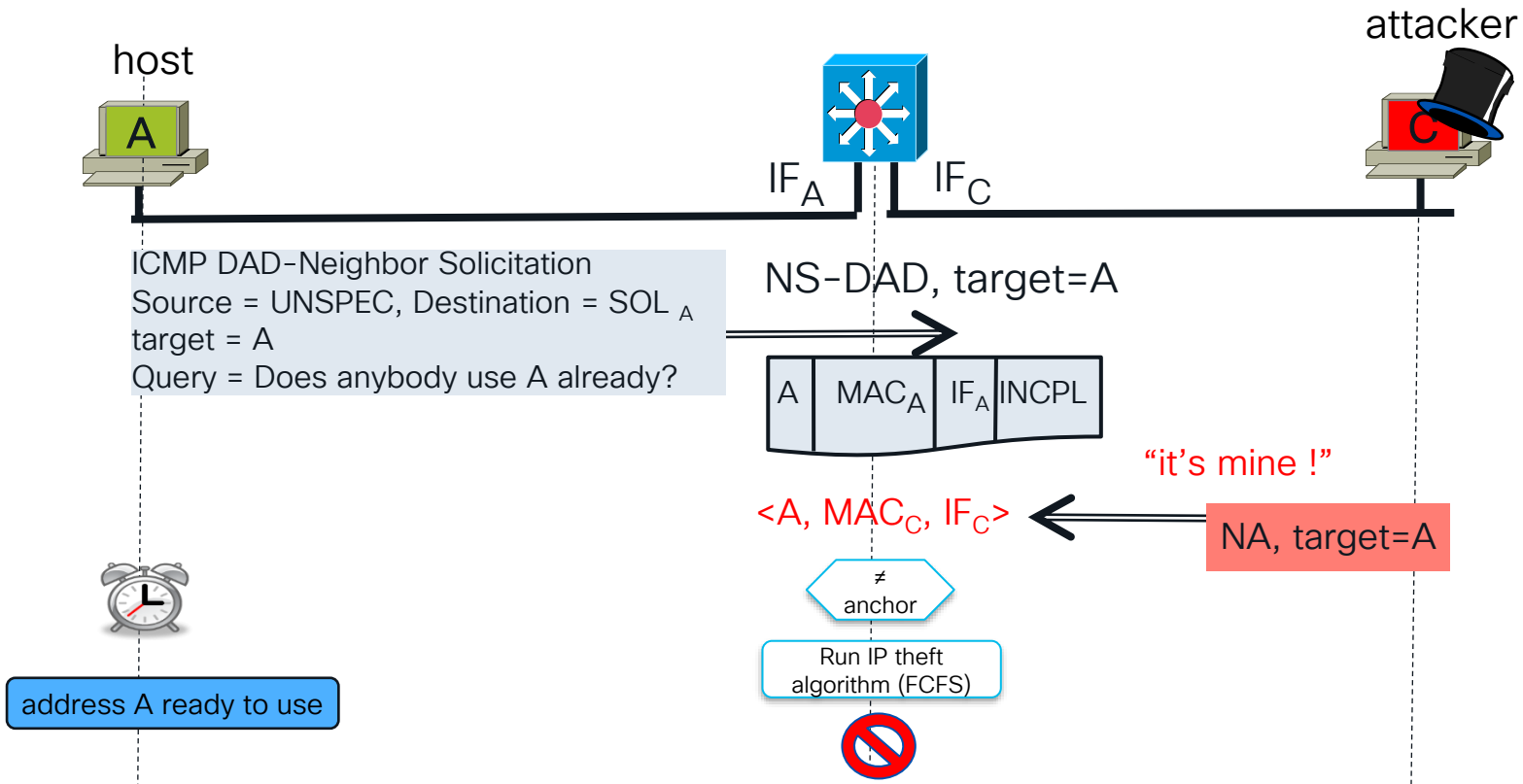
NA, target=A

"it's mine !"

Address cannot be used

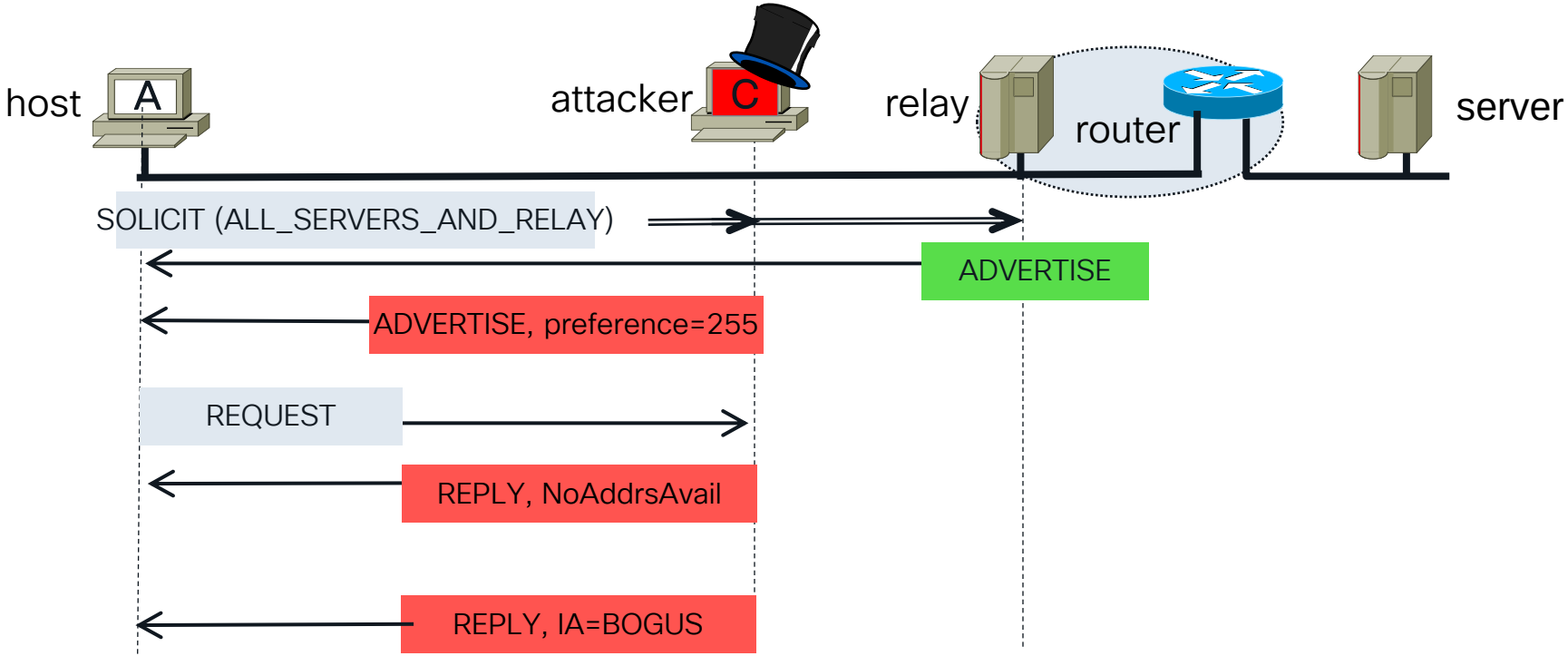
Victim can't configure IP address and can't communicate

Mitigating Denial of Address Initialization



DoS attack: denial of Address assignment

Vulnerability: attacker hacks DHCP server role



DoS attack mitigation: DHCP Guard

Denial of address assignment

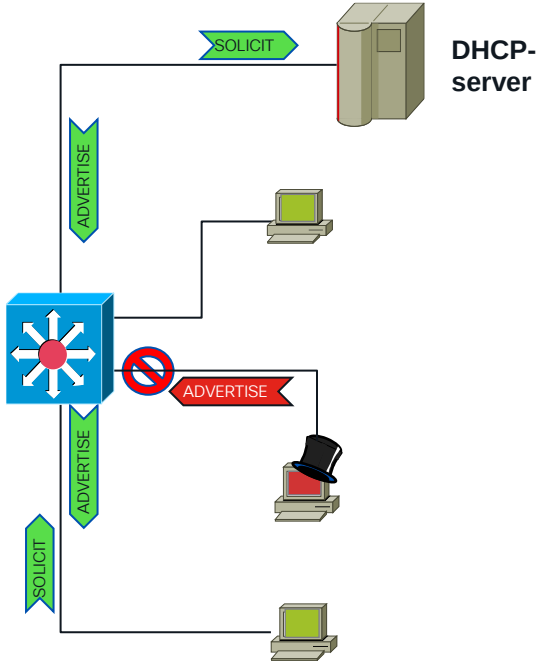
- **Port ACL:** blocks all DHCPv6 “server” messages on client-facing ports

```
interface FastEthernet0/2
  ipv6 traffic-filter CLIENT_PORT in
  access-group mode prefer port
```

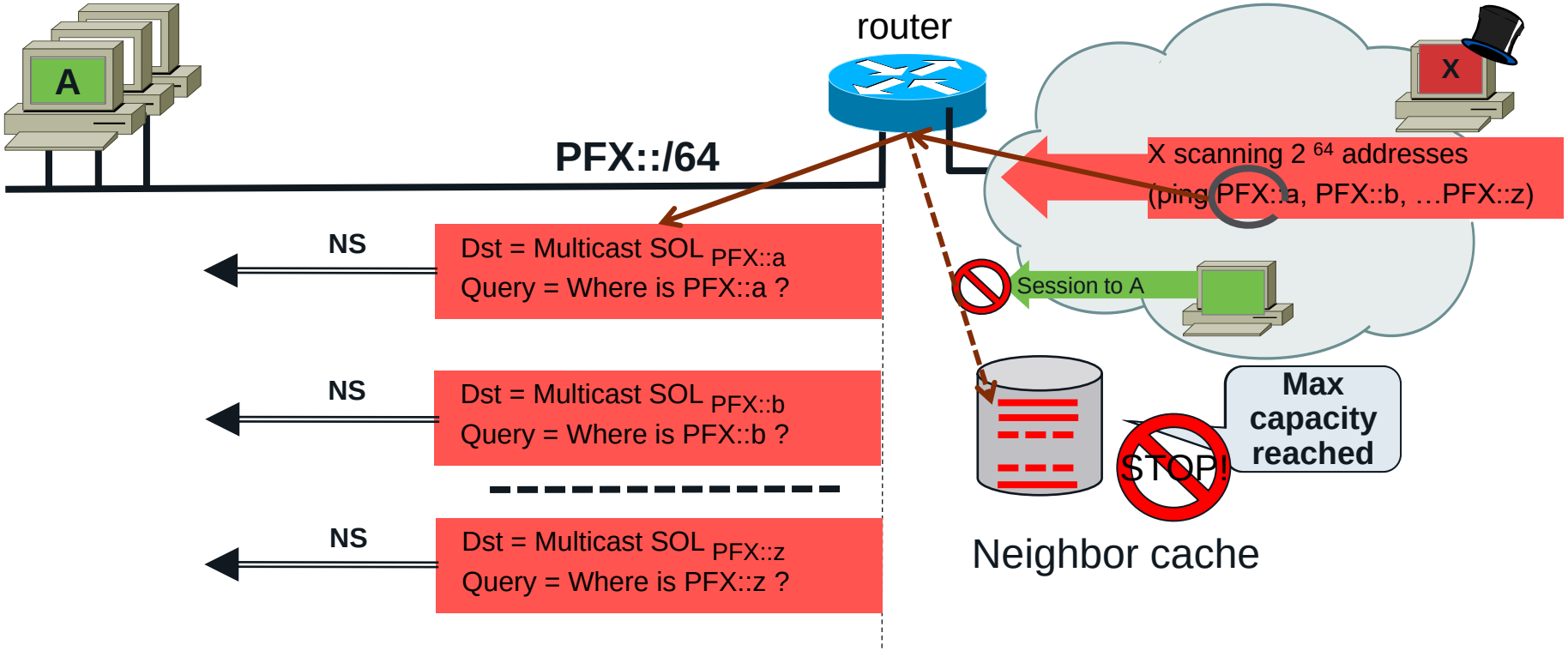
- **DHCP guard:** deep DHCP packet inspection

```
ipv6 dhcp guard policy CLIENT
   device-role client

ipv6 nd raguard policy SERVER
   device-role server

vlan configuration 100
   ipv6 dhcp guard attach-policy CLIENT vlan 100

interface FastEthernet0/0
  ipv6 dhcp guard attach-policy SERVER
```

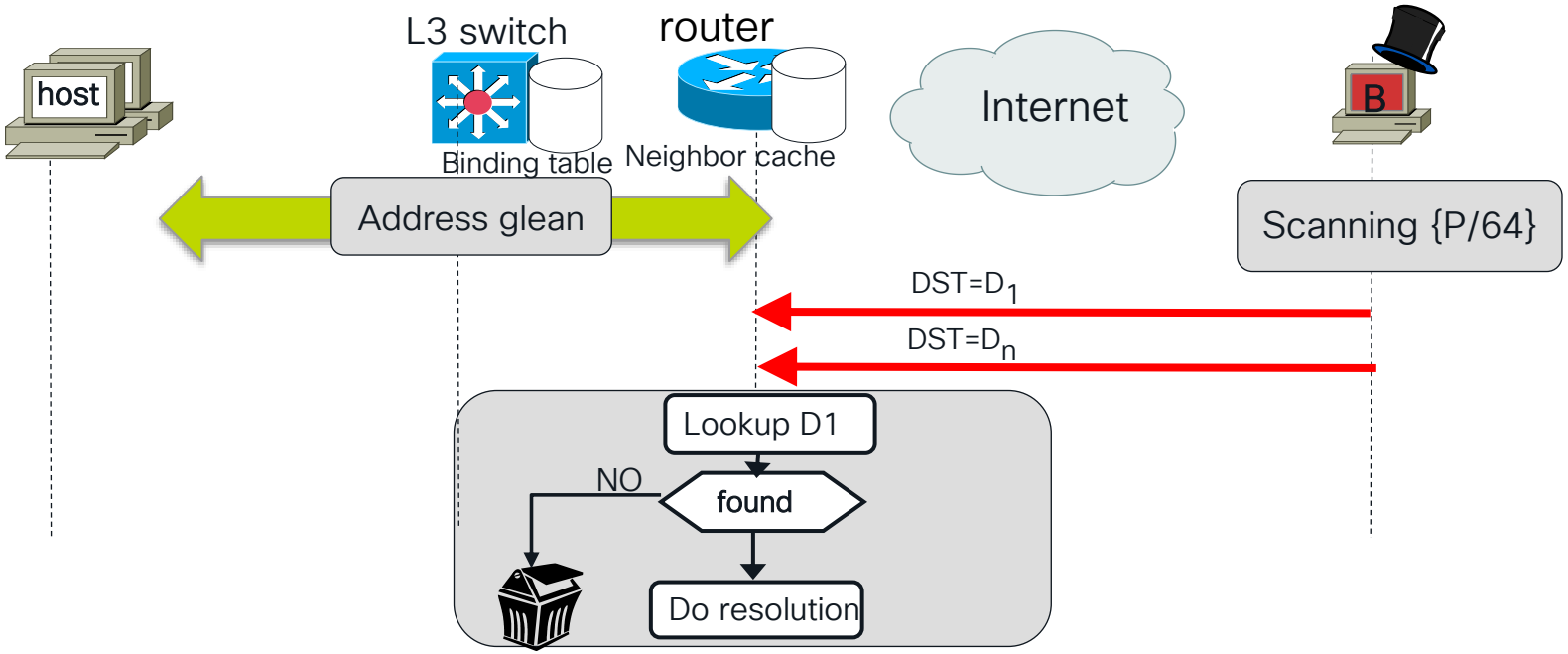
- Source
- Prefix list
- CGA credentials



DoS attack: denial of address resolution



Destination Guard



- Mitigate prefix-scanning attacks and Protect ND cache
- Useful at last-hop router and L3 distribution switch
- Drops packets for destinations without a binding entry

More Information on FHS

More demos on Youtube

Demo	Title	link
Router theft & mitigations	Cisco IPv6 Router Advertisement (RA) Guard Demo	https://www.youtube.com/watch?v=fE-TQ0ekffU
Address theft & mitigations	Cisco IPv6 snooping Demo	https://www.youtube.com/watch?v=KL4NwRr8n6w
DoS attack on ND cache & mitigation	Cisco IPv6 Destination Guard Demo	http://www.youtube.com/watch?v=QDyqV7u4HSY
Misdirect & mitigation	Cisco IPv6 Source Guard Demo	http://www.youtube.com/watch?v=-vOY0xXLoj0

Monitoring (done via SYSLOG)

Address Theft (IP)	%SISF-4-IP_THEFT: IP Theft A=2001::DB8::1 V=100 I=Et0/0 M=0000.0000.0000 New=Et1/0
Address Theft (MAC)	%SISF-4-MAC_THEFT: MAC Theft A=2001::DB8::1 V=100 I=Et1/0 M=0000.0000.0000 New=Et1/0
Address Theft (MAC/IP)	%SISF-4-MAC_AND_IP_THEFT: MAC_AND_IP Theft A=2001::DB8::1 V=100 I=Et0/0 M=0000.0000.0000 New=Et1/0
DHCP Guard	%SISF-4-PAK_DROP: Message dropped A=2001::DB8::1 G=2001:2DB::2 V=2 I=Gi3/0/24 P=DHCPv6::REP Reason=Packet not authorized on port
RA Guard	%SISF-4-PAK_DROP: Message dropped A=2001::DB8:2 G=- V=1 I=Gi3/2 P=NDP::RA Reason=Message unauthorized on port

Many FHS Features

- *RA-Guard*
  - *Only trusted routers can send RA*
- *Device tracking*
  - *Learn the MAC/IP addresses binding and enforce it (first talker wins)*
- *DHCPv6 Guard*
  - *Block DHCP packet from non trusted DHCP servers*
- *Destination Guard*
  - *Block ingress packet whose destination is unknown (not in the binding table learned by device tracking)*
- Source Guard
  - block packets with invalid source IPv6 addresses (learned from device tracking of NDP & DHCP), mainly for layer-2 switches
- Prefix Guard
  - block packets with invalid source IPv6 addresses (learned DHCP prefix delegation), mainly for CPE
- RA Throttler
  - Reduce the amount of multicast RA as multicast is bad for Wi-Fi (battery lifetime, reliance, and performance)
- ND Suppress Multicast:
  - Rewrite the destination MAC address from multicast to unicast for some traffic (also based on the binding learned by device tracking)

IPv6 First Hop Security Platform Support

Feature/Platform	Catalyst 6500 Series	Catalyst 4500 Series	Catalyst 2K/3K Series	ASR1000 Router	7600 Router	Catalyst 3850	Wireless LAN Controller (Flex 7500, 5508, 2500, WISM-2)	Nexus 7k	Nexus 3k/Nexus 9k	Nexus ACI	Meraki
RA Guard	15.0(1)SY	15.1(2)SG	15.0.(2)SE		15.2(4)S	15.0(1)EX	7.2	NX-OS 8.0	7.0(3)	3.0	MR 27
Device-tracking	15.0(1)SY[1]	15.1(2)SG	15.0.(2)SE	XE 3.9.0S	15.2(4)S	15.0(1)EX	7.2	NX-OS 8.0	7.0(3)	3.0	
DHCPv6 Guard	15.2(1)SY	15.1(2)SG	15.0.(2)SE		15.2(4)S	15.0(1)EX	7.2	NX-OS 8.0	7.0(3)	3.0	
Source/Prefix Guard	15.2(1)SY	15.2(1)E	15.0.(2)SE[2]	XE 3.9.0S	15.3(1)S		7.2				
Destination Guard	15.2(1)SY	15.1(2)SG	15.2(1)E	XE 3.9.0S	15.2(4)S						
RA Throttler	15.2(1)SY	15.2(1)E	15.2(1)E			15.0(1)EX	7.2				
ND Multicast Suppress	15.2(1)SY	15.1(2)SG	15.2(1)E	XE 3.9.0S		15.0(1)EX	7.2				MR27

Note 1: IPv6 Snooping support in 15.0(1)SY does not extend to DHCP or data packets; only ND packets are snooped
Note 2: Only IPv6 Source Guard is supported in 15.0(2)SE; no support for Prefix Guard in that release
Note 3: No support on virtual switches

Available Now | Not Available | Roadmap

IPv6 Security Beyond the Local Area ?

IPv6 Security Beyond the Local Area ?

- IPv6 differs from IPv4 mainly in:
  - NDP vs. ARP: this class was about securing the difference
  - Extension Headers: a large topic, see also BRKSEC-2044 “Secure operations of an IPv6 network”

- I.e., beyond local area, normal security BCP are similar:
  - Anti-spoofing with uRPF checks
  - Infrastructure ACL
  - Routing security
  - VPN, firewalls, IDS, ...

Summary

Summary

- IPv6 NDP/DHCP are vastly different than IPv4 ARP/DHCP
  - A common approach can work for both
  - Trusted devices (AP, switches, fabric, ...) can learn dynamic states and enforce the binding

- Do not forget that
  - an IPv6 network exists as soon as you have an IPv6 host, no need for IPv6 Internet
  - If there are 2 IPv6, then one can attack the other one
  - I.e., please deploy IPv6 FHS NOW

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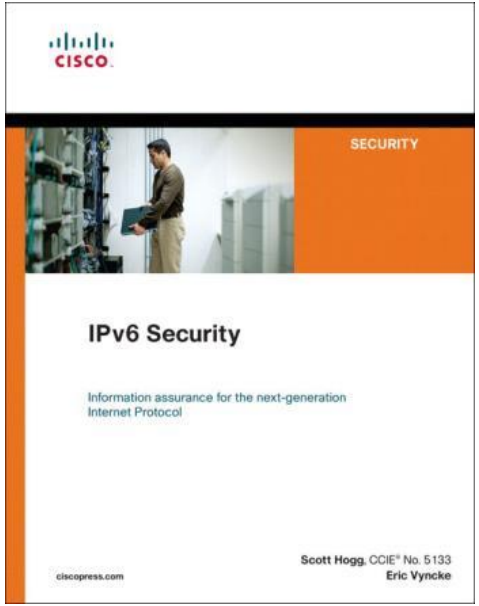
For Even More Information




```
Internet Engineering Task Force (IETF)                    E. Levy-Abegnoli
Request for Comments: 6105                                 G. Van de Velde
Category: Informational                                      Cisco Systems
ISSN: 2070-1721                                             C. Popoviciu
                                                              Technodyne
                                                              J. Mohacsi
                                                           NIIF/Hungarnet
                                                            February 2011

                    IPv6 Router Advertisement Guard
```

```
Internet Engineering Task Force (IETF)                        E. Nordmark
Request for Comments: 6620                                  Cisco Systems
Category: Standards Track                                     M. Bagnulo
ISSN: 2070-1721                                                     UC3M
                                                          E. Levy-Abegnoli
                                                            Cisco Systems
                                                                 May 2012

     FCFS SAVI: First-Come, First-Served Source Address Validation
          Improvement for Locally Assigned IPv6 Addresses
```

```
Internet Engineering Task Force (IETF)                          F. Gont
Request for Comments: 7113                            Huawei Technologies
Updates: 6105                                               February 2014
Category: Informational
ISSN: 2070-1721

  Implementation Advice for IPv6 Router Advertisement Guard (RA-Guard)
```

Other IPv6 Learning Opportunities this Week

- Verifying your Systems Transition to IPv6
  - Mon 13 8:00 AM: BRKIPV-2000
- Let's Deploy IPv6 NOW
  - Mon 13 2:30 PM: BRKENT-2109
- Sharing Experience on IPv6 Deployments in Enterprise
  - Tue 14 10:30 AM: IBOIPV-2000
- IPv6 - What Do you Mean there isn't a Broadcast?
  - Tue 14 2:30 PM: BRKENT-1616

- Secure Operations for an IPv6 Network
  - Mon 13 1 PM: BRKSEC-2044
- IPv6 Security in the Local Area with First Hop Security
  - Tue 14 4 PM: BRKENT-3002
- IPv6 - Powering the World of IoT
  - Wed 15 1 PM: BRKENT-2122

- Learning IPv6 in the Enterprise for Fun and (fake) Profit: A Hands-On Lab
  - Mon 13 1 PM : LTRENT-2016
- IPv6 Routing and Services Lab
  - HOLIPV-3600.a
- IPv6 Routing, SD-WAN and Services Lab
  - Tue 14 1 PM: LTRENT-2052

Other IPv6 Learning Opportunities this Week

- Experience the Journey to IPv6-Only With Cisco Meraki
  - Tue 14 1:00 PM: BRKIPV-1752
- Let's Discuss the IPv6 Implementation of Meraki
  - Wed 15 2:30 PM: IBOIPV-2001
- Cisco Routing Meraki Access with IPv6 (CRMAv6) - A Practical Guide
  - Wed 15 4:00 PM: BRKIPV-2751
- Migrating a Large Cisco Enterprise Wireless Network to IPv6 by Facebook
  - Wed 15 4 PM: CSSGEN-2000
- IPv6 Enabled Software Defined Wireless Access - Design , Deploy and Troubleshoot
  - On demand BRKENS-2834

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