



RIPE NCC

RIPE NETWORK COORDINATION CENTRE

IPv6 Security

Training Course

April 2025

RIPE NCC Learning & Development

RIPE NCC Training Material



Please find your training material at the following link

<https://www.ripe.net/training-material>





09:00 - 09:30

Coffee, Tea

11:00 - 11:15

Break

13:00 - 14:00

Lunch

15:30 - 15:45

Break

17:30

End



Introductions



- Name
- Experience with Security and IPv6
- Goals



Introduction

Basic IPv6 Protocol Security

Basic header, Extension Headers, Addressing

IPv6 Associated Protocols Security

ICMPv6, NDP, MLD, DNS, DHCPv6

Internet-wide IPv6 Security

Filtering, DDoS, Transition Mechanisms

Tips and Tools

Up-to-date information, Security Tools, Device features

Legend





Introduction to IPv6 Security

Section 1

IPv6 is Happening...



▼ RANK	IPV6%	COUNTRY / REGION
1	100%	Christmas Island
2	100%	Western Sahara
3	80%	Pitcairn
4	70.6%	India
5	67.2%	Montserrat
6	66.5%	Tokelau
7	62.1%	Malaysia
8	60.3%	Germany
9	59.8%	France
10	59.4%	Uruguay
11	54.8%	Saudi Arabia
12	54.2%	Belgium
13	52.5%	Nepal
14	52.5%	Japan
15	52.2%	United States
16	50.8%	Viet Nam
17	48.5%	Greece
18	47.5%	Thailand
19	47.4%	United Arab Emirates
20	46.5%	Brazil

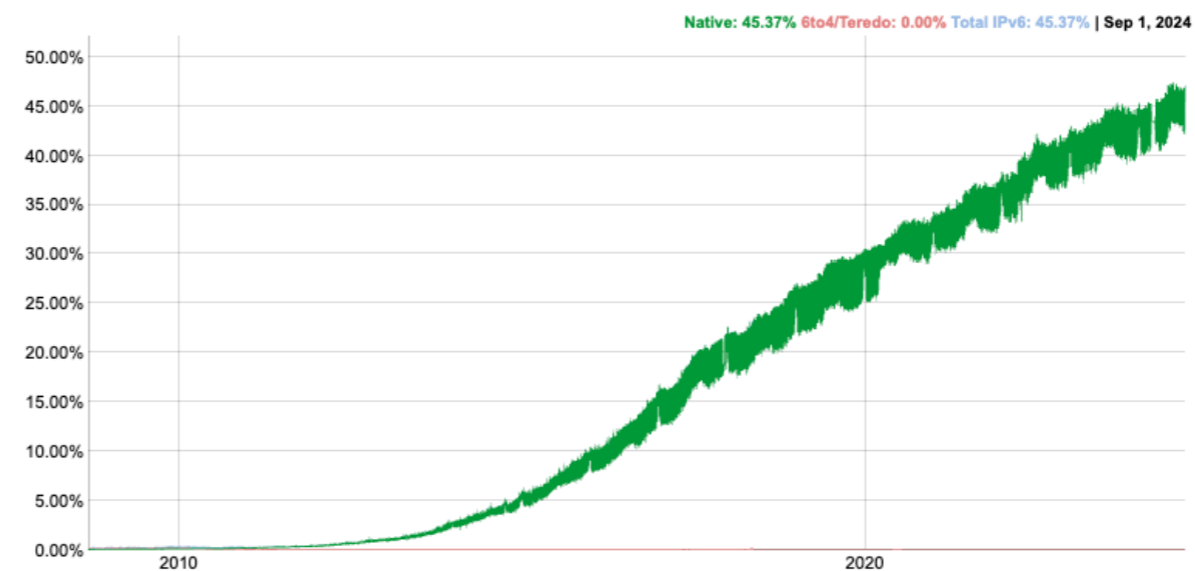
IPv6 Adoption By Networks

*Networks data is limited to the top 200 networks ranked by total IPv6 hits to platform.

▼ RANK	IPV6%	NETWORK
1	71.5%	Comcast Cable
2	73.5%	AT&T Communications Americas
3	91.3%	Reliance Jio Infocomm Limited
4	60.1%	Verizon Business
5	92.5%	T-Mobile
6	60.1%	Charter Communications Inc - TWC
7	79.7%	Bharti Airtel Enterprise Ltd.
8	74%	Deutsche Telekom Germany
9	51.1%	Charter Communications Inc.

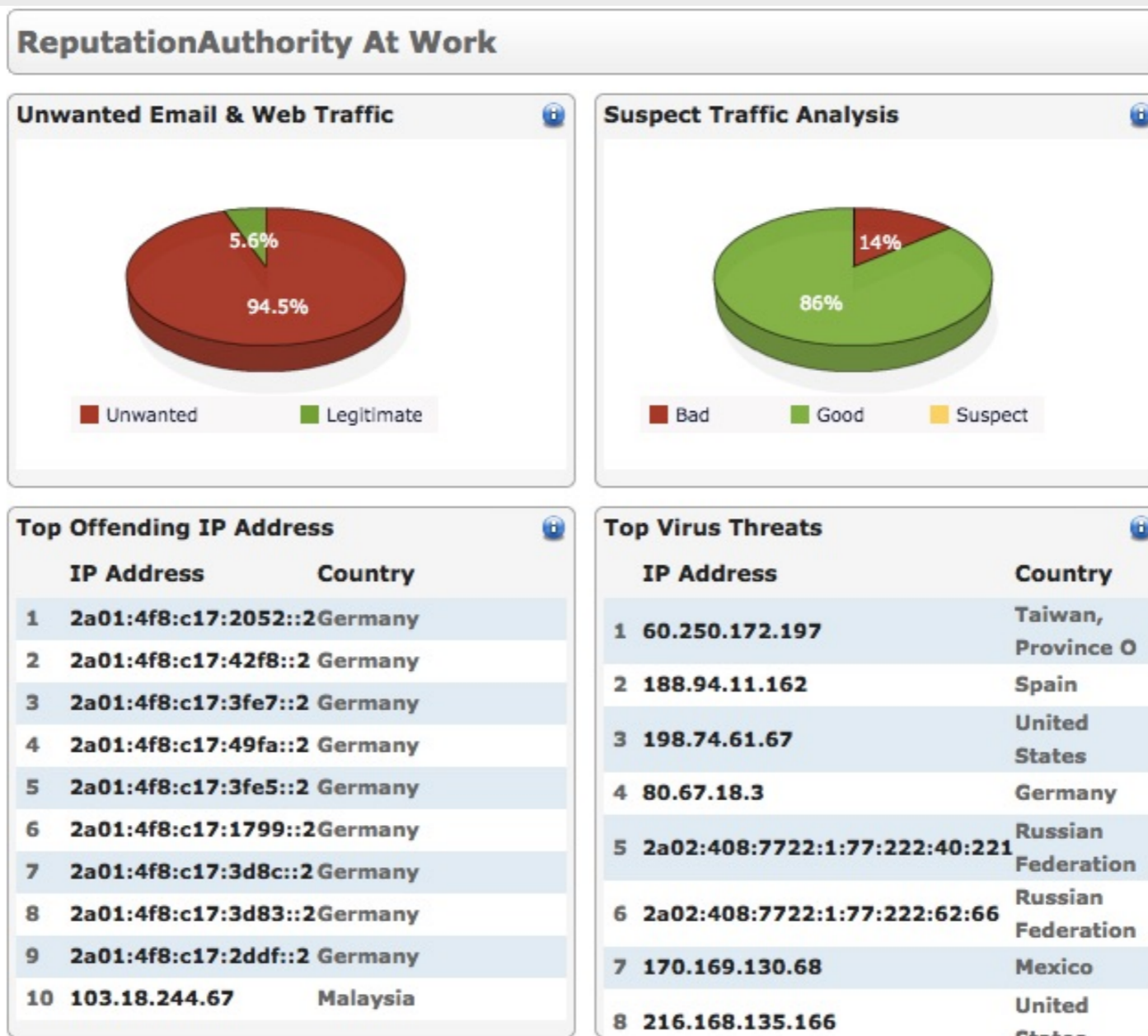
IPv6 Adoption

We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.



Source: Akamai, Google

... and So Are IPv6 Security Threats!



IPv6 Security Statements



1

2

3

4

5

6

7

8

- IPv6 is **more secure** than IPv4
- IPv6 has better security and it's **built in**

Reason:

- RFC 4294 - IPv6 Node Requirements: IPsec **MUST**

Reality:

- RFC 8504 - IPv6 Node Requirements: IPsec **SHOULD**
- IPsec available. Used for security in IPv6 protocols

IPv6 Security Statements



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8

- IPv6 has no NAT. Global addresses used
- I'm exposed to attacks from Internet

Reason:

- End-2-End paradigm. Global addresses. No NAT

Reality:

- Global addressing does not imply global reachability
- You are responsible for reachability (filtering)

IPv6 Security Statements



1

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- IPv6 Networks are too big to scan

Reason:

- Common LAN/VLAN use /64 network prefix
- 18,446,744,073,709,551,616 hosts

Reality:

- Brute force scanning is not possible [RFC5157]
- New scanning techniques

IPv6 Security Statements



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8

- IPv6 is too new to be attacked

Reason:

- Lack of knowledge about IPv6 (*it's happening!*)

Reality:

- There are tools, threats, attacks, security patches, etc.
- You have to be prepared for IPv6 attacks

IPv6 Security Statements



1

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- IPv6 is just IPv4 with 128 bits addresses
- There is nothing new

Reason:

- Routing and switching work the same way

Reality:

- Whole new addressing architecture
- Many associated new protocols

IPv6 Security Statements



1

2

3

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6

7

8

- IPv6 support is a yes/no question

Reason:

- Question: "Does it support IPv6?"
- Answer: "Yes, it supports IPv6"

Reality:

- IPv6 support **is not** a yes/no question
- Features missing, immature implementations, interoperability issues

IPv6 Security Statements



1

2

3

4

5

6

7

8

- IPv6 is not a security problem in my IPv4-only network

Reason:

- Networks only designed and configured for IPv4

Reality:

- IPv6 available in many hosts, servers, and devices
- Unwanted IPv6 traffic. Protect your network

IPv6 Security Statements



1

2

3

4

5

6

7

8

- It is not possible to secure an IPv6 network
- Lack of resources and features

Reason:

- Considering IPv6 completely different than IPv4
- Think there are no BCPs, resources or features

Reality:

- Use IP independent security policies
- There are BCPs, resources and features

Conclusions



A change of mindset is necessary

- IPv6 is not more or less secure than IPv4
- Knowledge of the protocol is the best security measure



Basic IPv6 Protocol Security

Section 2



IPv6 Basic Header and Extension Headers

Section 2.1

Basic IPv6 Header: Threat #1



Version	Traffic Class	Flow Label		
Payload Length		Next Header	Hop Limit	
Source Address				
Destination Address				

Basic IPv6 Header: Threat #1



IP spoofing:

Using a fake IPv6 source address



Solution:

ingress filtering and RPF (*reverse path forwarding*)

Basic IPv6 Header: Threat #2



Version	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source Address			
Destination Address			

Basic IPv6 Header: Threats #2



Covert Channel:

Using Traffic Class and/or Flow Label



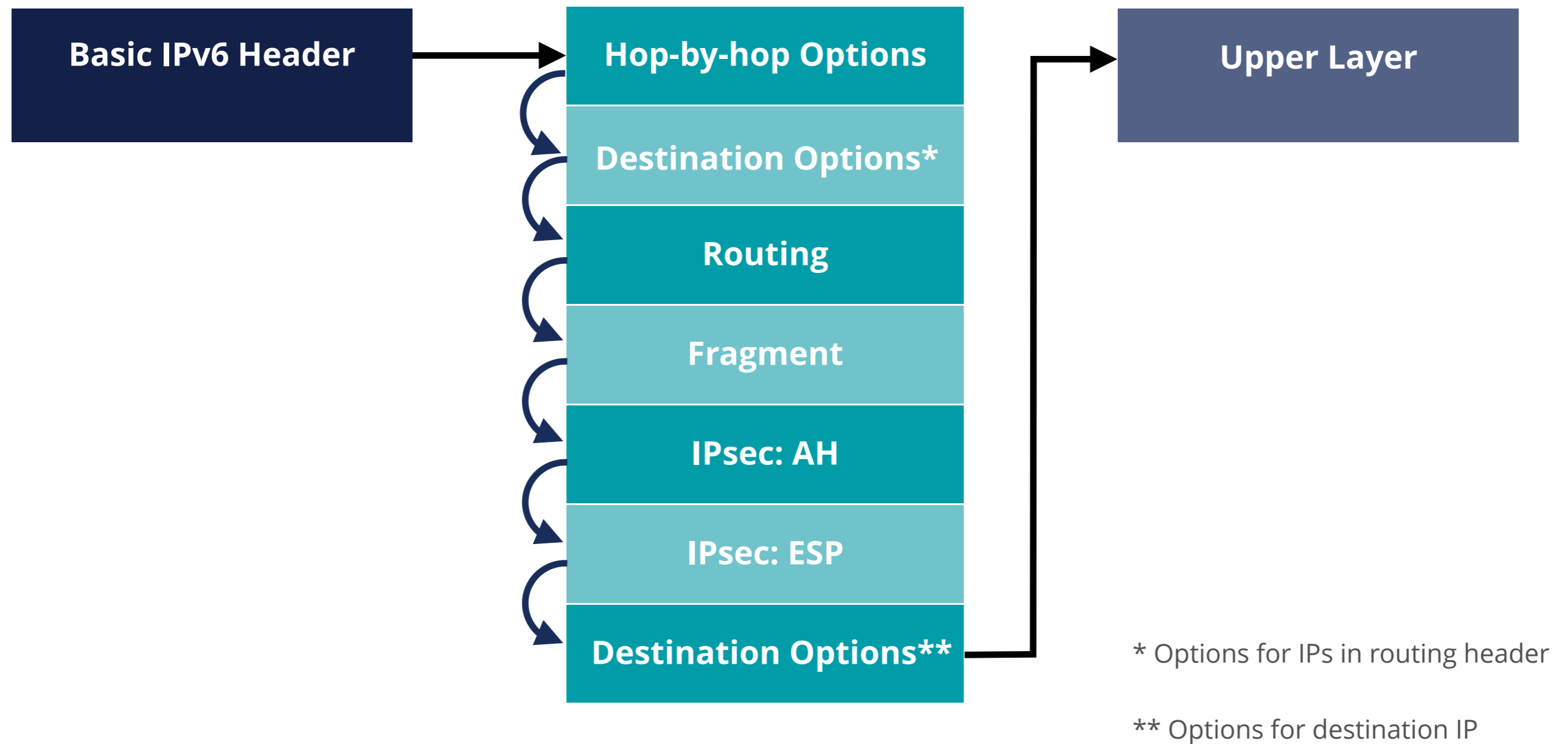
Solution:

Inspect packets (IDS / IPS)

Expected values:

- Traffic Class: 0 (*unless QoS is used*)
- Flow Label: 0

IPv6 Extension Headers



Extension Headers Properties



1	Flexible <i>(use is optional)</i>
2	Only appear once <i>(except Destination options)</i>
3	Fixed <i>(types and order)</i>
4	Processed only at endpoints <i>(except Hop-by-Hop and Routing)</i>



- Flexibility means **complexity**
- Security devices / software must process the **full chain of headers**
- Firewalls must be able to filter based on **Extension Headers**

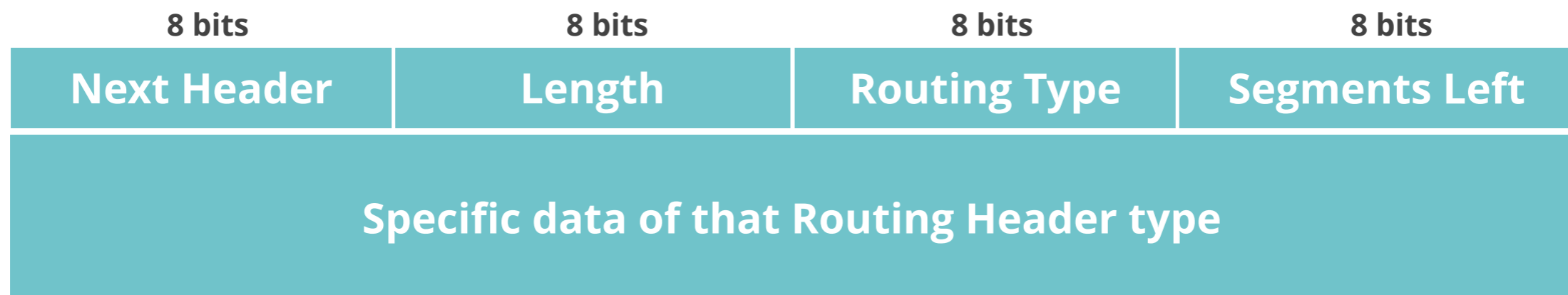


Routing Header



Includes one or more IPs that should be “*visited*” in the path

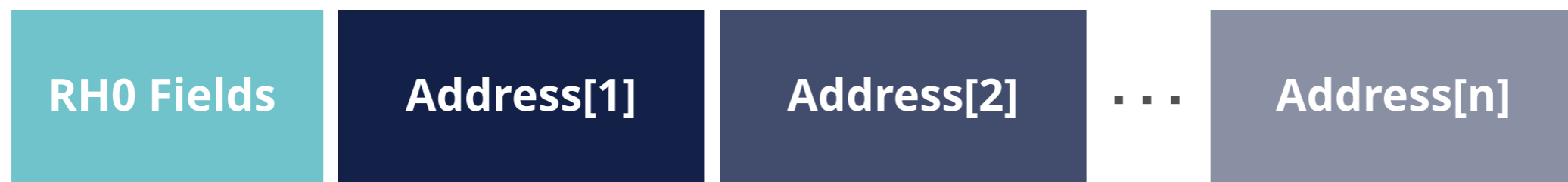
- Processed by the **visited routers**

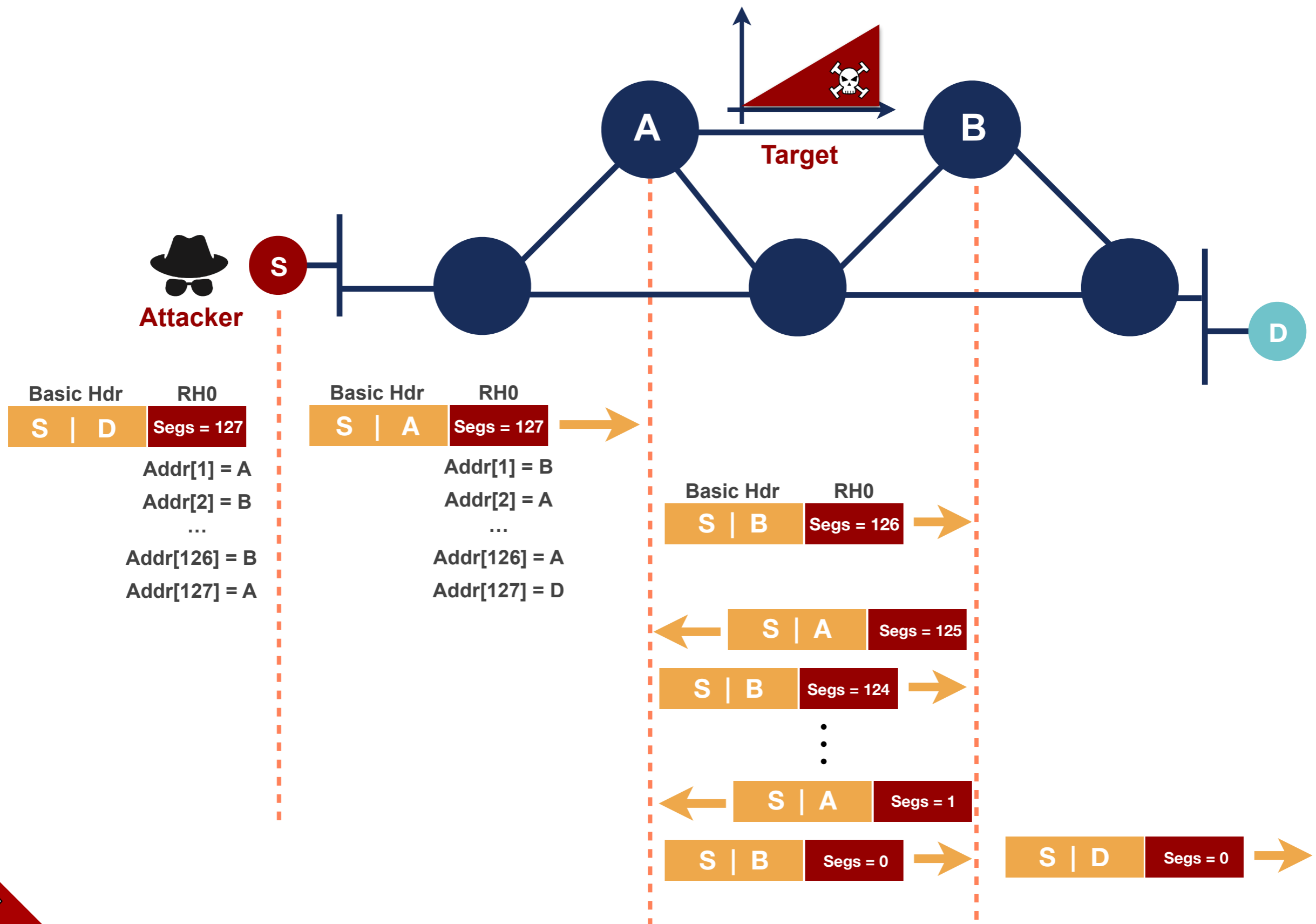




Routing Header Threat

- **Routing Header (Type 0):**
 - RH0 can be used for traffic amplification over a remote path
- **RH0 Deprecated [RFC5095]**
 - RH1 deprecated. RH2 (MIPv6), RH3 (RPL) and RH4 (SRH) are valid





Extension Headers Solutions



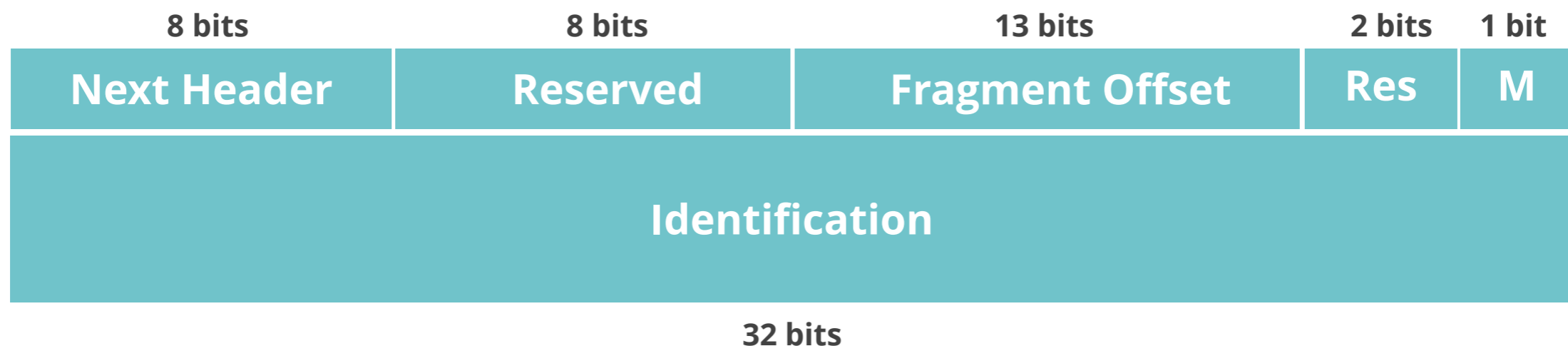
- Require security tools to inspect Header Chain properly





Fragment Header

- Used by IPv6 source node to send a packet **bigger than path MTU**
- **Destination host** processes fragment headers

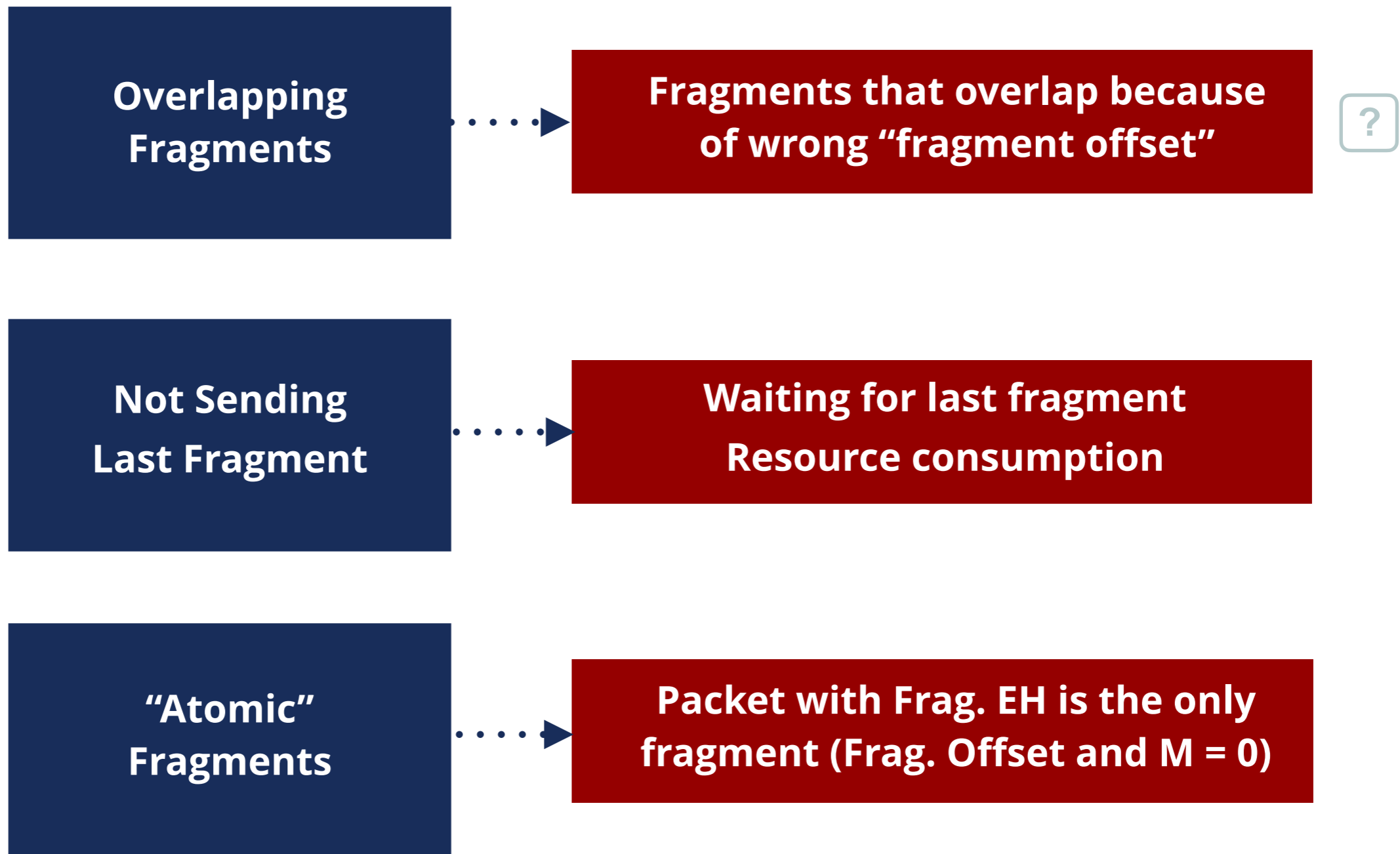


M Flag:

1 = more fragments to come;

0 = last fragment

EH Threats: Fragmentation



EH Solutions: Fragmentation



**Overlapping
Fragments**



**Not allowed in IPv6 [RFC5722]
Packets are discarded**

**Not Sending
Last Fragment**



**Timer and discard packets
(default 60 secs)**

**“Atomic”
Fragments**



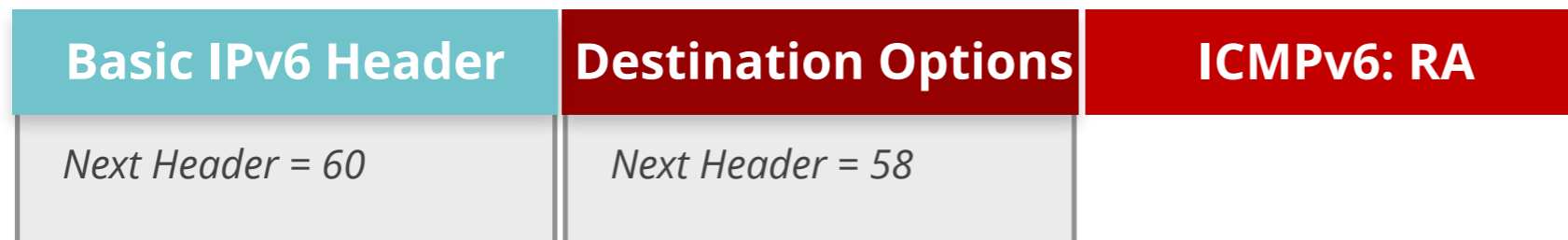
**Processed in isolation from any
other packets/fragments [RFC6946]**



Bypassing RA Filtering/RA-Guard



Using **any** Extension Header



If it only looks at Next Header = 60, it does not detect the RA



Bypassing RA Filtering/RA-Guard



Using **Fragment** Extension Header

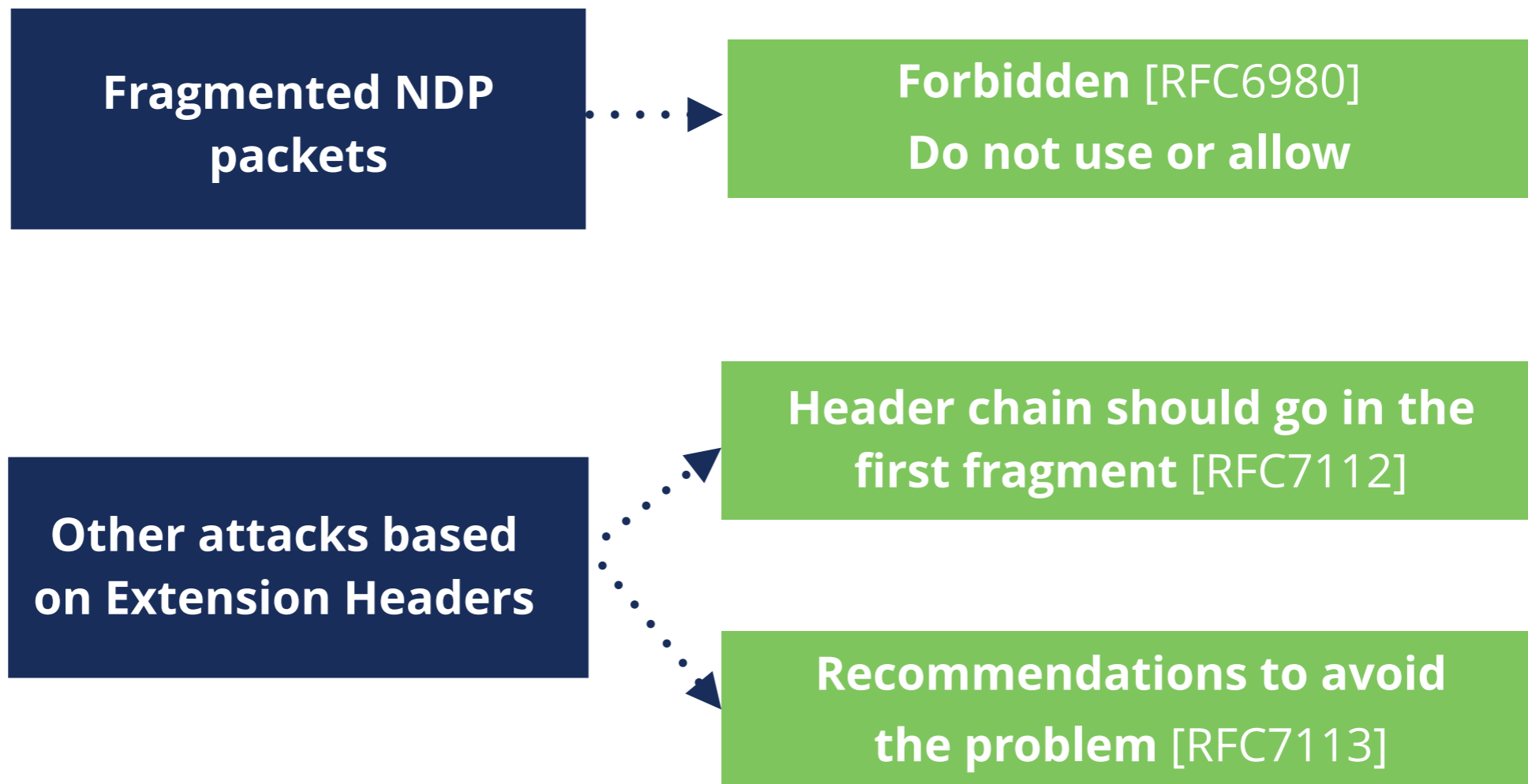
Basic IPv6 Header	Fragment	Destination Options
<i>Next Header = 44</i>	<i>Next Header = 60</i>	<i>Next Header = 58</i>

Basic IPv6 Header	Fragment	Destination Options	ICMPv6: RA
<i>Next Header = 44</i>	<i>Next Header = 60</i>	<i>Next Header = 58</i>	

Needs all fragments to detect the RA



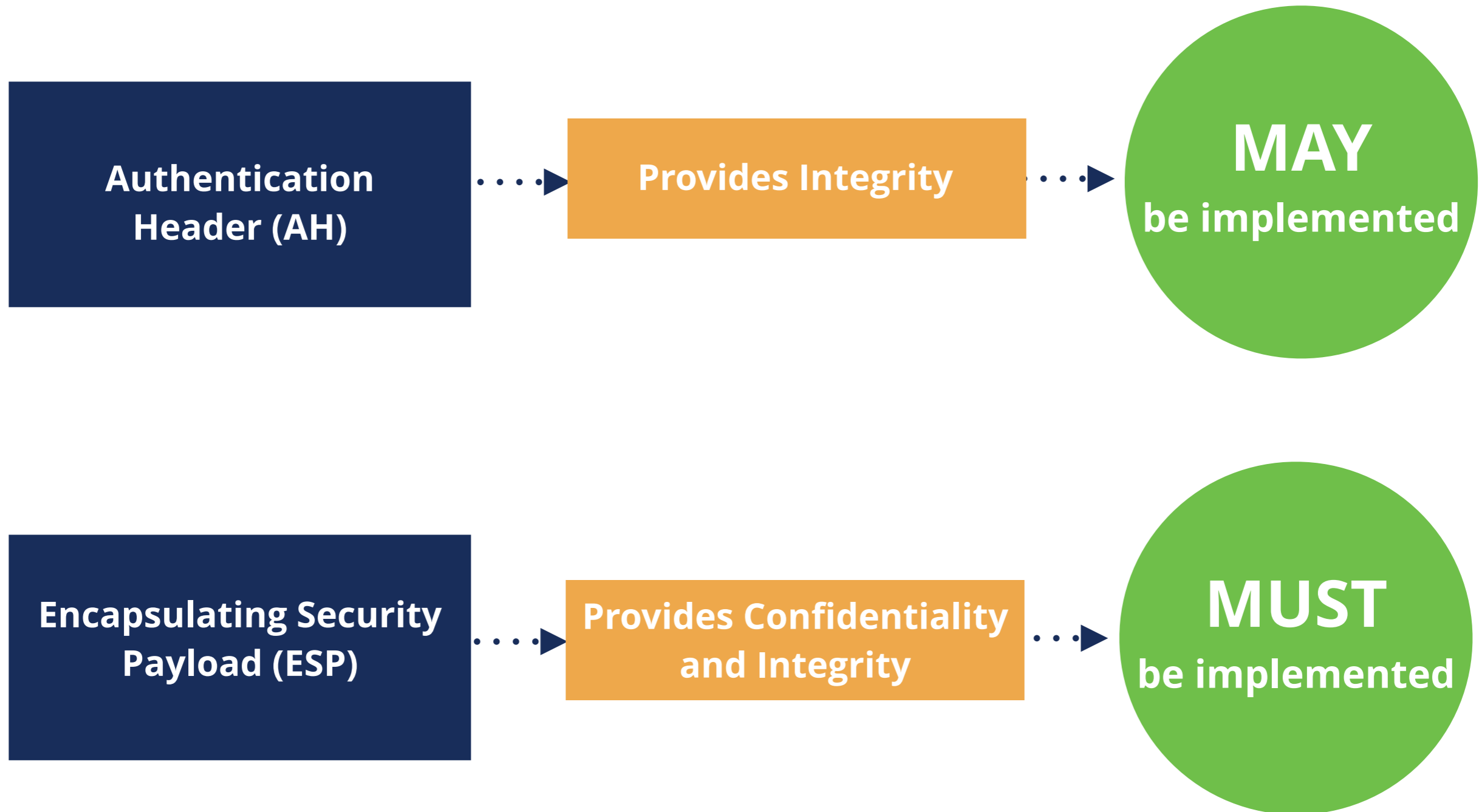
Extension Headers Solutions



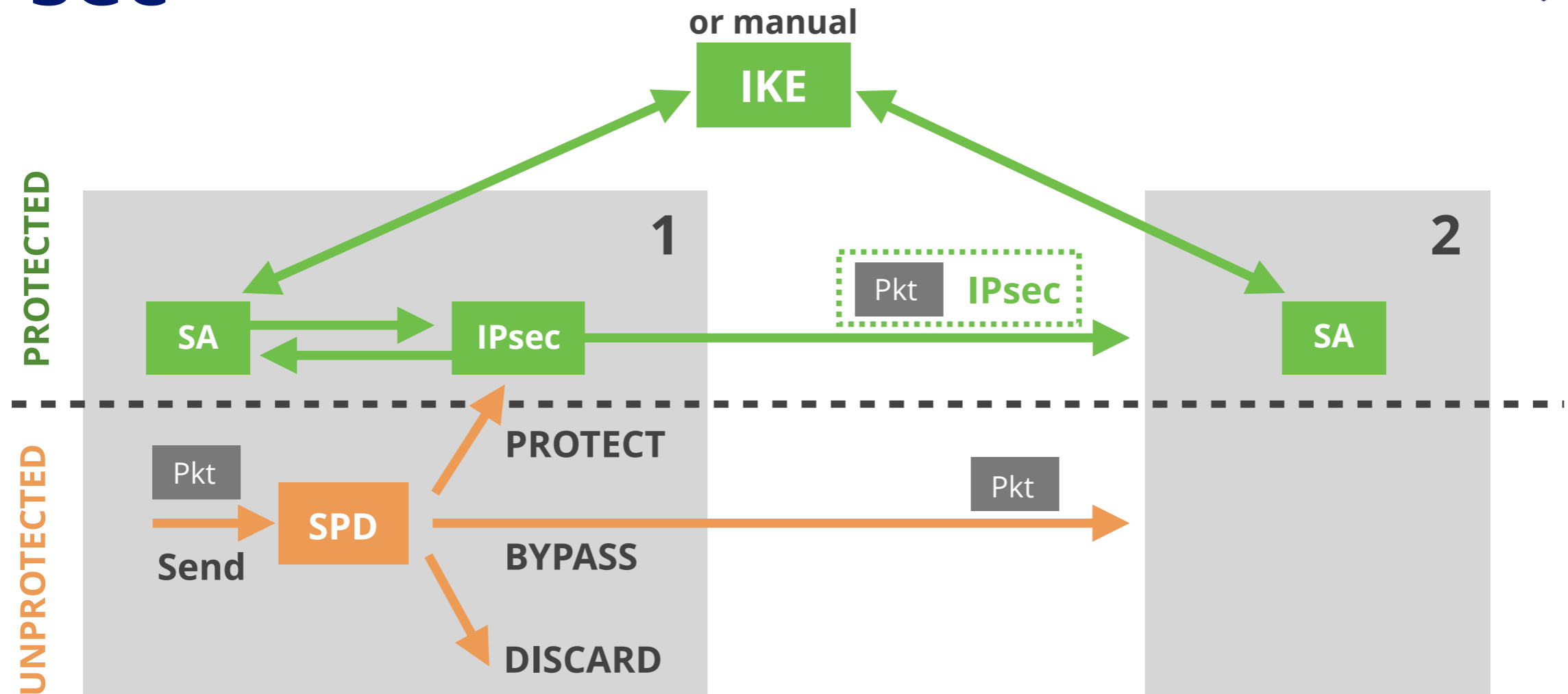
- **Require** security tools to inspect Header Chain properly



IPsec - Security Protocols



IPsec



SPD

Security Policy Database indicates what to do with packets

SA

Security Association: info needed for IPsec with 1 host, 1 direction

IKE

Internet Key Exchange allows automatic creation of SAs

IPsec Modes



Tunnel Mode

IPv6 | IPsec | IPv6 | Upper Layers



Transport Mode

IPv6 | IPsec | Upper Layers

IPsec: Authentication Header

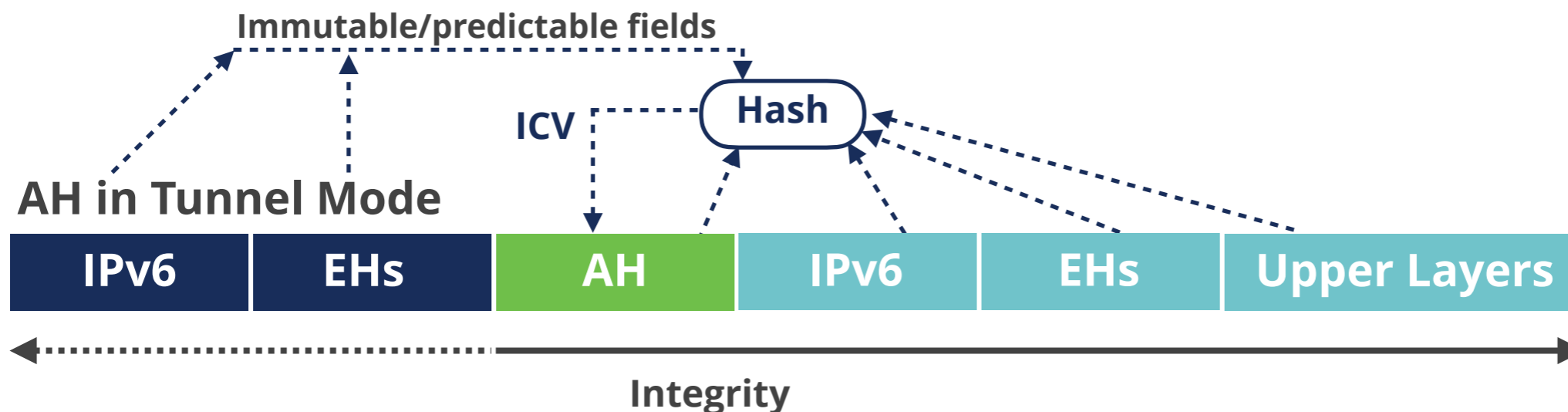
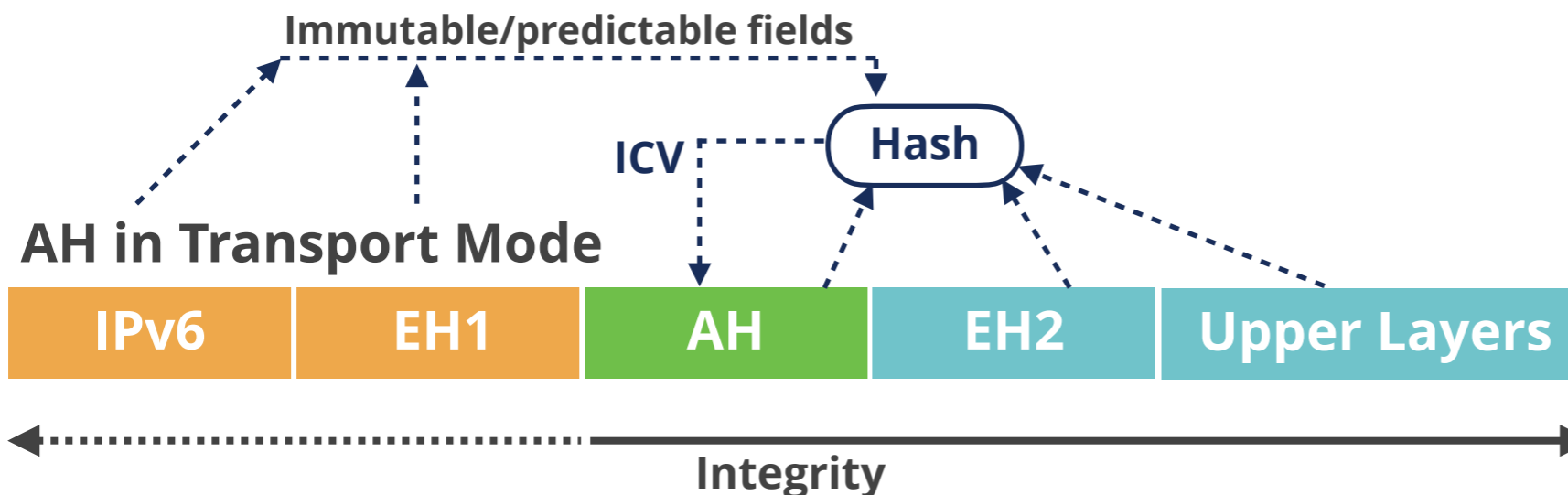


Unprotected IPv6



EH1 = Hop-by-Hop,
Dest. Options*,
Routing, Fragment

EH2 = Destination Options**



* Options for IPs in routing header

** Options for destination IP



IPsec: ESP



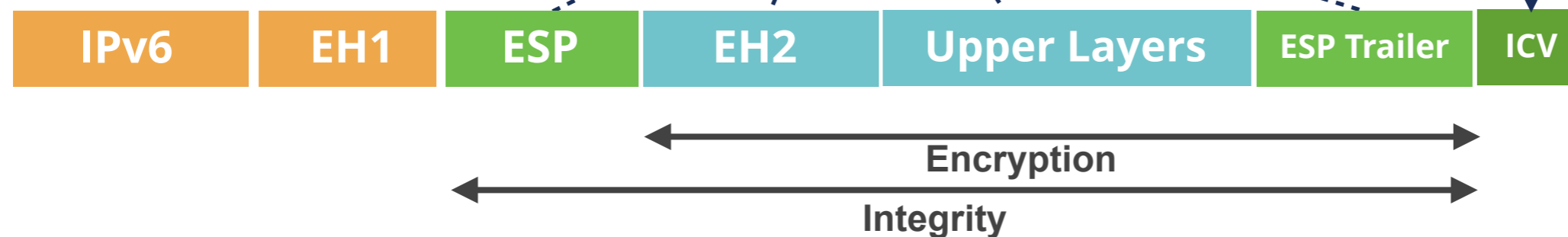
Unprotected IPv6



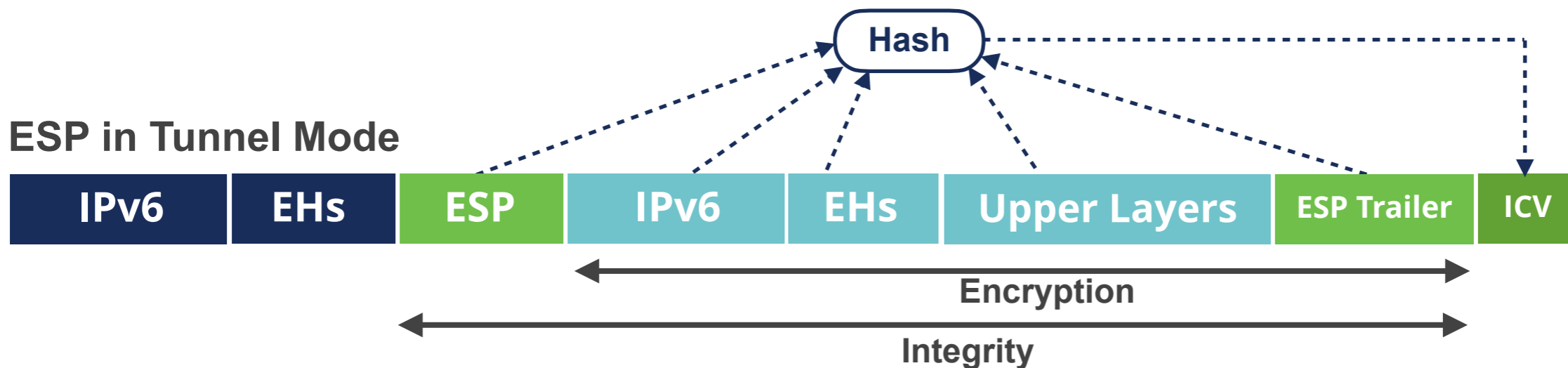
EH1 = Hop-by-Hop,
Dest. Options*,
Routing, Fragment

EH2 = Destination Options**

ESP in Transport Mode



ESP in Tunnel Mode



* Options for IPs in routing header

** Options for destination IP





IPv6 Packet Generation

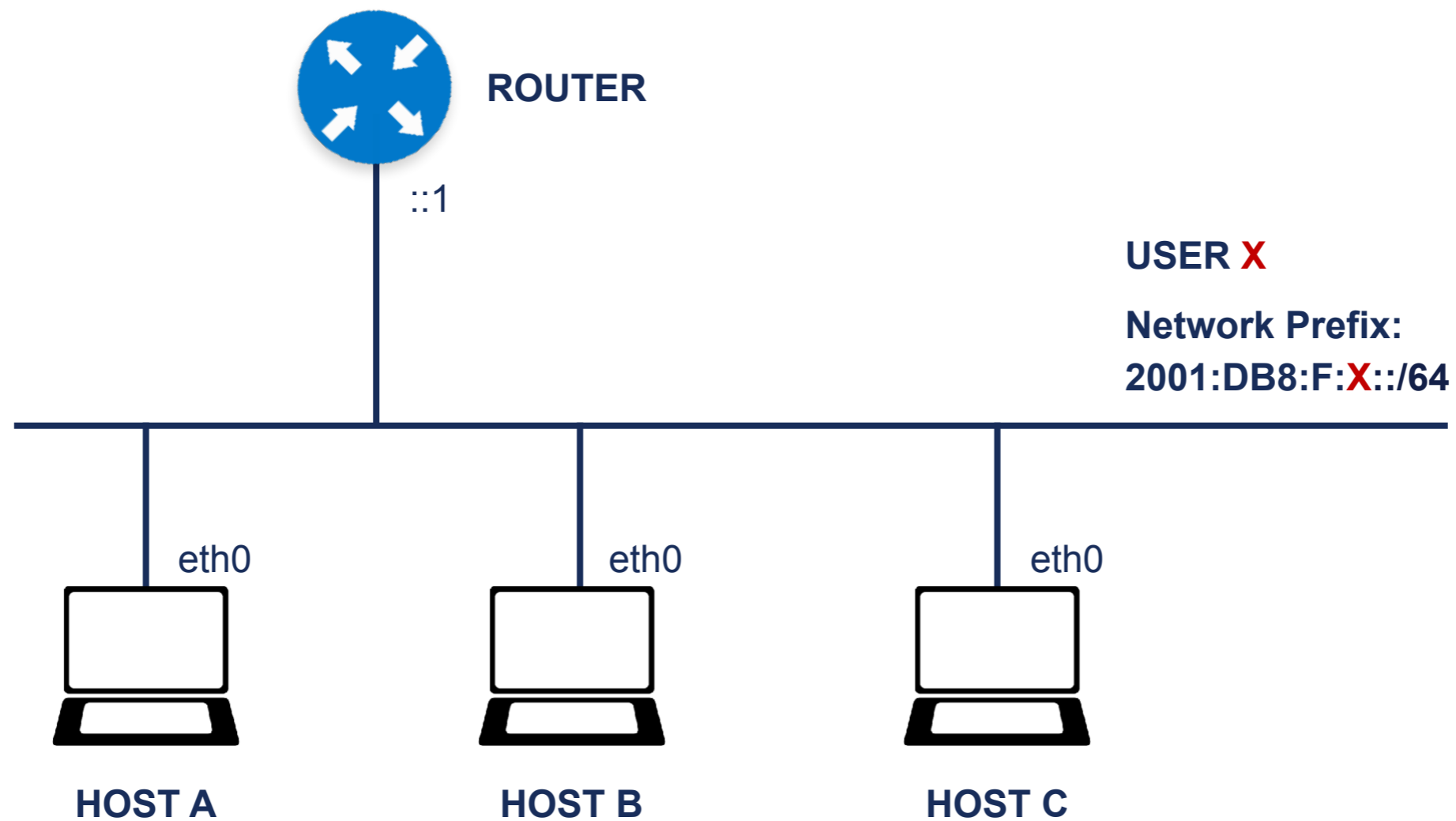
Exercise 2.1

Exercise 2.1: IPv6 Packet Generation



- **Description:** Use Scapy to generate IPv6 packets
- **Goals:**
 - Get familiar with lab environment
 - Learn the basics of Scapy tool
 - Learn to generate tailor made IPv6 packets
- **Time:** 30 minutes
- **Tasks:**
 - Login in to the lab environment
 - Generate IPv6 packets following instructions in Exercise Booklet

Exercise 2.1: Lab network



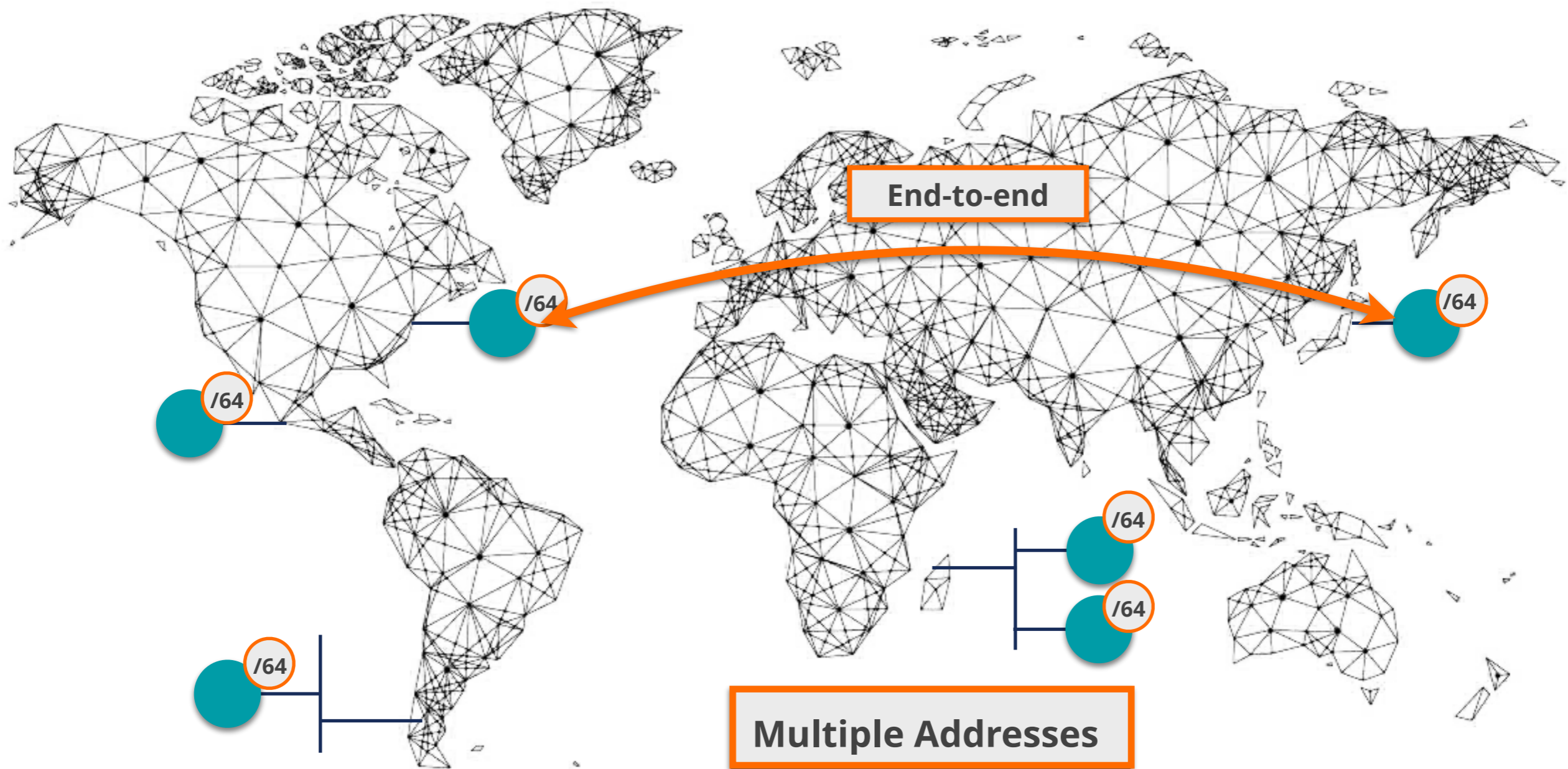


IPv6 Addressing Architecture

Section 2.2



340,282,366,920,938,463,463,374,607,431,768,211,456



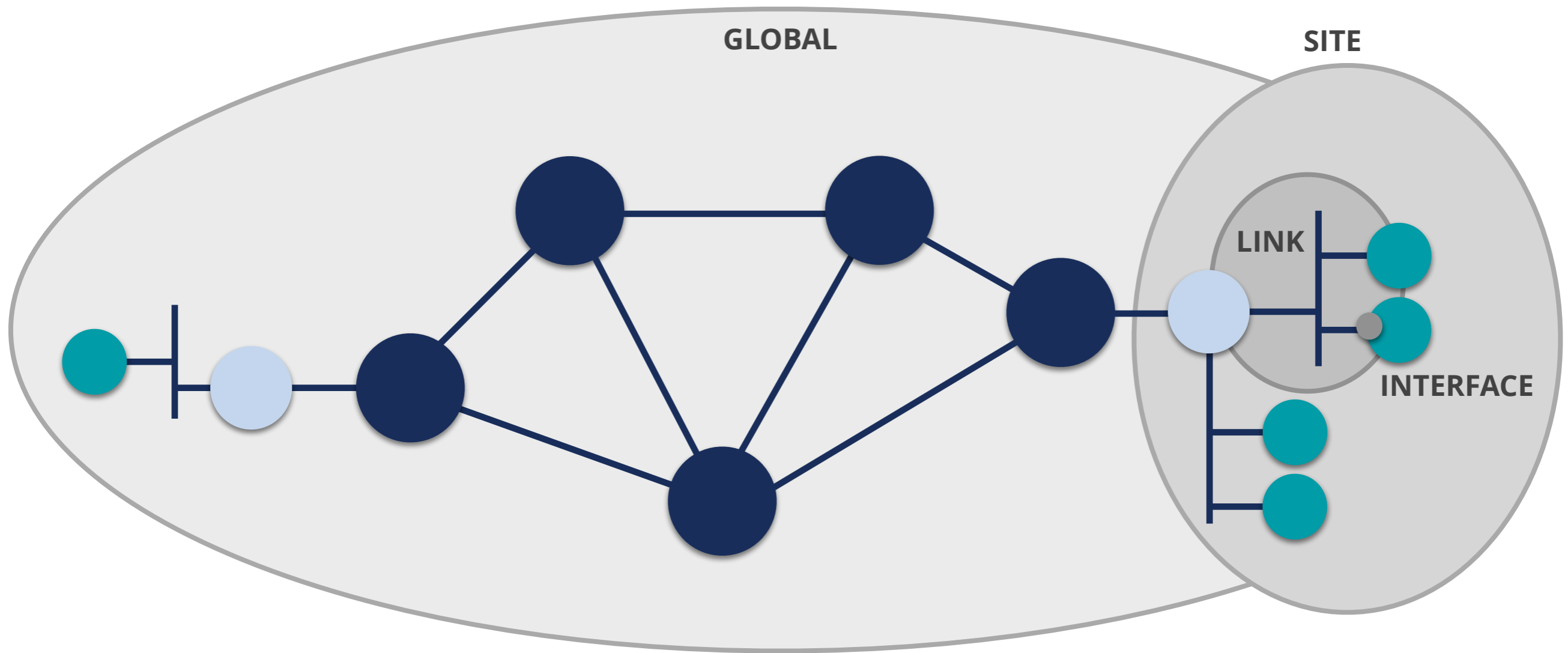
Multiple Addresses

Link-local

Global (GUA)

Multicast

IPv6 Address Scope



fe80::a:b:100

ff01::2

2001:67c:2e:1::c1

fd00:a:b::100

ff05::1:3

ff02::1

IPv6 Network Scanning



64 bits

64 bits

Network Prefix

Interface ID (IID)

Network Prefix determination (64 bits)

Common patterns in addressing plans

DNS direct and reverse resolution

Traceroute

Interface ID determination (64 bits)

“brute force” no longer possible

IID Generation Options



64 bits

Interface ID (IID)

Modified EUI-64 (uses MAC address)

Stable, semantically opaque *[RFC7217]*

Temporary Address Extensions *[RFC8981]*

“stable” IID
for SLAAC

“temporary”
IID for SLAAC

DHCPv6

Manually

Others (CGA, HBA)

SLAAC IIDs Currently



- Consider IID bits “**opaque**”, no value or meaning *[RFC7136]*

How to generate IIDs *[RFC7217]*

Different for each interface in the same network prefix

Not related to any fixed interface identifier

Always the same when same interface connected to same network

- Widely used** and **standardised** for “stable” addresses
[RFC8064]

Guessing IIDs



64 bits = 18,446,744,073,709,551,616 Addresses

EUI-64

OUI: 24 bits
FFFE: 16 bits

IPv4-based

2001:db8:1::10.0.0.5

Sequential

Low-bits / Trivial (::1)

Service port

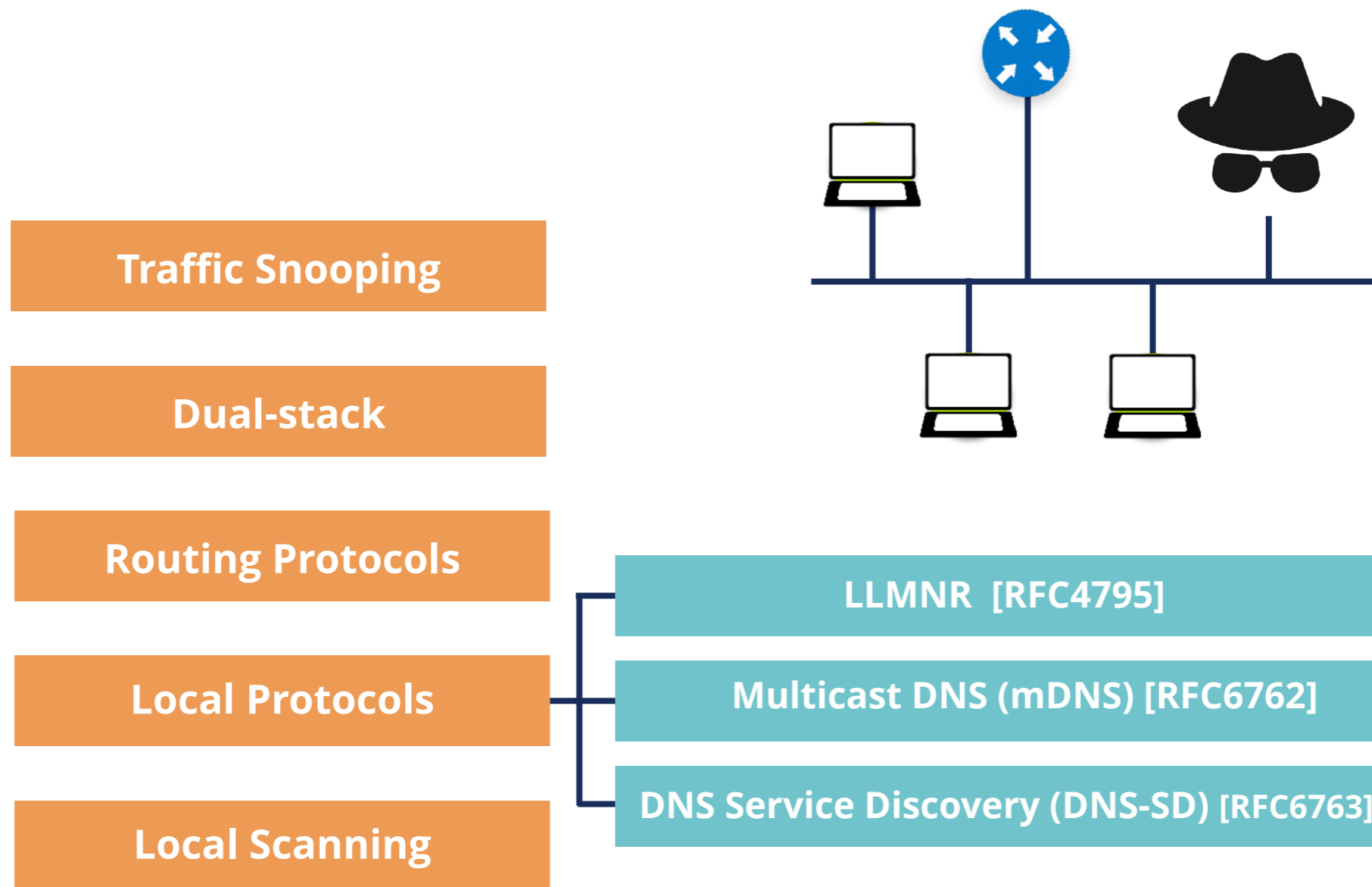
2001:db8:1::80

Wordy Address

2001:db8::bad:cafe



Locally Scanning IPv6 Networks



Special / Reserved IPv6 Addresses



Name	IPv6 Address	Comments
Unspecified	::/128	When no address available
Loopback	::1/128	For local communications
IPv4-mapped	::ffff:0:0/96	For dual-stack sockets. Add IPv4 address 32 bits
Documentation	2001:db8::/32 & 3ff::/20	RFC 3849 & RFC 9637
IPv4/IPv6 Translators	64:ff9b::/96	RFC 6052
Discard-Only Address Block	100::/64	RFC 6666
Teredo	2001::/32	IPv6 in IPv4 Encapsulation Transition Mechanism
6to4	2002::/16	IPv6 in IPv4 Encapsulation Transition Mechanism
ORCHID	2001:10::/28	Deprecated RFC 5156
Benchmarking	2001:2::/48	RFC 5180
Link-local	fe80::/10	RFC 4291
Unique-local	fc00::/7	RFC 4193
6Bone	3ffe::/16, 5f00::/8	Deprecated RFC 3701
IPv4-compatible	::/96	Deprecated RFC 5156

<http://www.iana.org/assignments/iana-ipv6-special-registry/>

Security Tips



- Use **hard to guess** IIDs
 - RFC 7217 better than Modified EUI-64
 - RFC 8064 establishes RFC 7217 as the default
- Use **IPS/IDS** to detect scanning
- **Filter** packets where appropriate
- Be careful with routing protocols
- Use "default" **/64** size IPv6 subnet prefix





IPv6 Network Scanning

Exercise 2.2

Exercise 2.2: IPv6 Network Scanning



- **Description:** Use available toolsets to scan a subnet
- **Goals:**
 - Know about two new toolsets: THC-IPV6 and The IPv6 Toolkit
 - Learn how to use them to scan a subnet
- **Time:** 10 minutes
- **Tasks:**
 - Use The IPv6 Toolkit to scan your lab's subnet
 - Use THC-IPV6 to scan your lab's subnet



IPv6 Associated Protocols Security

Section 3



ICMPv6

Section 3.1



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

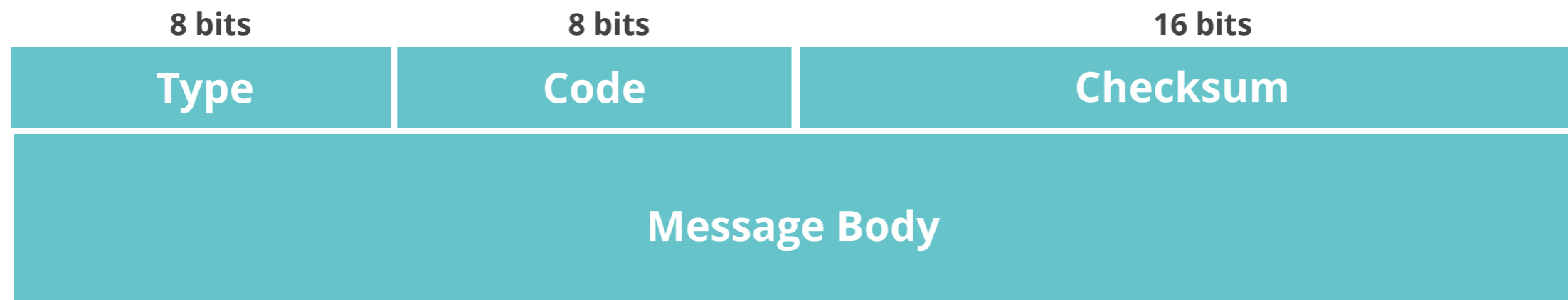
NDP

MLD

ICMPv6 Format



- General Format



- Extended Format [*RFC4884*]

Used by:

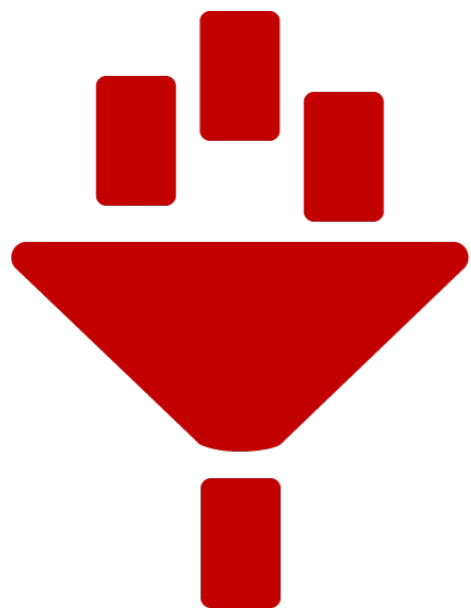
Destination Unreachable

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

Echo Reply responding an Echo Request is
Optional



avoids



not recommended



Hosts Discovery

Amplification Attacks

Smurf Attacks





NDP

Section 3.2



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





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

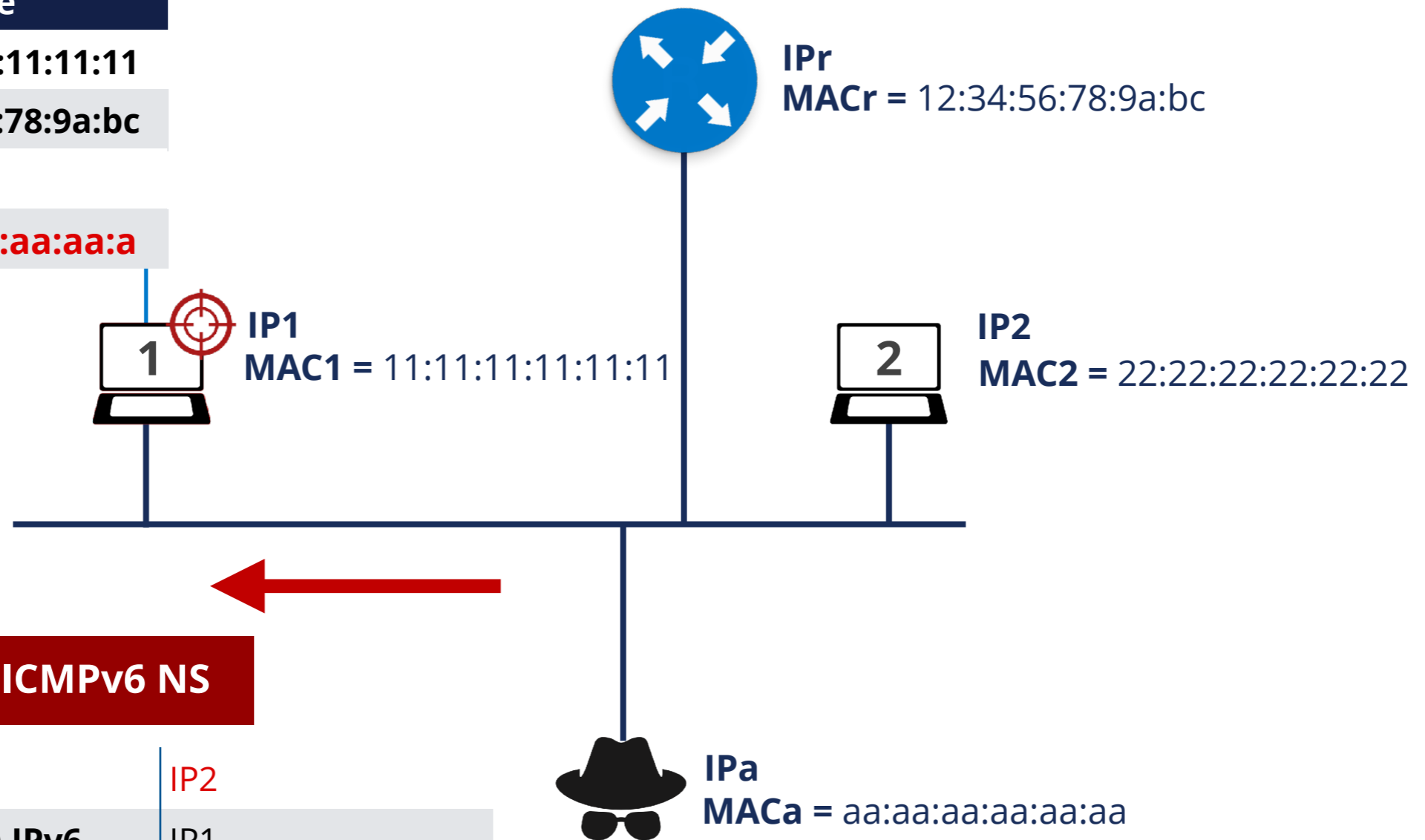




NS Spoofing (Redirection / DoS)

Neighbour Cache

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



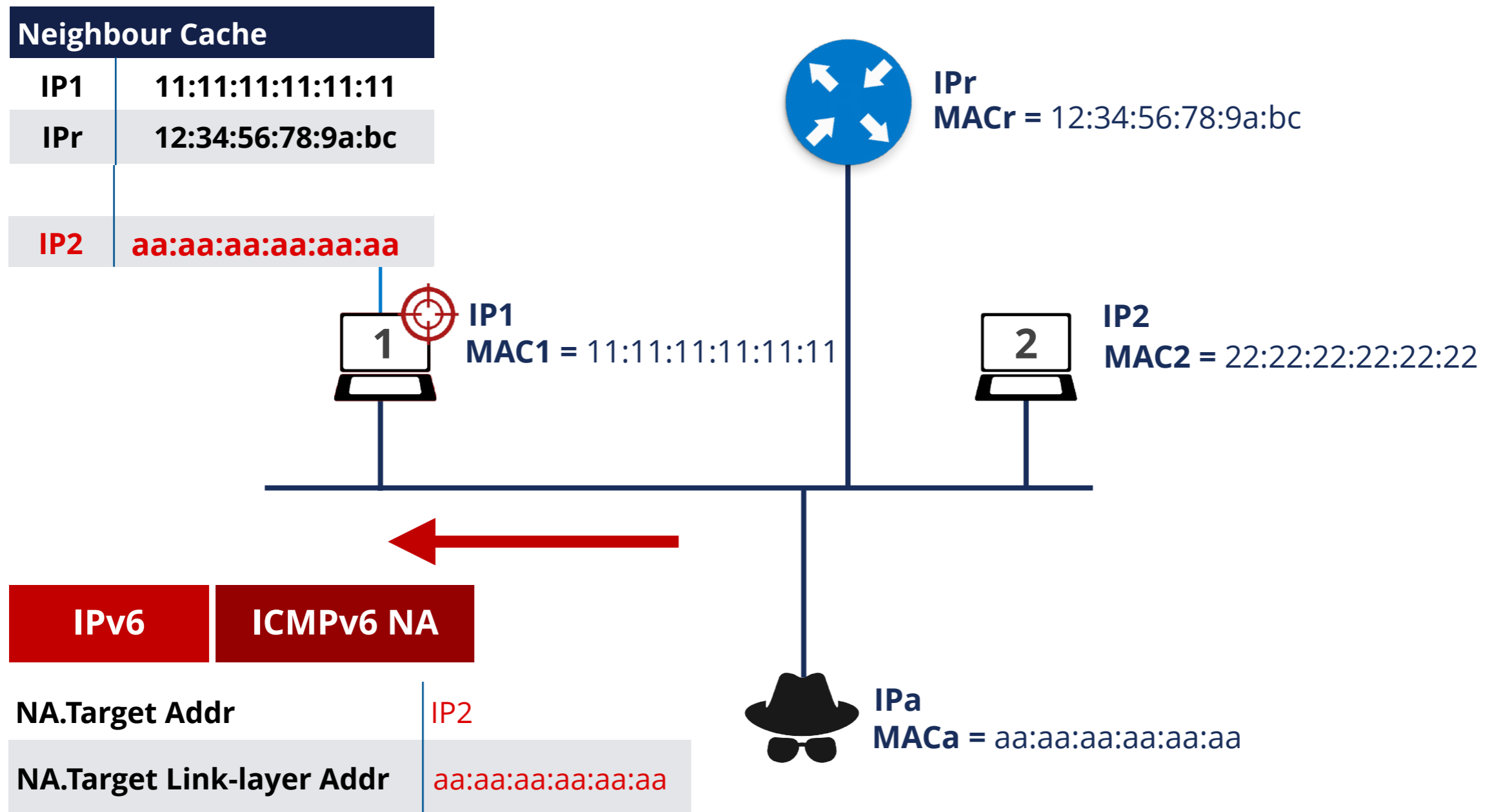
IPv6

ICMPv6 NS

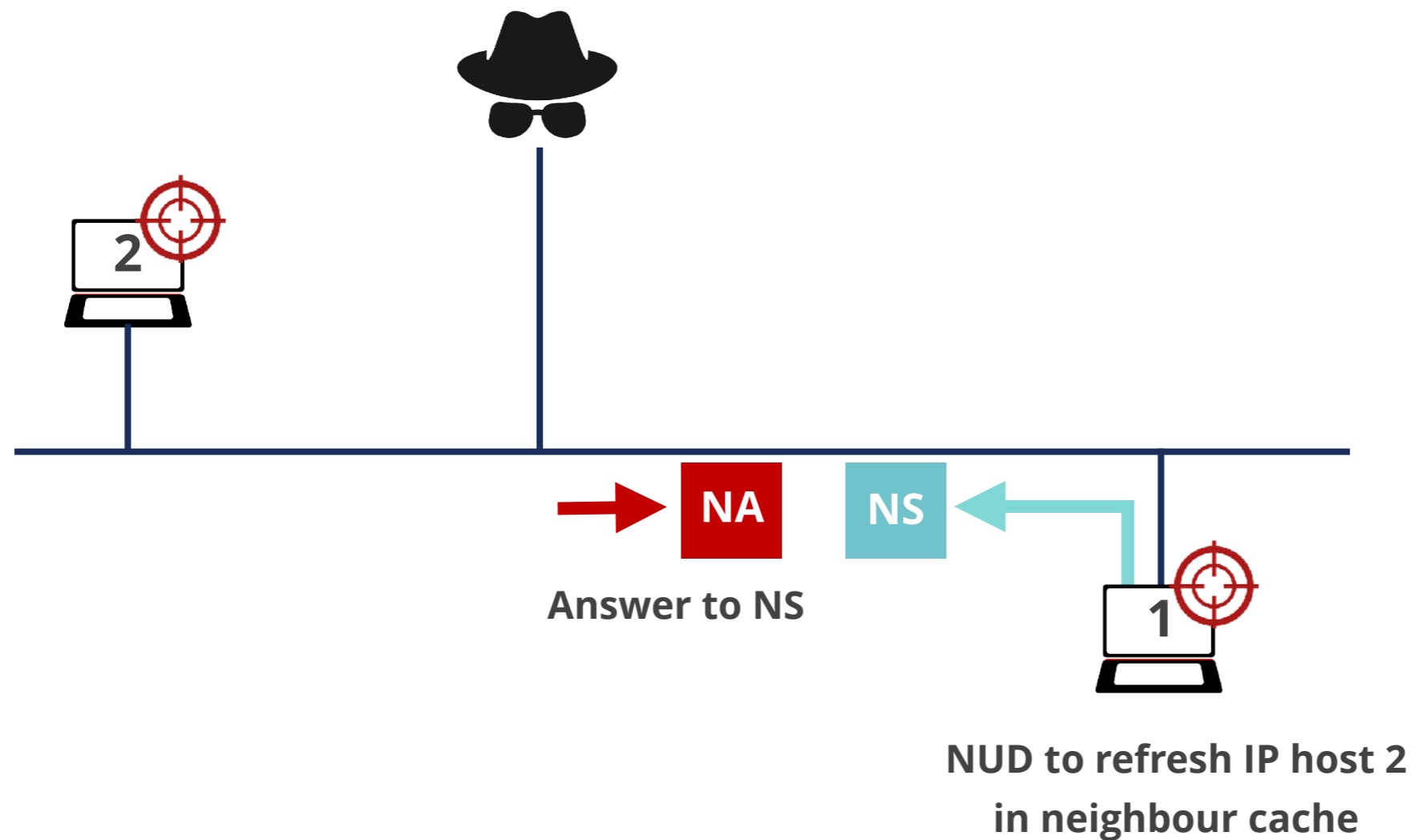
IPv6.Source IPv6	IP2
IPv6.Destination IPv6	IP1
NS.Target Addr	IP1
NS.Src Link-layer Addr	aa:aa:aa:aa:aa:aa



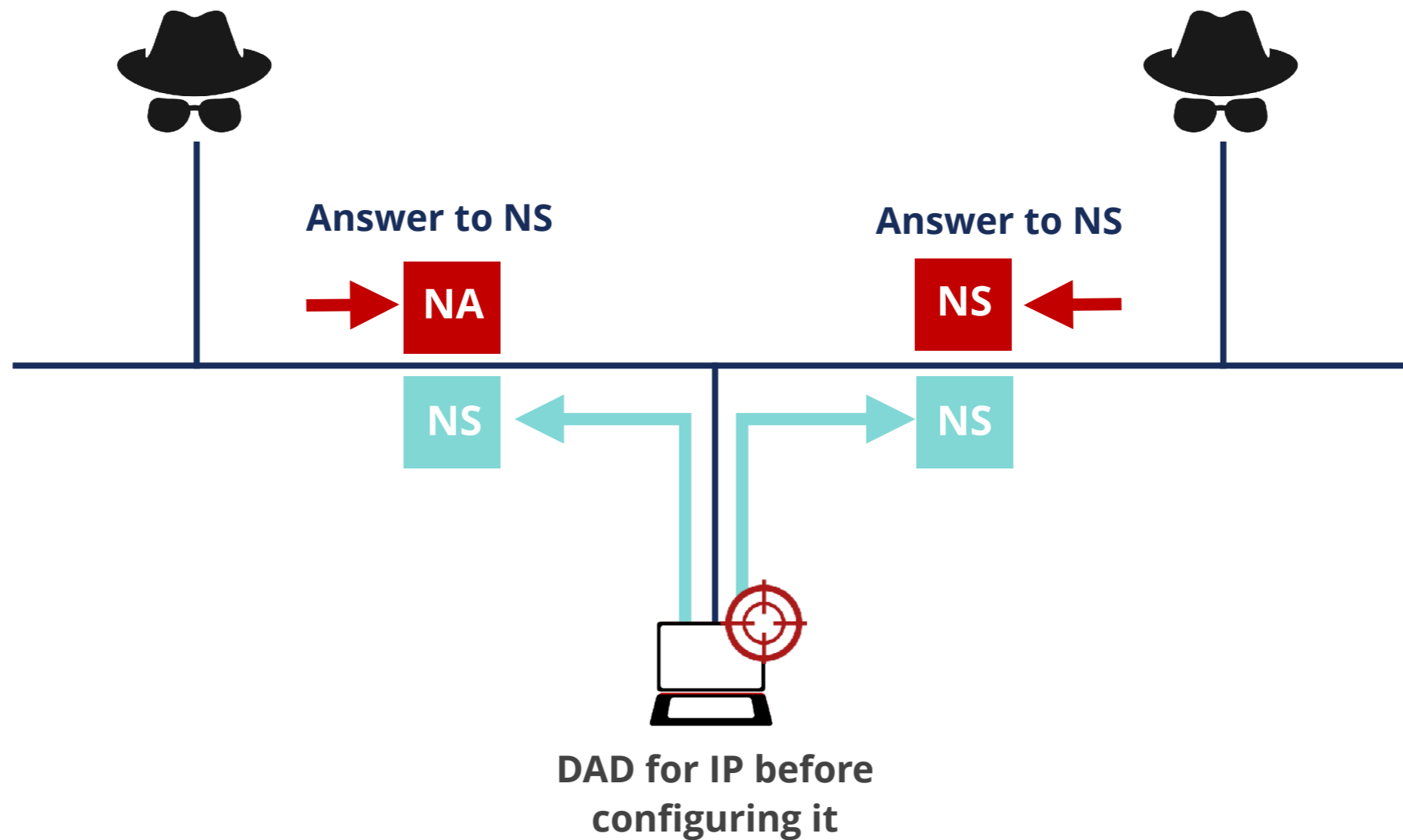
Unsolicited NA (Redirection / DoS)



NUD Failure (DoS attack)



DAD (DoS Attack)





NDP

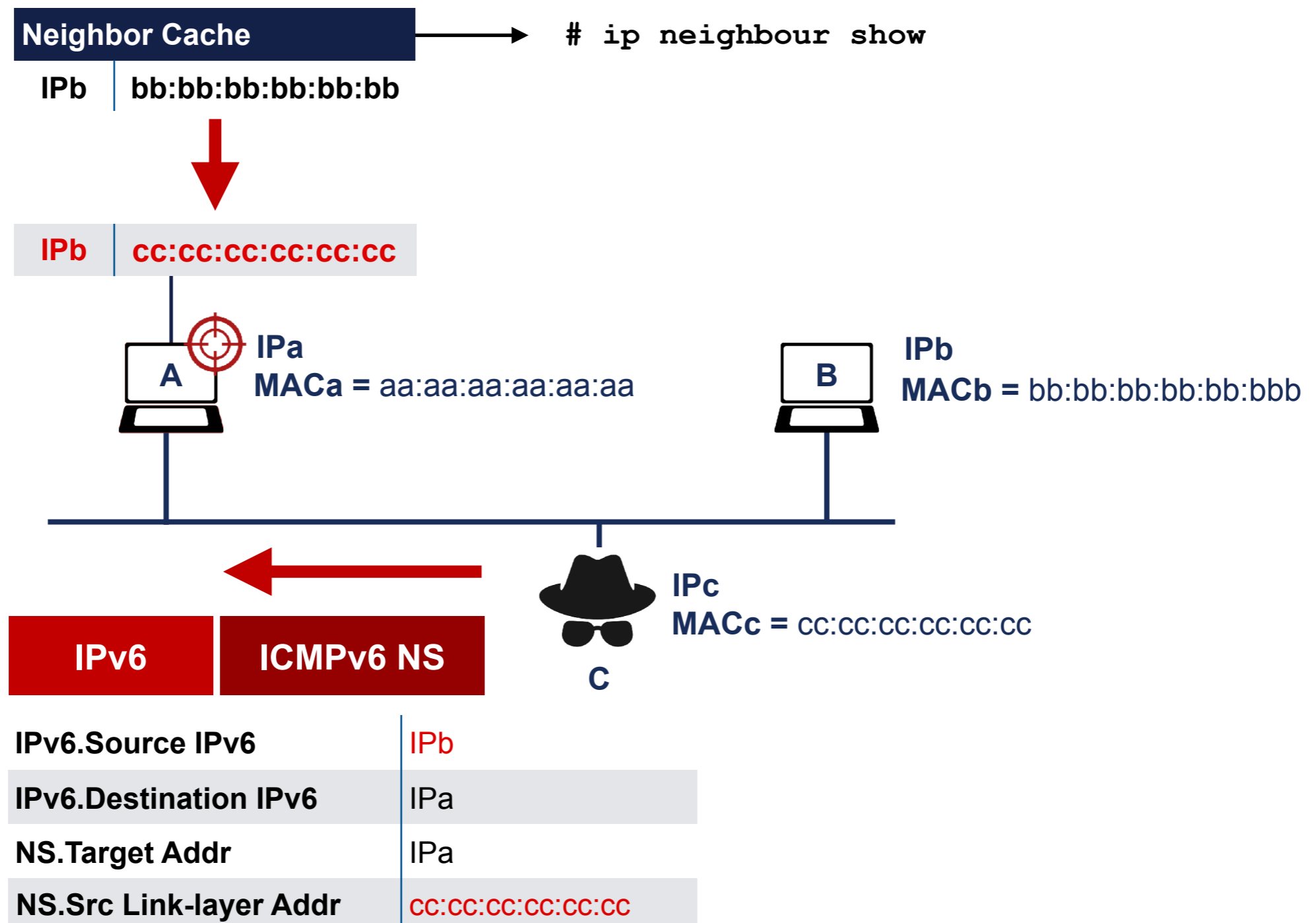
Exercise 3.2-a

Exercise 3.2-a NDP

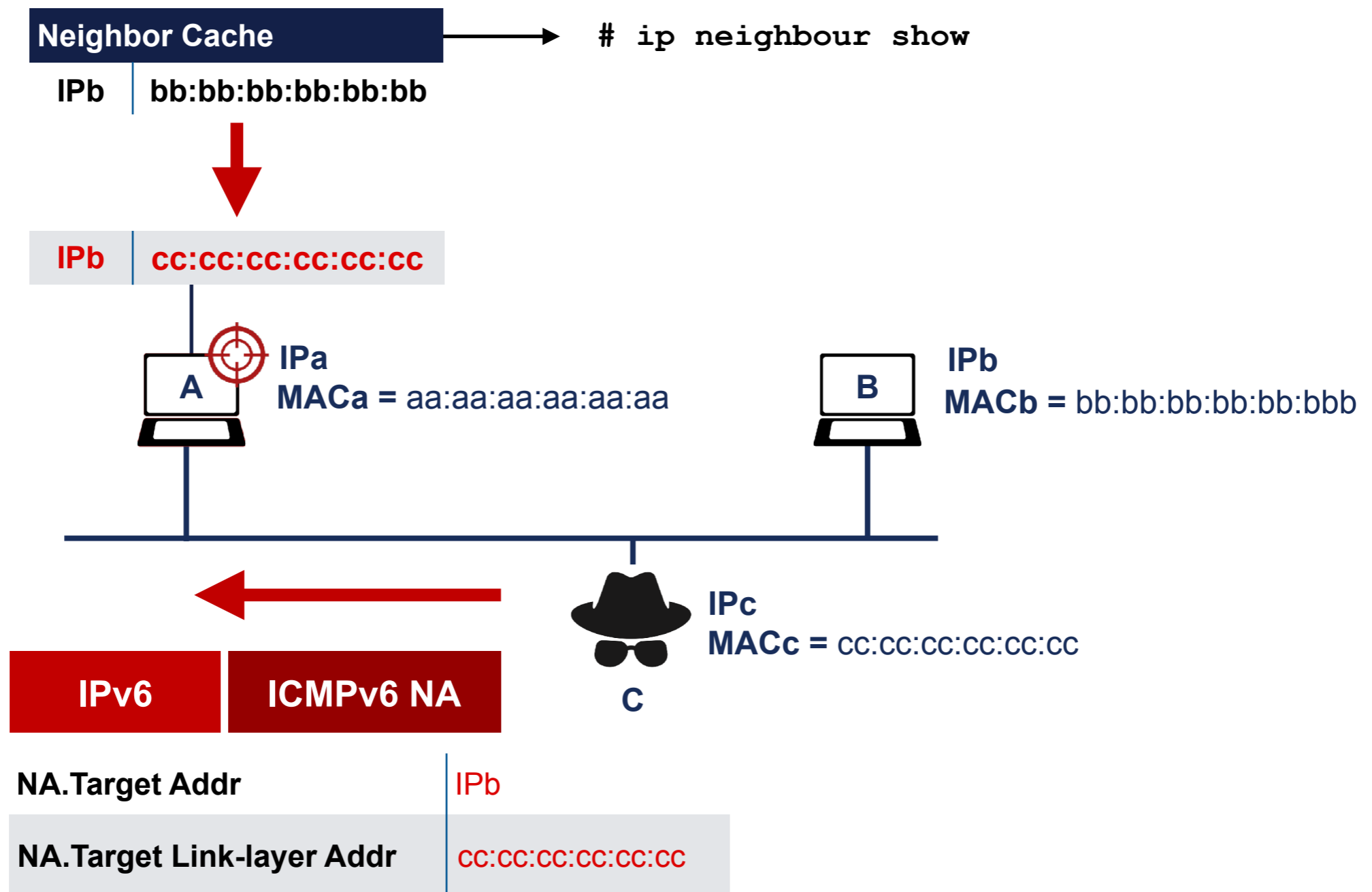


- **Description:** Create packets to poison neighbor cache
- **Goals:**
 - Practice with Scapy tool
 - Learn how to modify the neighbor cache of another host in the same network
- **Time:** 15 minutes
- **Tasks** (at least one of them):
 - Generate NS packets that change other host's neighbor cache
 - Generate NA packets that change other host's neighbor cache

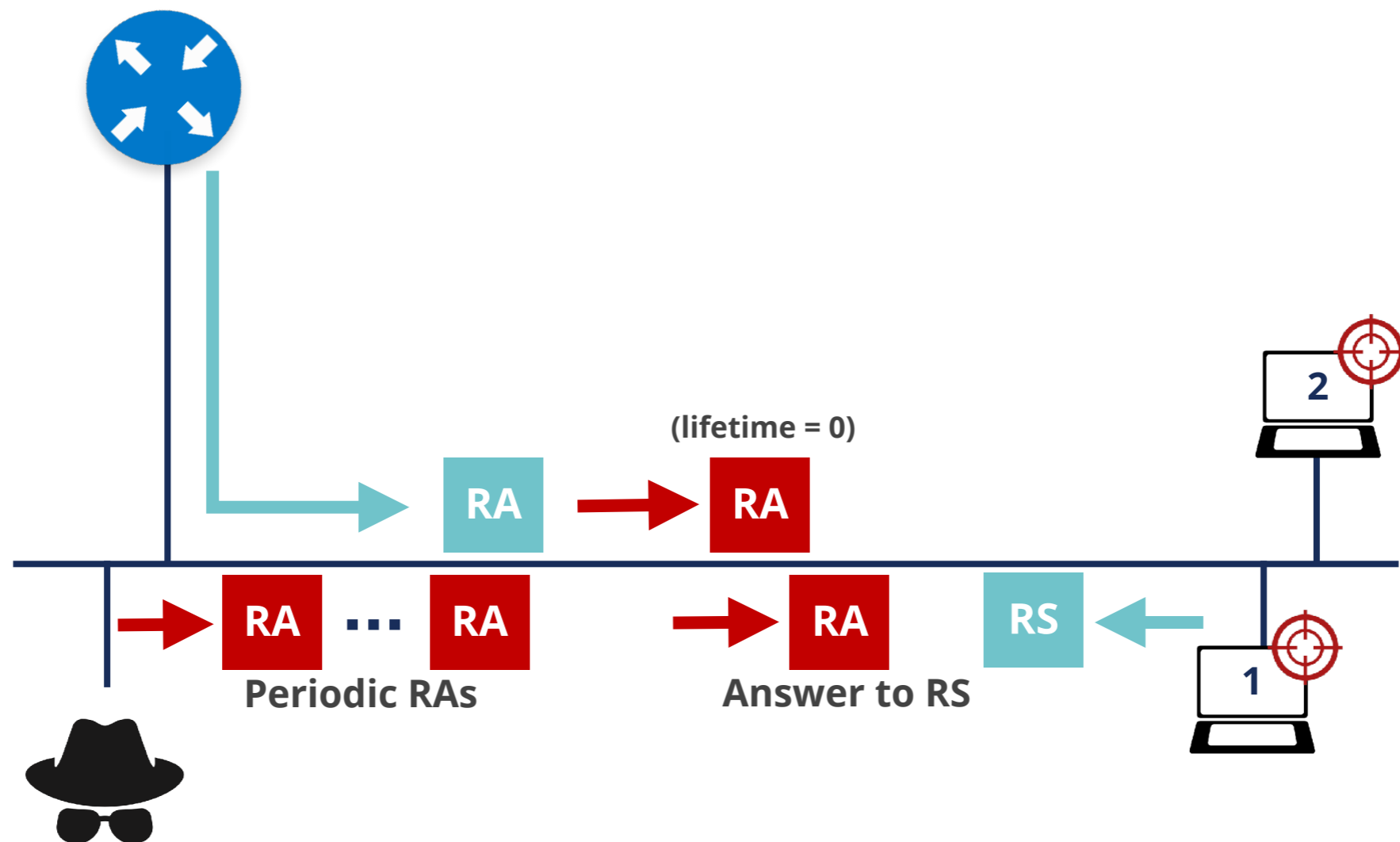
3.2-a: Neighbor cache attack using NS



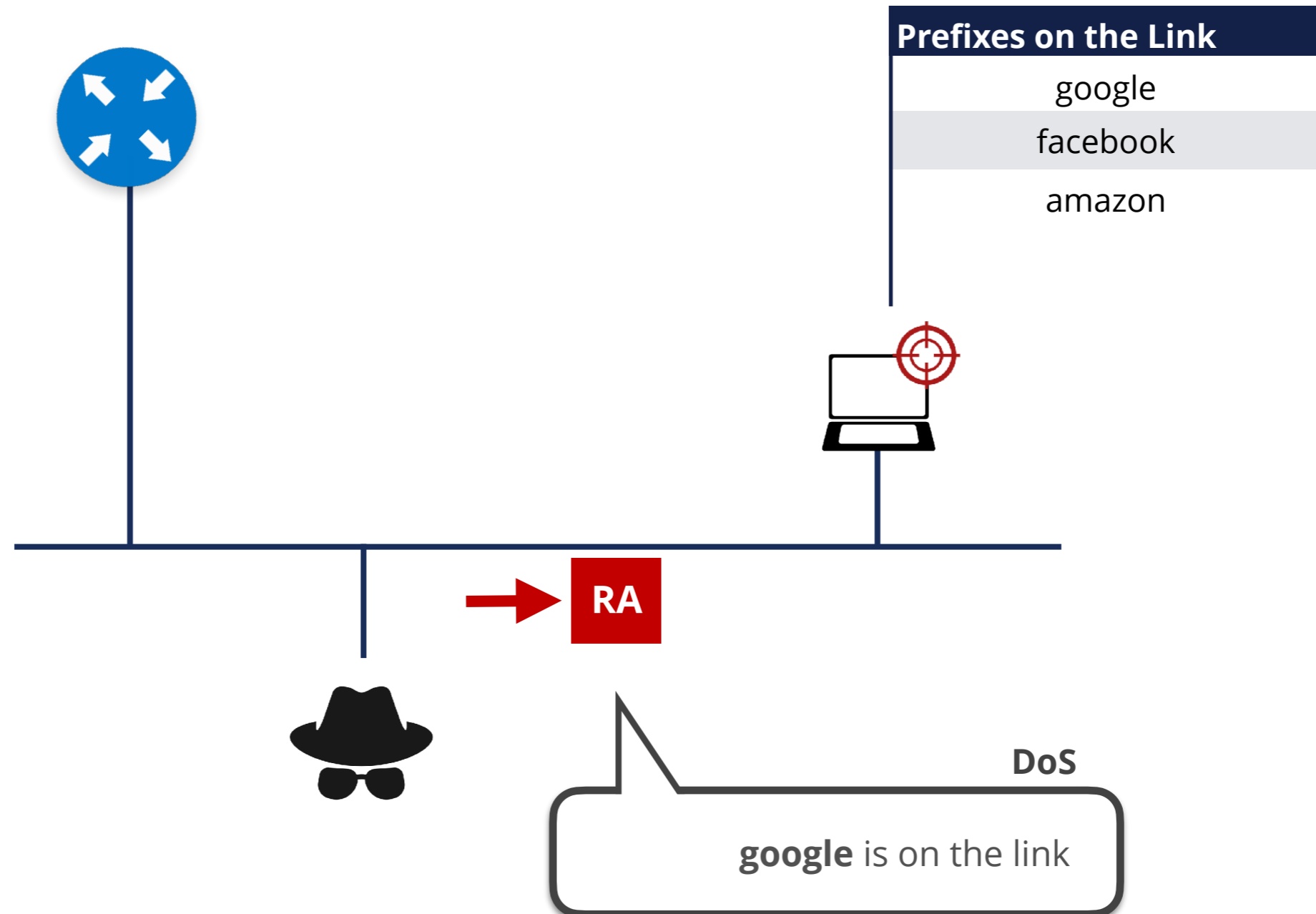
3.2-a: Neighbor cache attack using NA



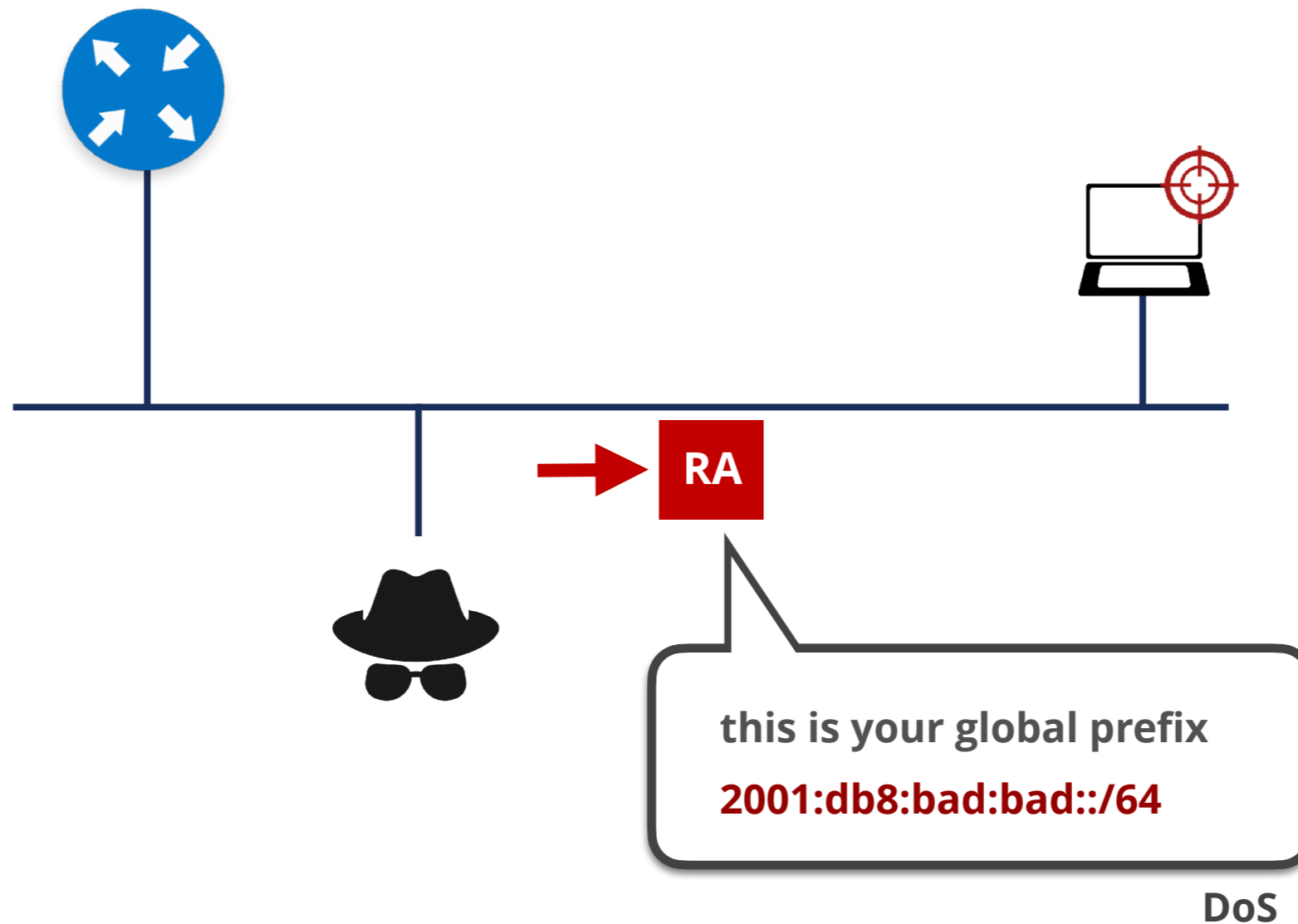
Malicious Last Hop Router



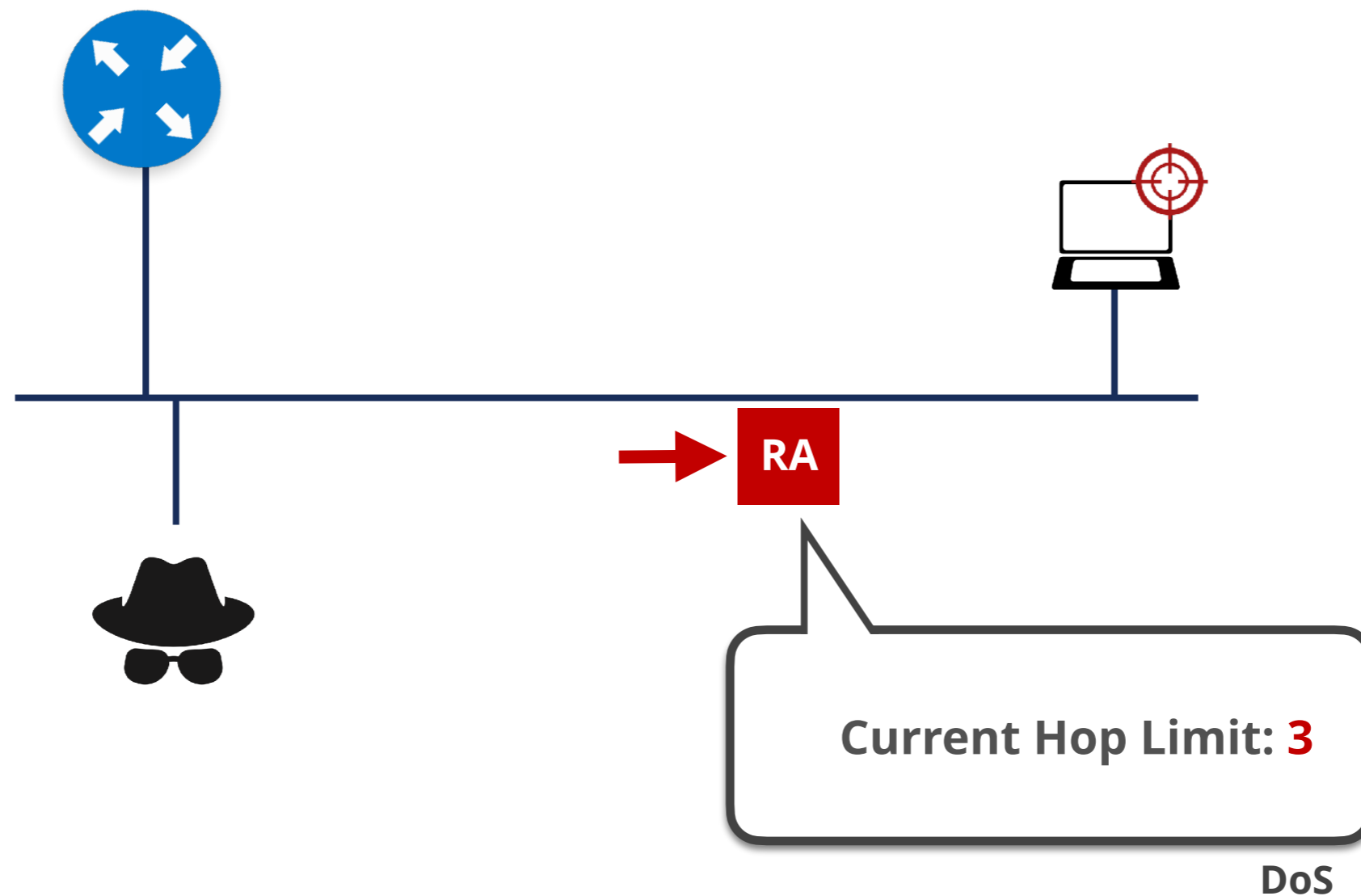
Bogus On-Link Prefix



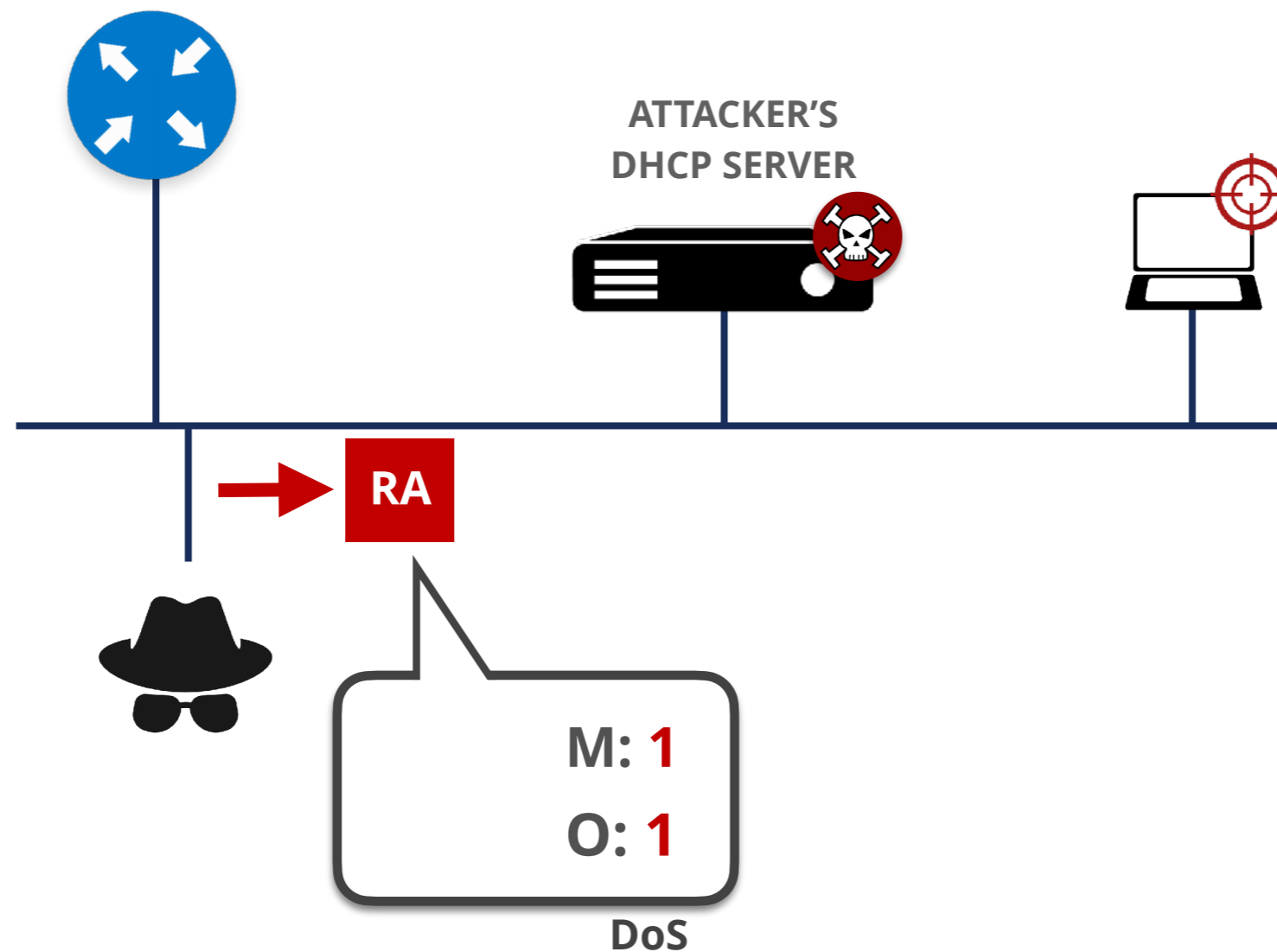
Bogus Address Configuration Prefix



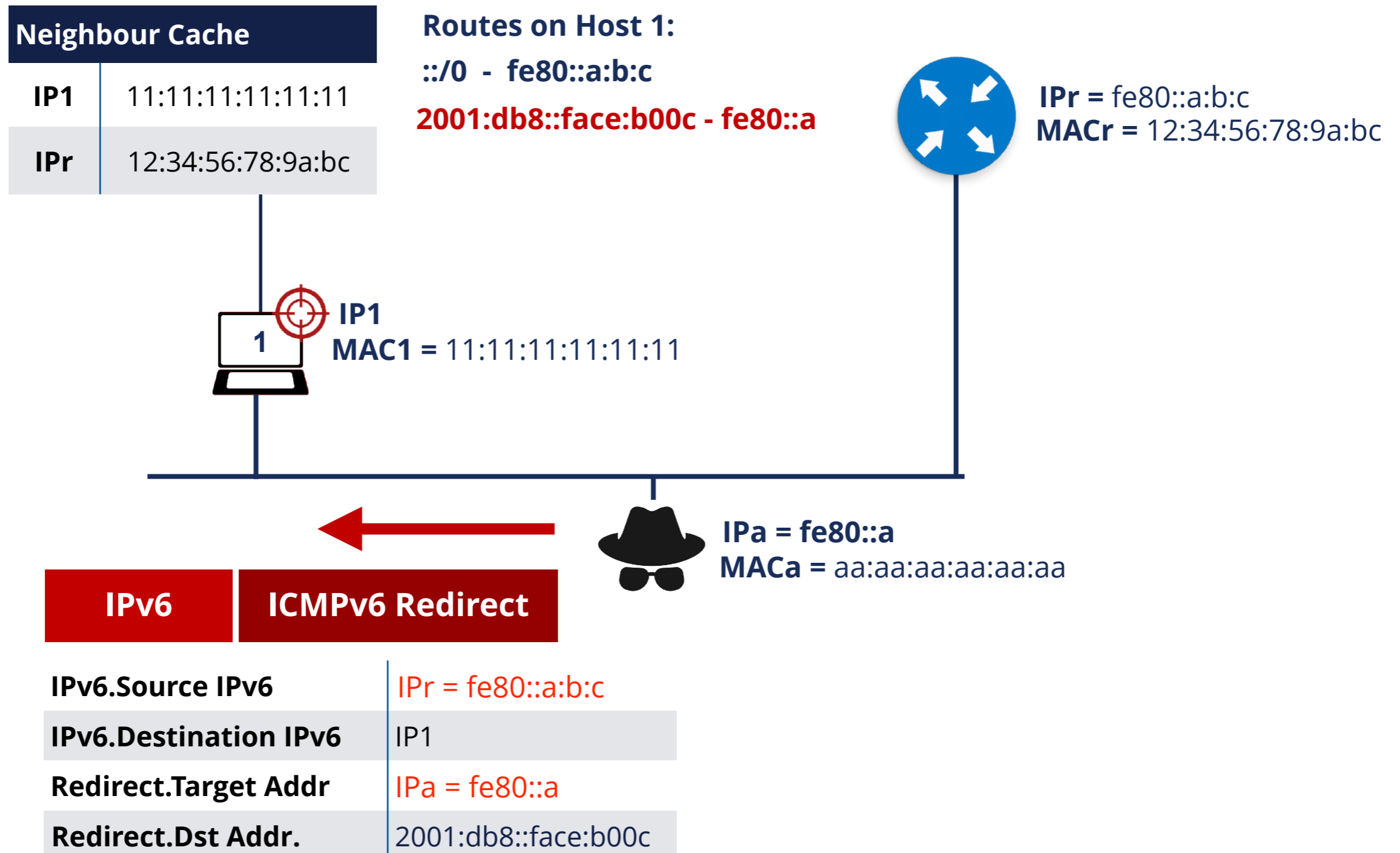
Parameter Spoofing: Hop Limit



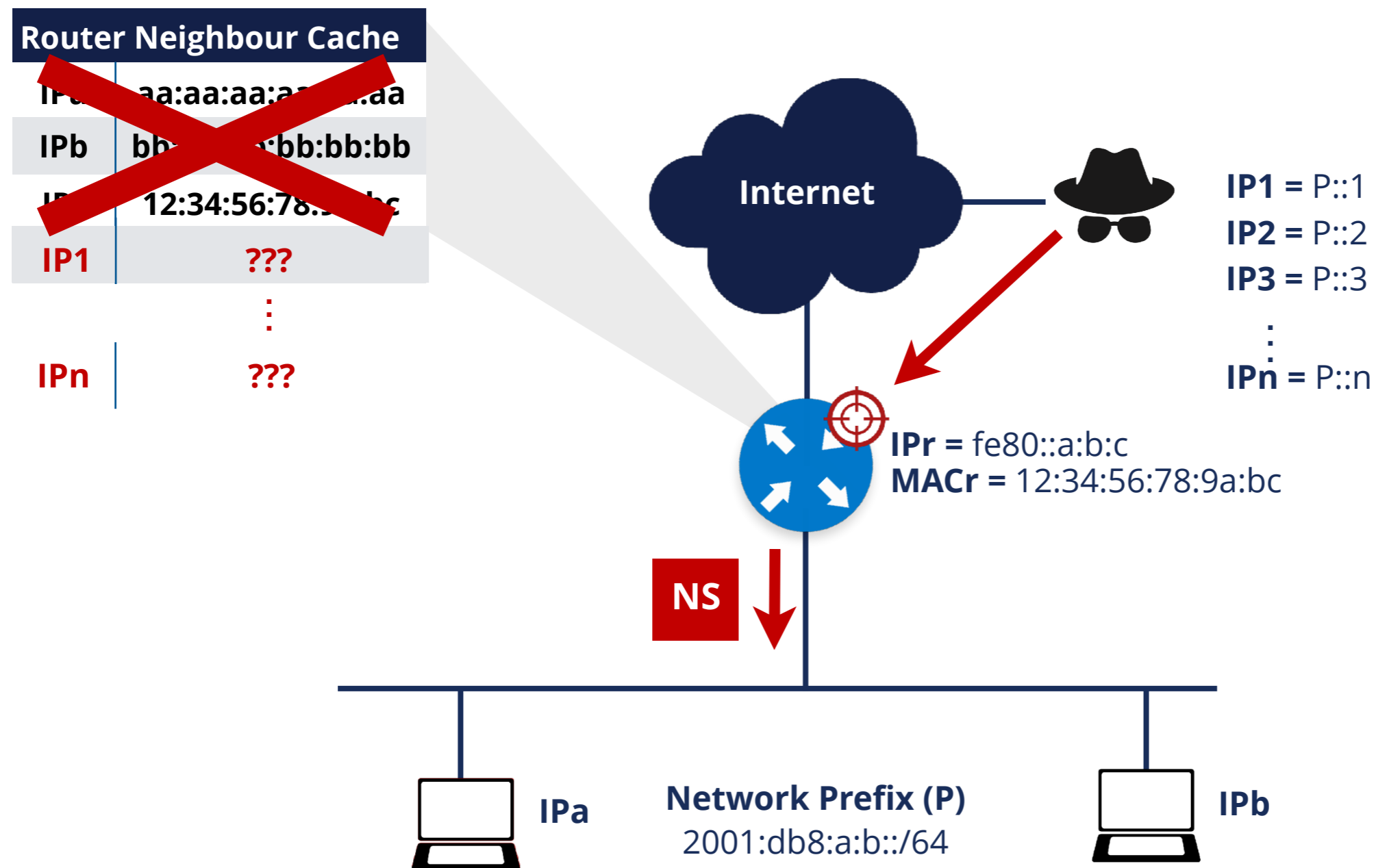
Parameter Spoofing: DHCPv6



Spoofed Redirect Message



Neighbour Discovery DoS Attack





NDP

Exercise 3.2-b

Exercise 3.2-b NDP



- **Description:** Send RA messages to perform attacks
- **Goals:**
 - Practice with Scapy tool
 - Use RA messages to perform attacks on a link
- **Time:** 20 minutes
- **Tasks:**
 - Send RA messages with bogus address configuration prefix

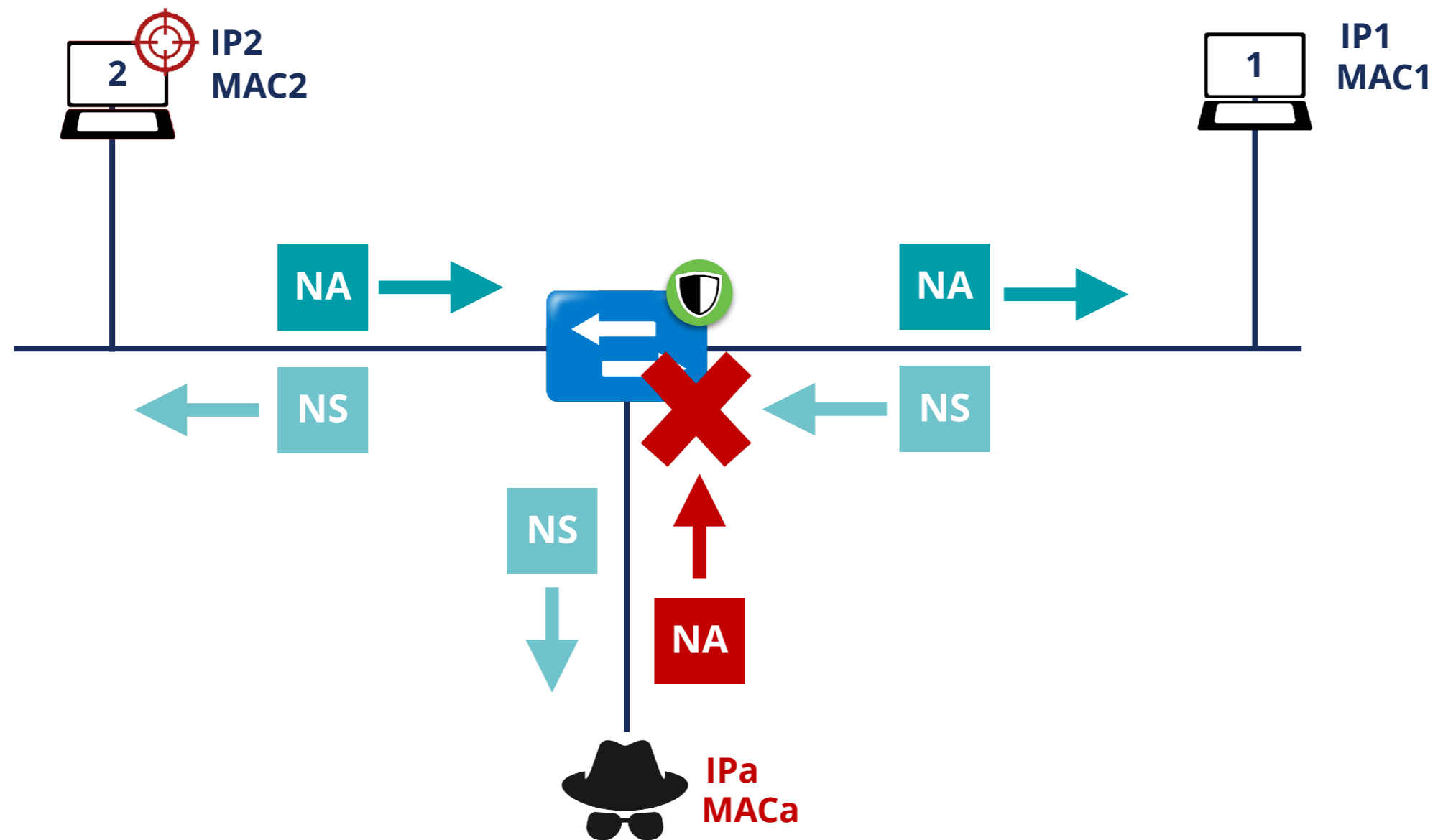


First Hop Security

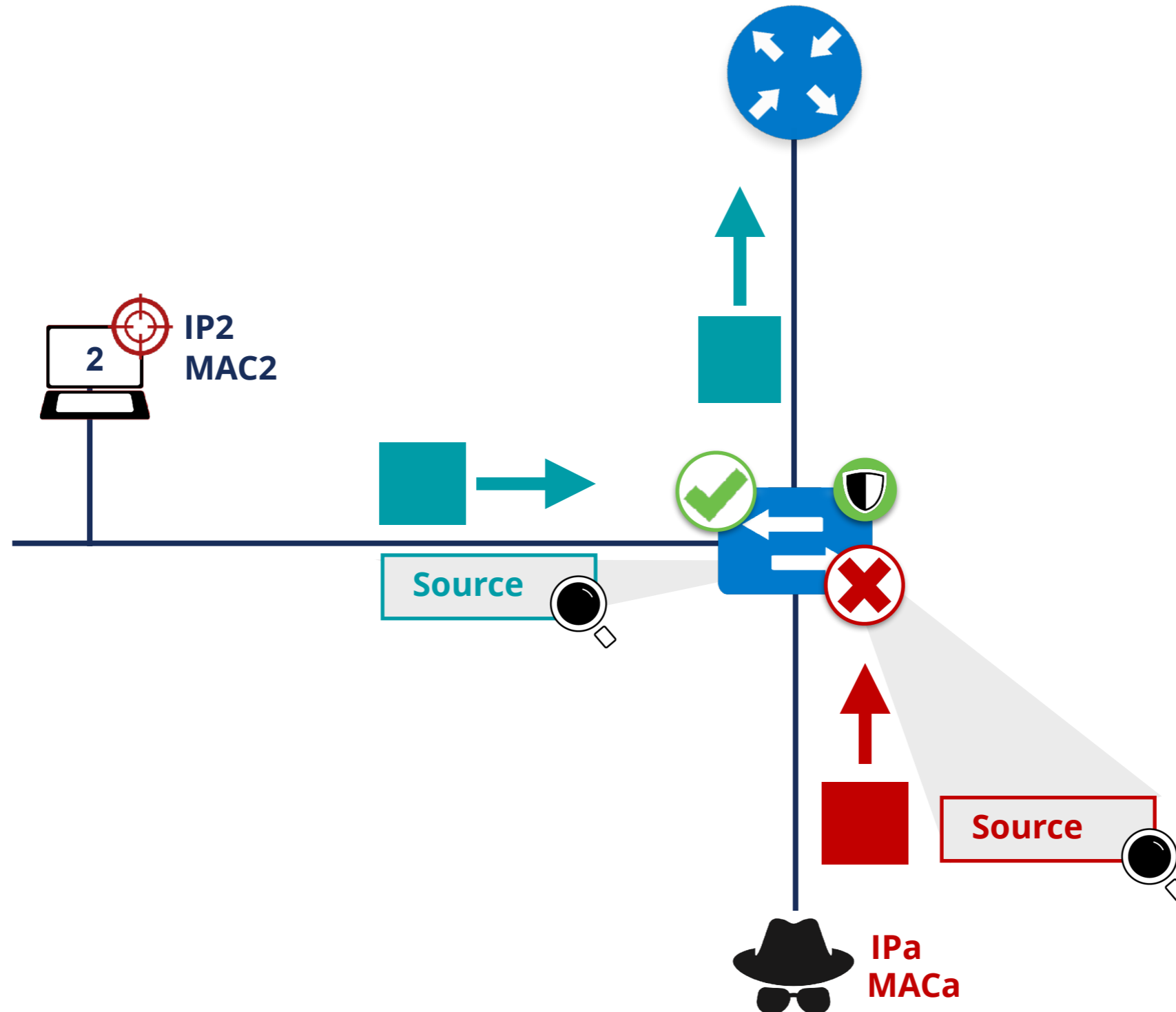
- Security implemented **on switches**
- There is a number of techniques available:
 - RA-GUARD
 - IPv6 Snooping (*ND inspection + DHCPv6 Snooping*)
 - IPv6 Source / Prefix Guard
 - IPv6 Destination Guard (*or ND Resolution rate limiter*)
 - MLD Snooping
 - DHCPv6 Guard



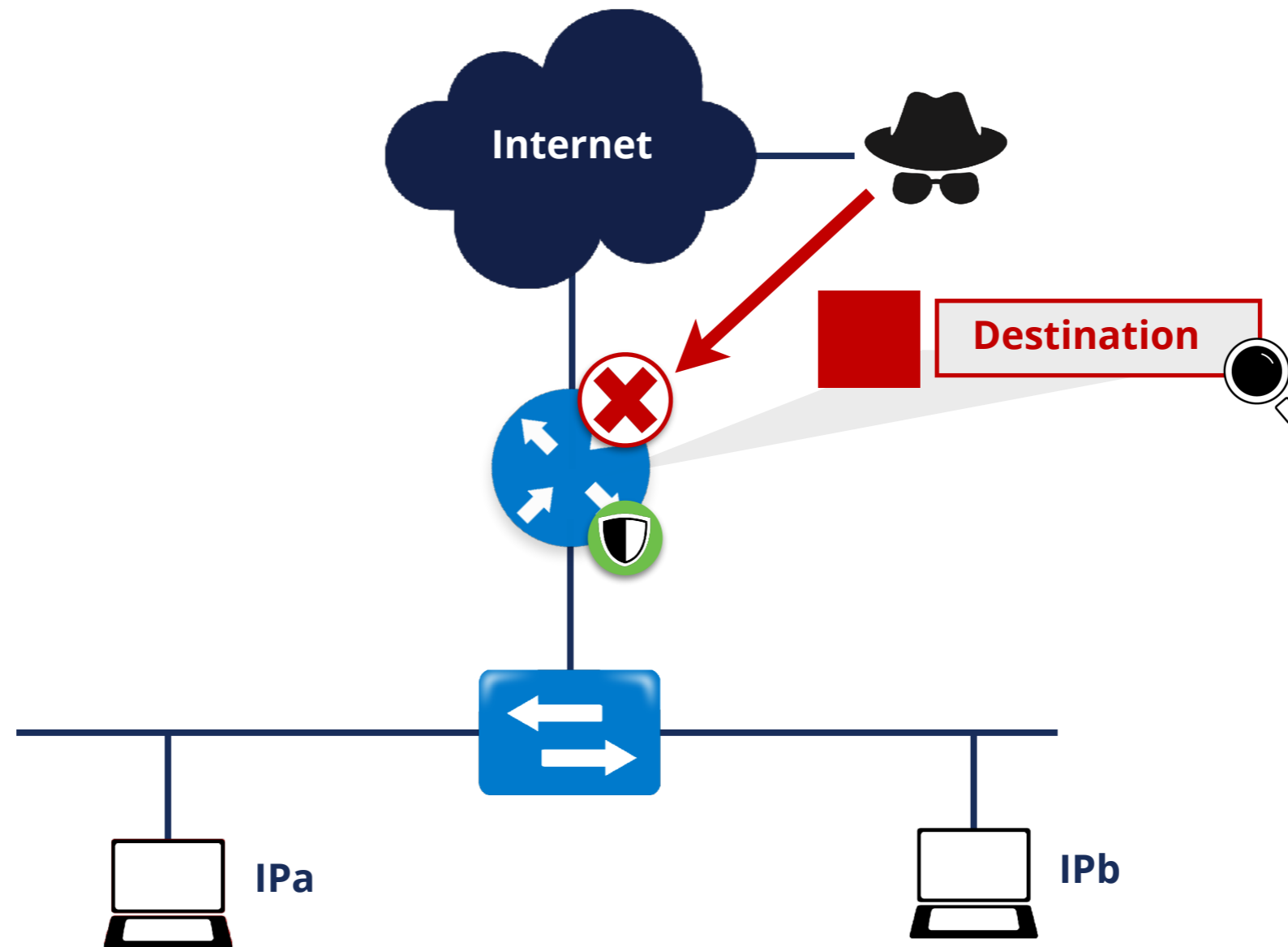
IPv6 Snooping



IPv6 Source / Prefix Guard



IPv6 Destination Guard

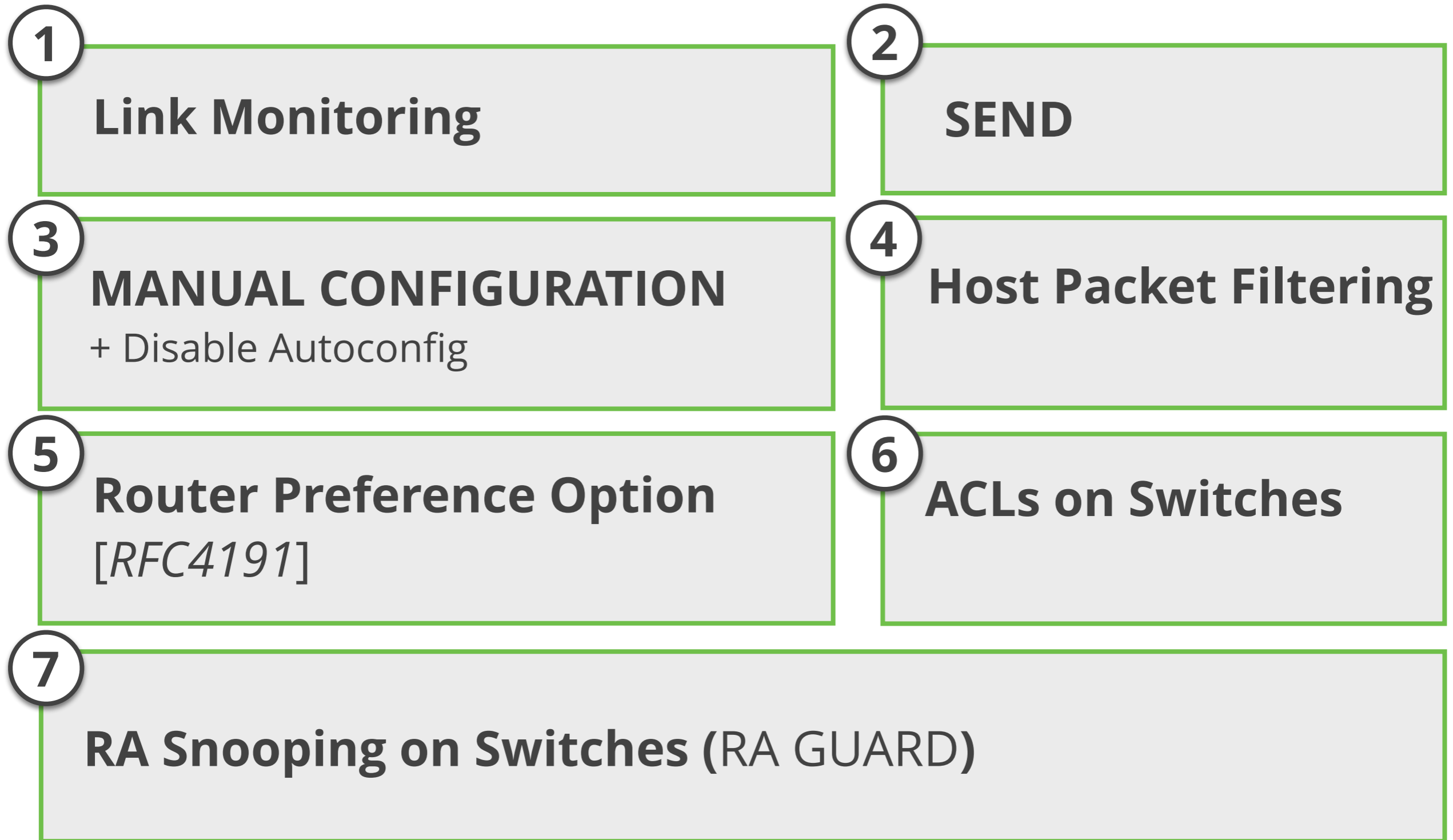




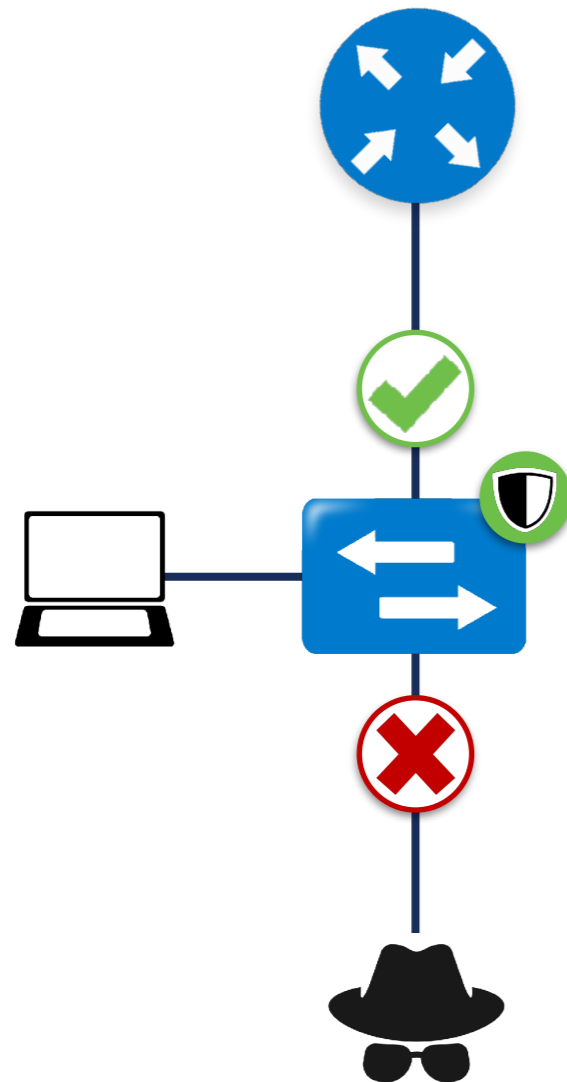
Rogue Router Advertisements



Rogue RA Solutions

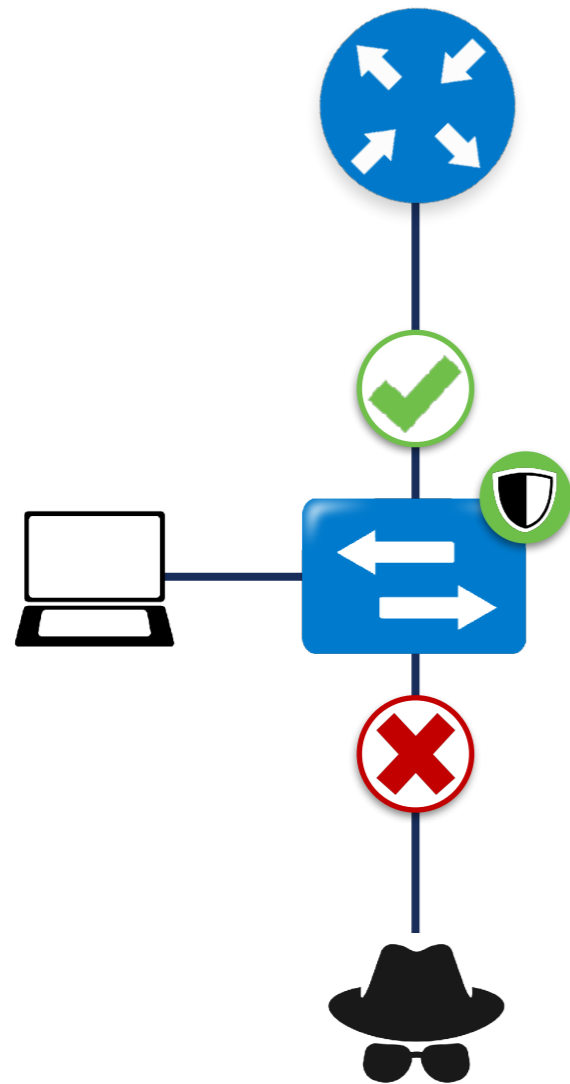


RA-GUARD [RFC6105]



- 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





MLD

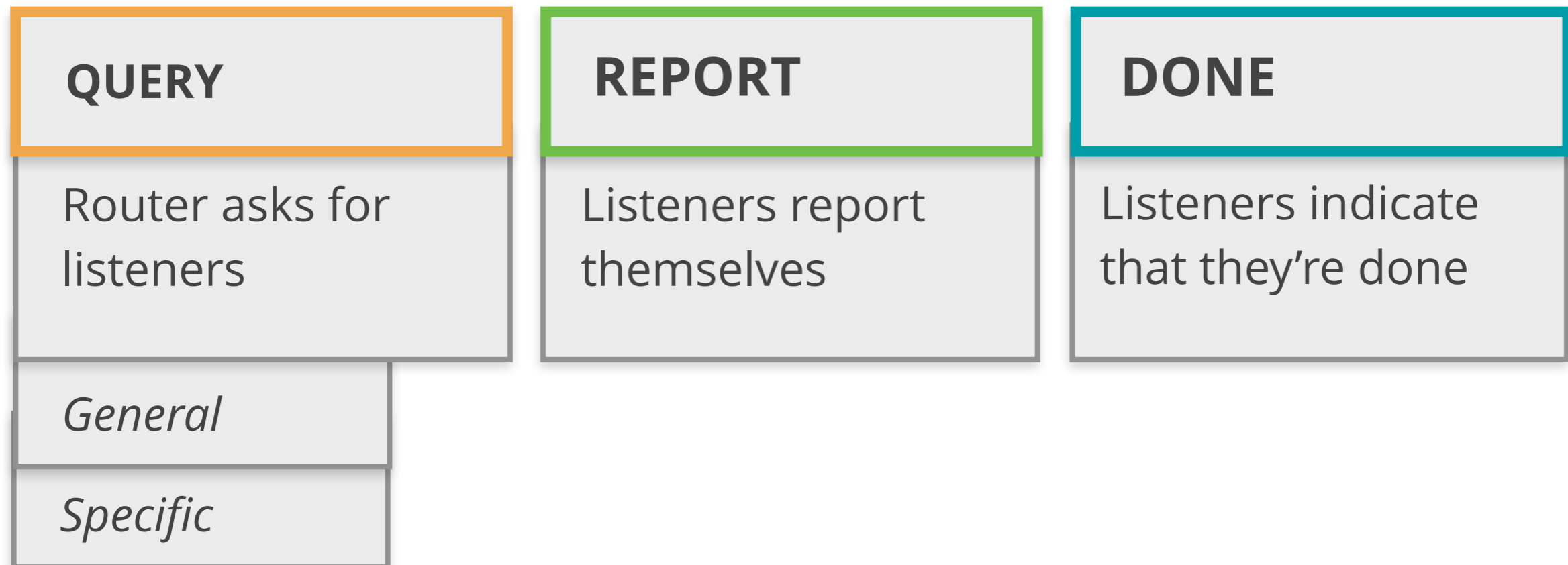
Section 3.3

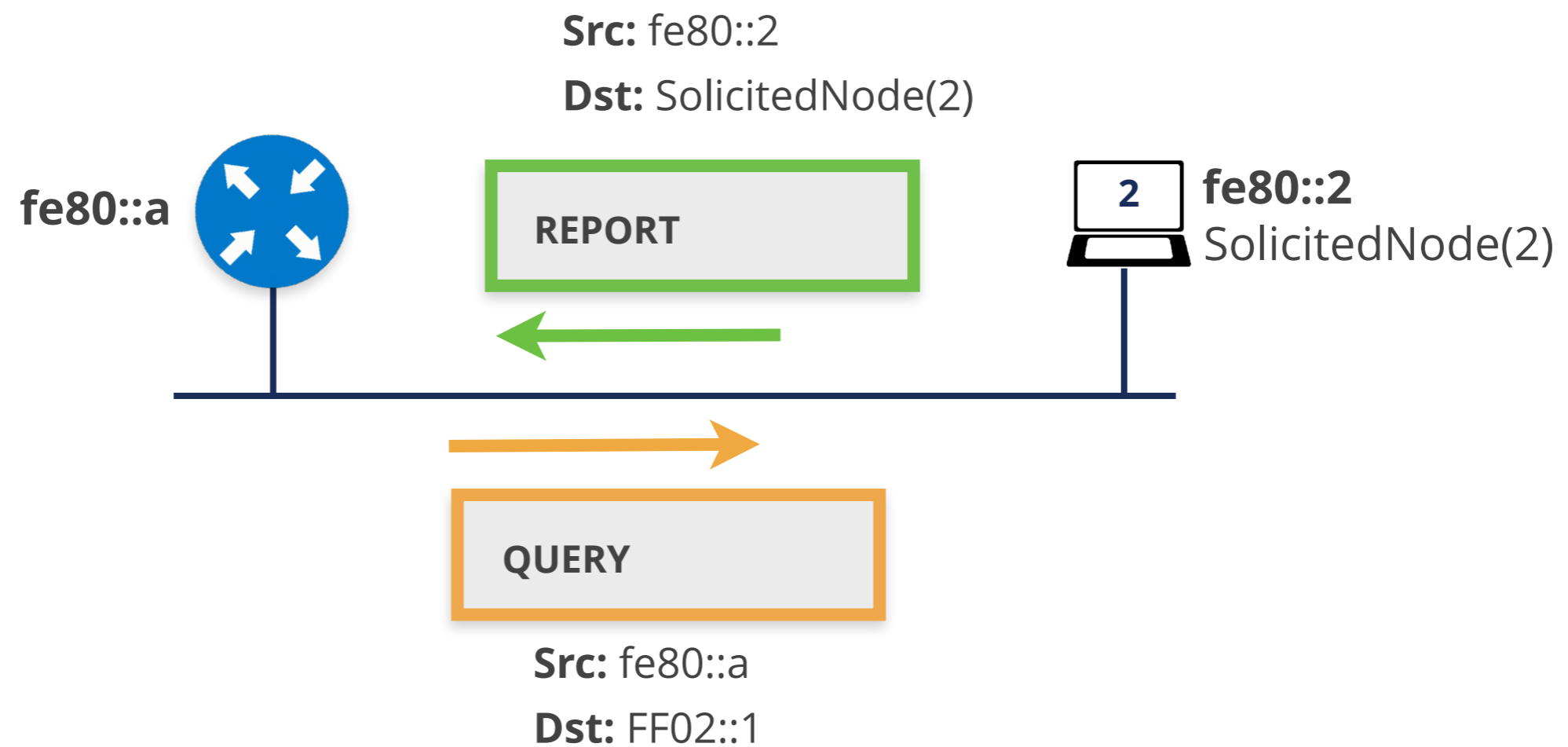


- MLD (**Multicast Listener Discovery**) is:
 - Multicast related protocol, used in the **local link**
 - Two versions: MLDv1 and MLDv2
 - Uses **ICMPv6**
 - Required by NDP and “IPv6 Node Requirements”
 - IPv6 nodes use it when **joining a multicast group**



MLDv1





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)

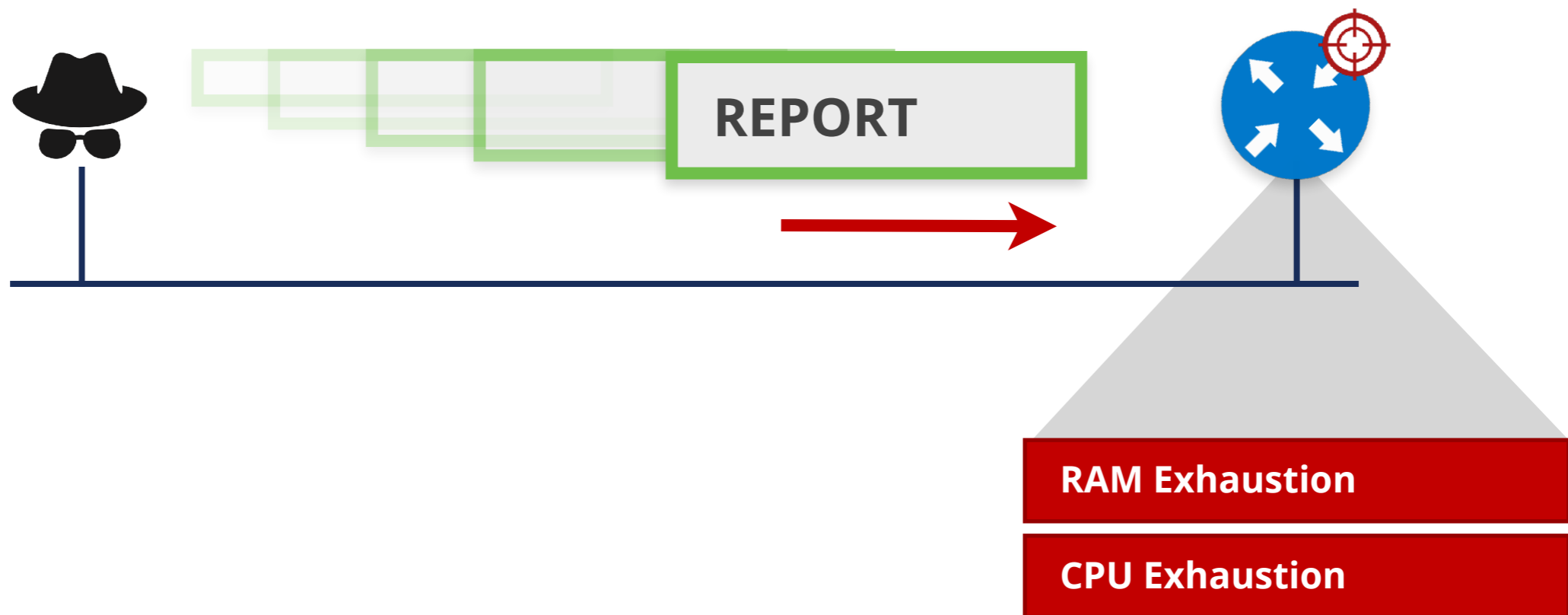
Sent to FF02::16

MLD Details

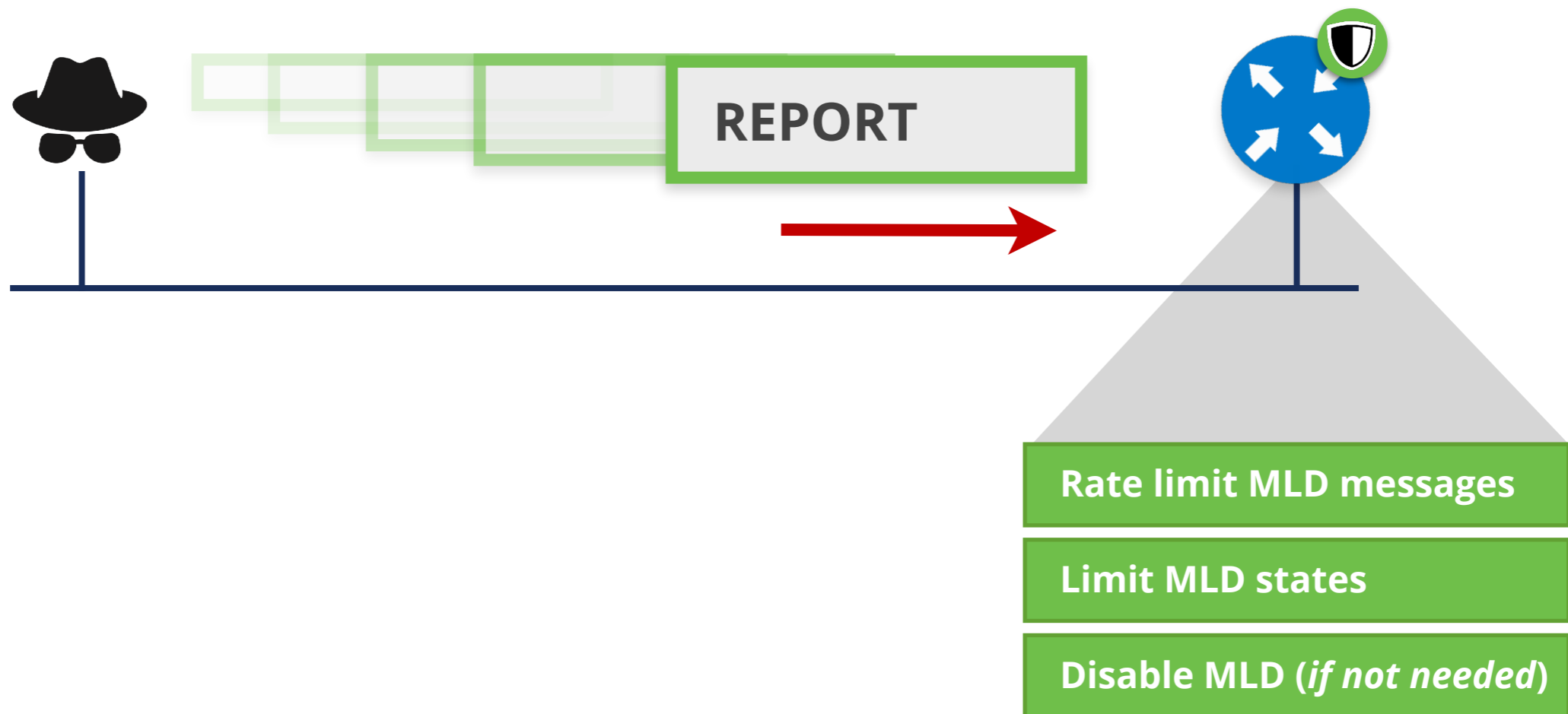


- Nodes **MUST** process QUERY to any of its unicast or multicast addresses
- MLDv2 **needs all nodes** using MLDv2
- **All OSs join** (REPORT) to the Solicited Node addresses

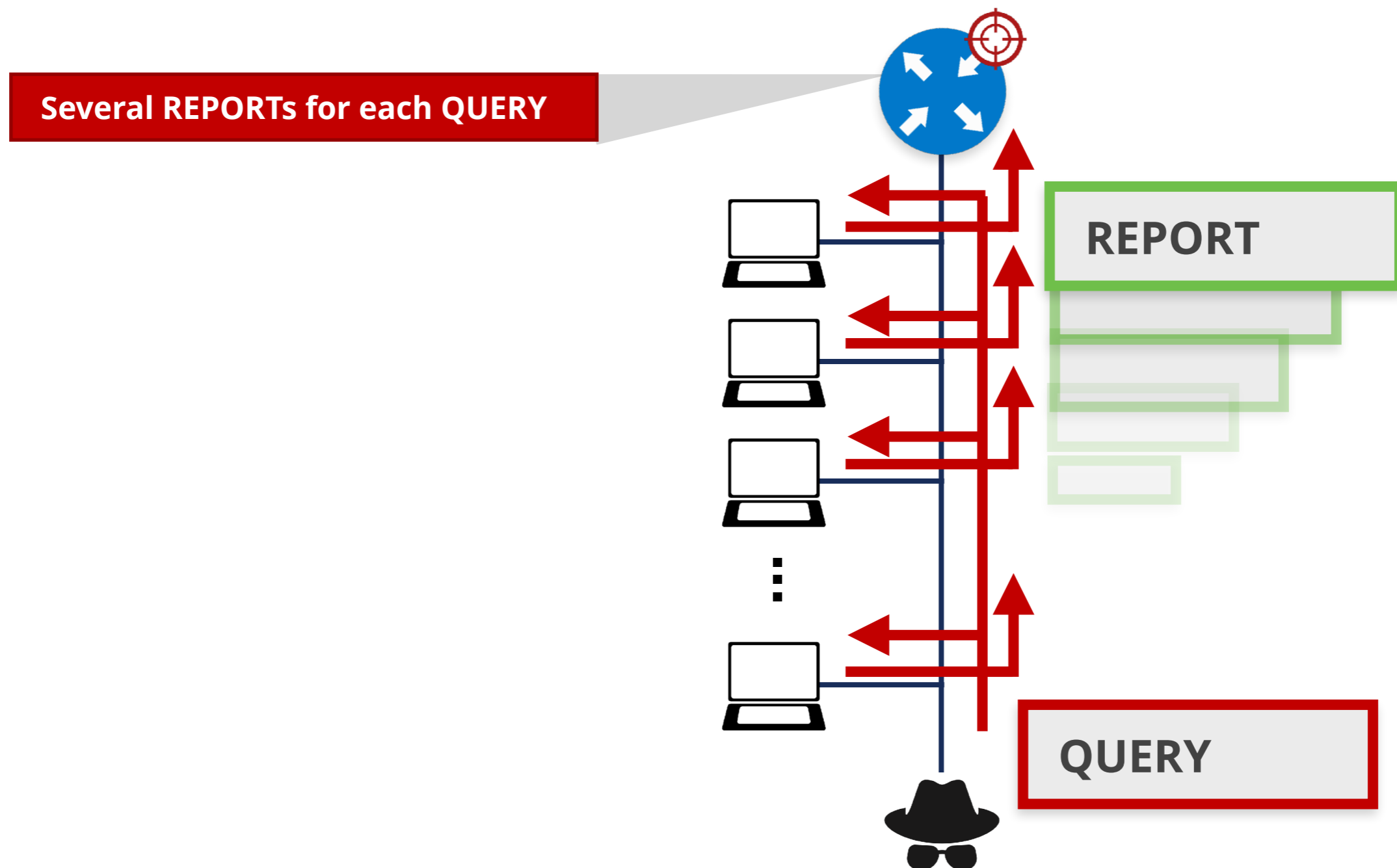
MLD Flooding



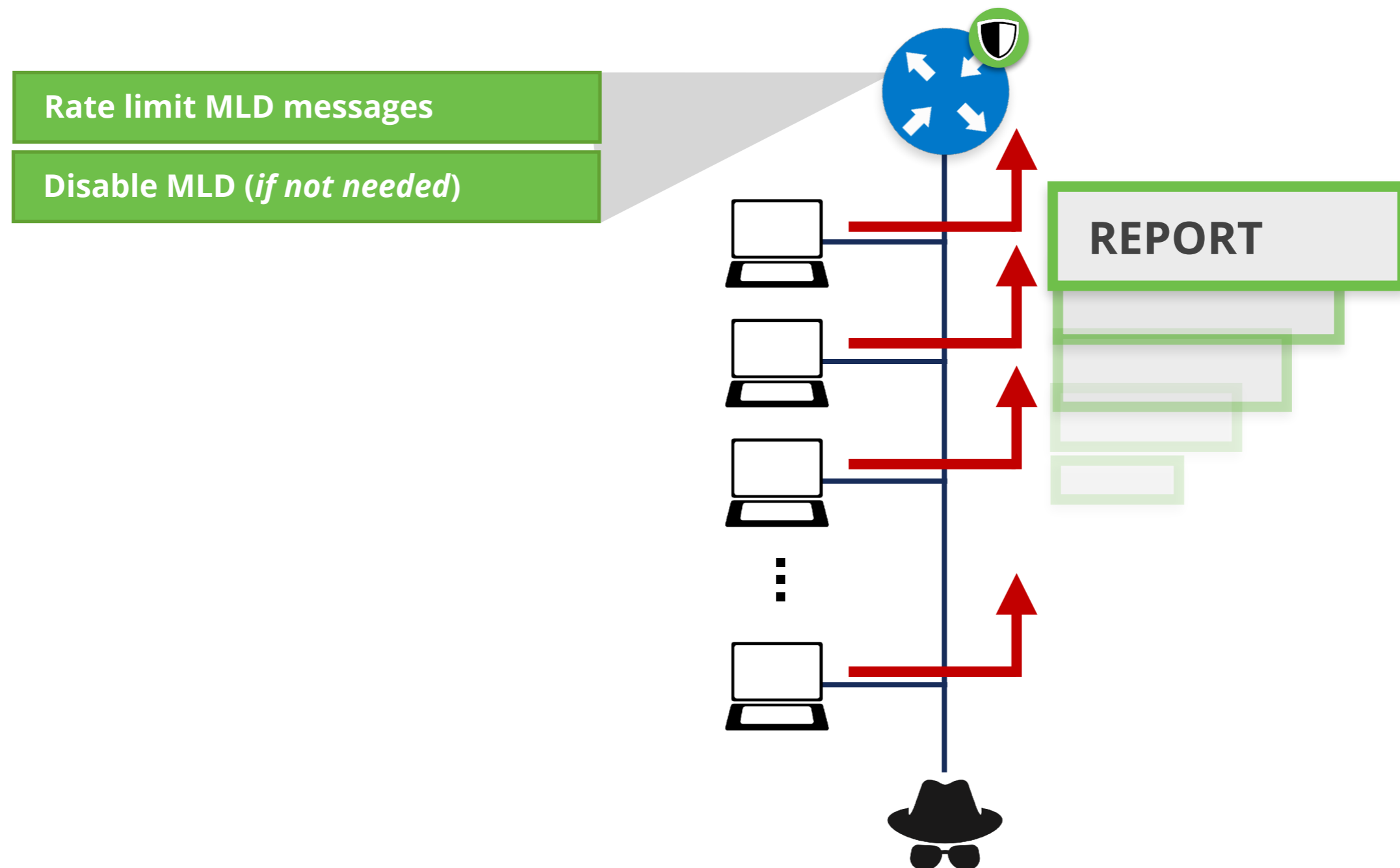
MLD Flooding



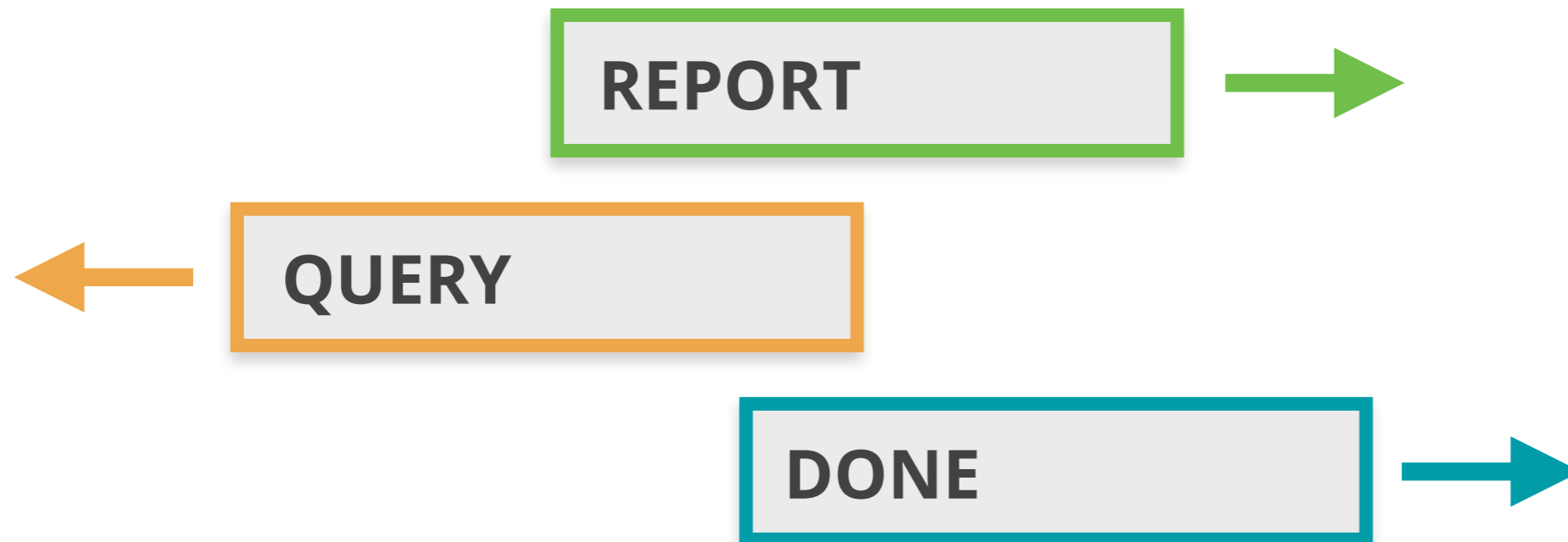
MLD Traffic amplification



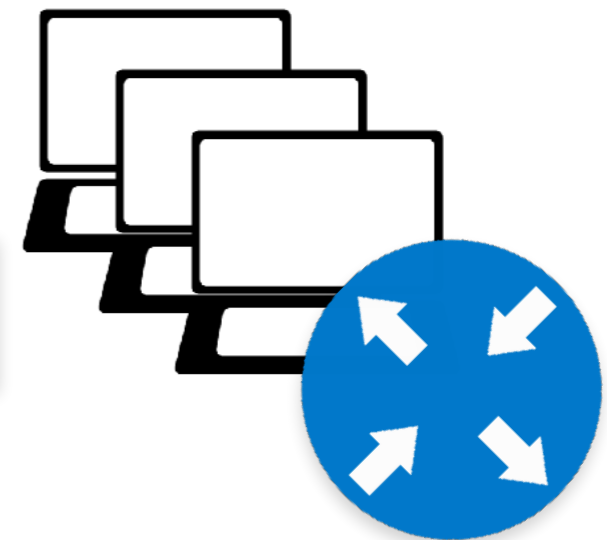
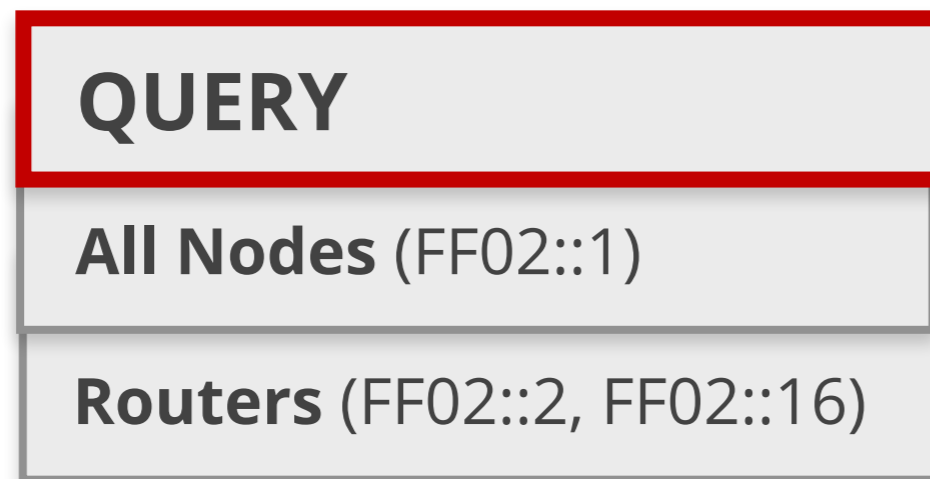
MLD Traffic amplification



Passive MLD Scanning



Active MLD Scanning



Built-in MLD Security



MLD Message

Source: Link local address **only**

Hop Limit = 1

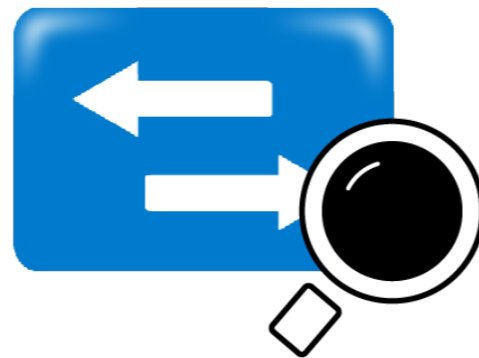
Router Alert option in Hop-by-Hop EH

Discard non-compliant messages



MLD Snooping

RFC4541

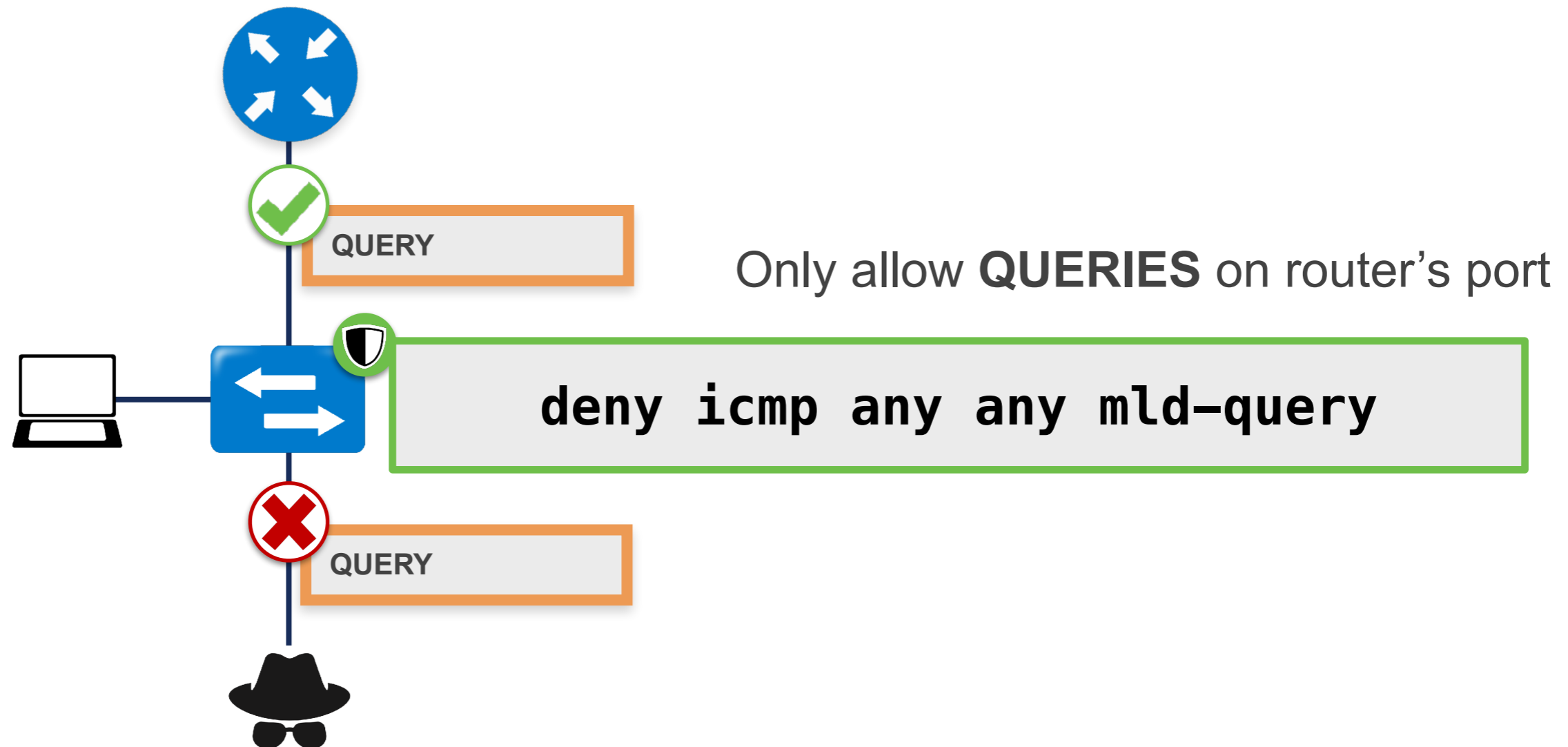


QUERY

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



MLD Protection on Switches





MLD

Exercise 3.3



Exercise 3.3 MLD

- **Description:** Network scanning using MLD
- **Goals:**
 - Craft a tailor-made message in Scapy
 - Capture the exchange of MLD messages
- **Time:** 10 minutes
- **Tasks:**
 - Scan your network using MLD Query message

Exercise 3.3 MLD



```
>>> d = IPv6(dst="ff02::1",hlim=1)
>>> e = IPv6ExtHdrHopByHop(options = RouterAlert())
>>> f = ICMPv6MLQuery2()
>>> pktv2 = d / e / f
```

```
>>> send(pktv2); pkts2=sniff(iface="eth0",lfilter = lambda x:x.haslayer(IPv6))
.
Sent 1 packets.
^C>>> pkts2.summary()
Ether / fe80::a8c1:abff:febb:fb28 > ff02::16 (0) / IPv6ExtHdrHopByHop / ICMPv6MLReport2
Ether / fe80::a8c1:abff:fe53:d3ea > ff02::16 (0) / IPv6ExtHdrHopByHop / ICMPv6MLReport2
Ether / fe80::a8c1:abff:fec3:2bb8 > ff02::16 (0) / IPv6ExtHdrHopByHop / ICMPv6MLReport2
```

Exercise 3.3 MLD



```
>>> pktv2.show()
###[ IPv6 ]###
  version    = 6
  tc         = 0
  fl         = 0
  plen       = None
  nh         = Hop-by-Hop Option Header
  hlim       = 1
  src        = fe80::a8c1:abff:fee8:78c3
  dst        = ff02::1
###[ IPv6 Extension Header - Hop-by-Hop Options Header ]###
  nh         = ICMPv6
  len        = None
  autopad    = 0n
  \options   \
    |###[ Router Alert ]###
    |  otype   = Router Alert [00: skip, 0: Don't change en-route]
    |  optlen  = 2
    |  value   = None
###[ MLDv2 - Multicast Listener Query ]###
  type       = MLD Query
  code       = 0
  cksum      = None
  mrd        = 10000
  reserved   = 0
  mladdr     = ::
  Resv       = 0
  S          = 0
  QRV        = 0
  QQIC       = 0
  sources_number = None
  sources    = [ ]
```

Exercise 3.3 MLD



```
>>> pkts2[2].show()
###[ Ethernet ]###
  dst      = 33:33:00:00:00:16
  src      = aa:c1:ab:53:d3:ea
  type     = IPv6
###[ IPv6 ]###
  version  = 6
  tc       = 0
  fl       = 0
  plen     = 36
  nh       = Hop-by-Hop Option Header
  hlim     = 1
  src      = fe80::a8c1:abff:fe53:d3ea
  dst      = ff02::16
###[ IPv6 Extension Header - Hop-by-Hop Options Header ]###
  nh       = ICMPv6
  len      = 0
  autopad  = 0n
  \options \
    |###[ Router Alert ]###
    | otype    = Router Alert [00: skip, 0: Don't change en-route]
    | optlen   = 2
    | value    = Datagram contains a MLD message
    |###[ PadN ]###
    | otype    = PadN [00: skip, 0: Don't change en-route]
    | optlen   = 0
    | optdata  = ''
###[ MLDv2 - Multicast Listener Report ]###
  type     = MLD Report Version 2
  res      = 0
  cksum    = 0x77cb
  reserved = 0
  records_number= 1
  \records \
    |###[ ICMPv6 MLDv2 - Multicast Address Record ]###
    | rtype    = 2
    | auxdata_len= 0
    | sources_number= 0
    | dst      = ff02::1:ff53:d3ea
    | sources  = [ ]
    | auxdata  = ''
```



DNS

Section 3.4

IPv6 DNS Configuration Attacks



Attacker becomes the DNS server of the victim using:

NDP	Autoconfiguration
Man-in-the-Middle	SLAAC
Neighbor Cache Poisoning	DHCPv6



IPv6 DNS Configuration Attacks



Depending on answers to DNS queries

Man-in-the-Middle

DoS Attack





DHCPv6

Section 3.5

Introduction



Similar to IPv4

Client / Server

UDP

Uses Relays

Message names change

SOLICIT

ADVERTISE

REQUEST

REPLY

...

Multicast in DHCPv6

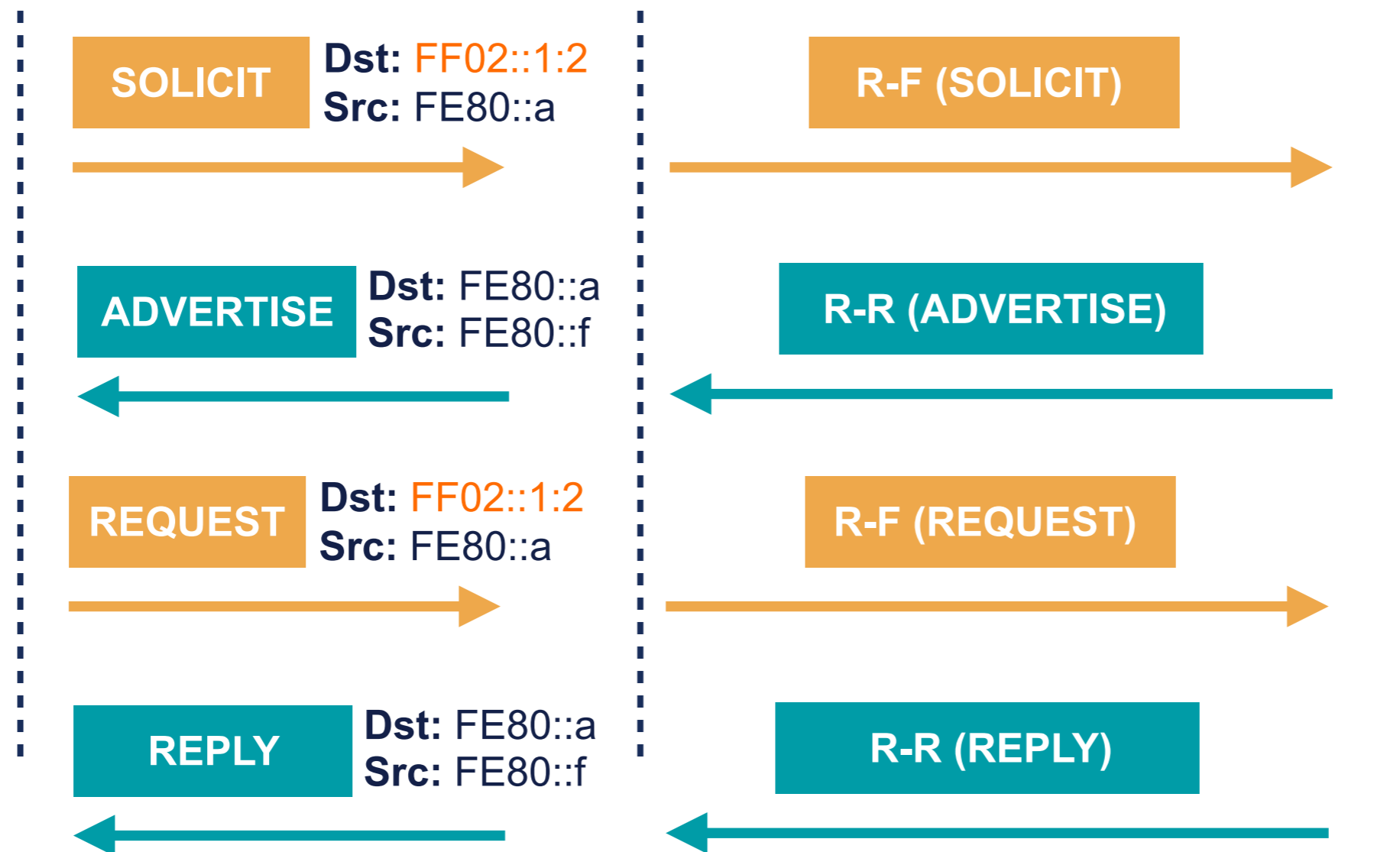
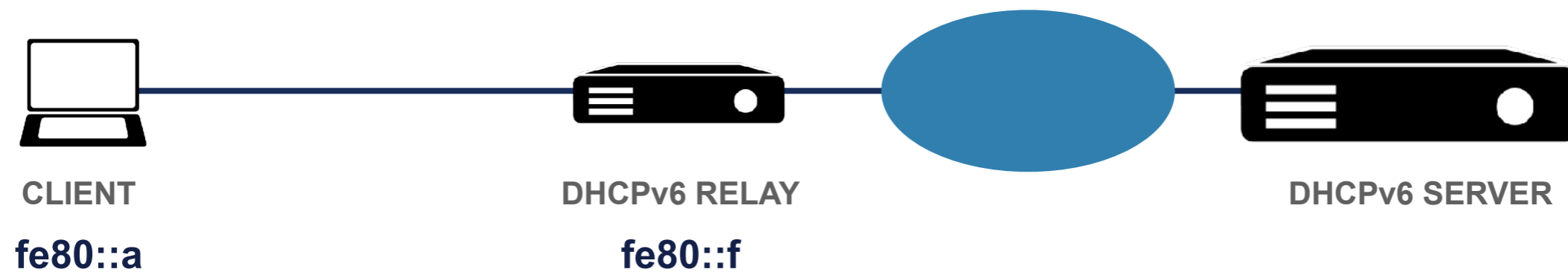


Servers and relays listen on multicast addresses

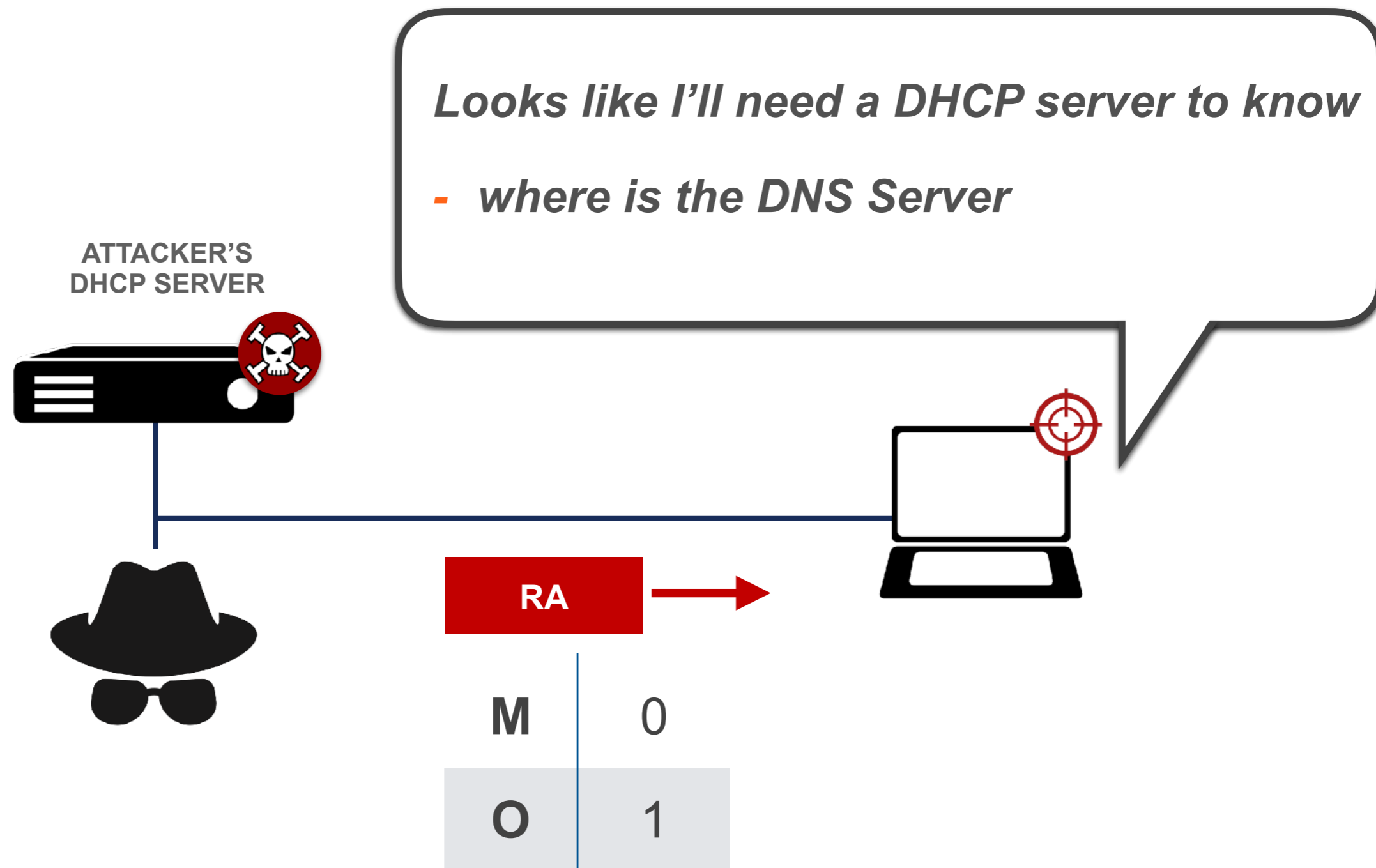
All DHCP Relay Agents and Servers	FF02::1:2
--	------------------

All DHCP Servers	FF05::1:3
-------------------------	------------------

How DHCPv6 works



Triggering the use of DHCP



Privacy Considerations



**Client information can be obtained from IDs
like the MAC from Client-ID**



LINK-LOCAL ADDRESS

MAC ADDRESS



Privacy Considerations



Server address assignment strategies:

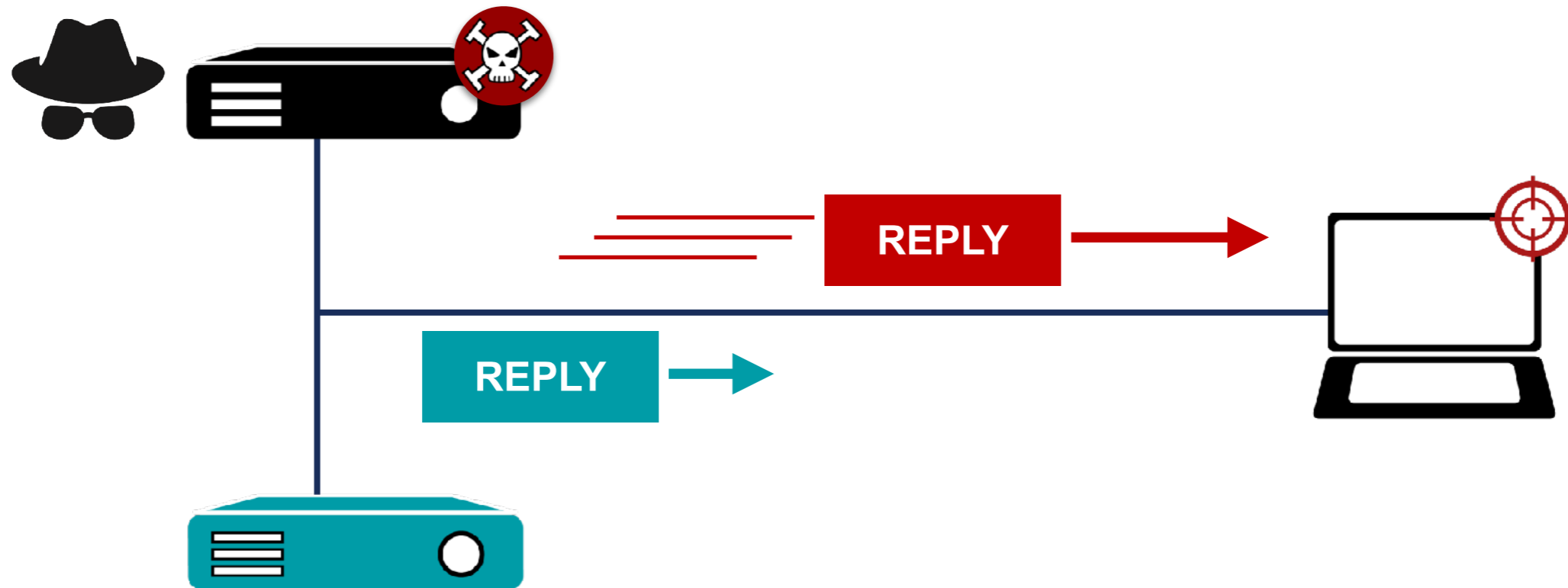
- **Iterative:** scanning easier
- **Identifier-based:** easier to track activity
- **Hash:** better, but still allows activity tracking
- **Random:** better privacy



Rogue DHCP Server



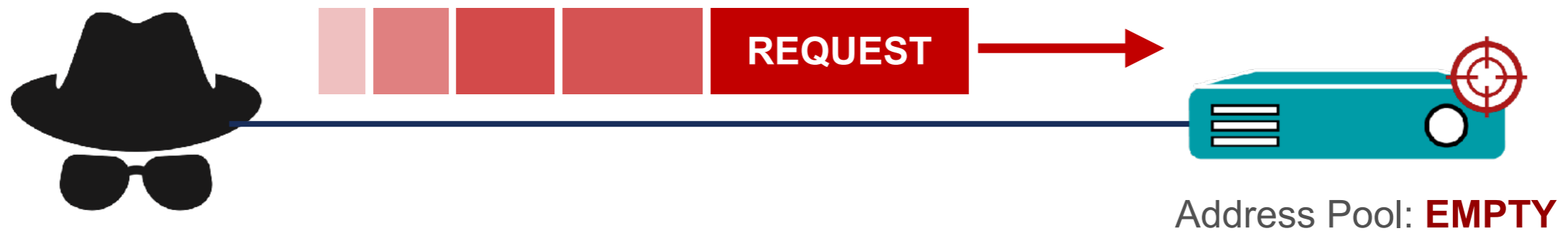
Answers before legitimate server



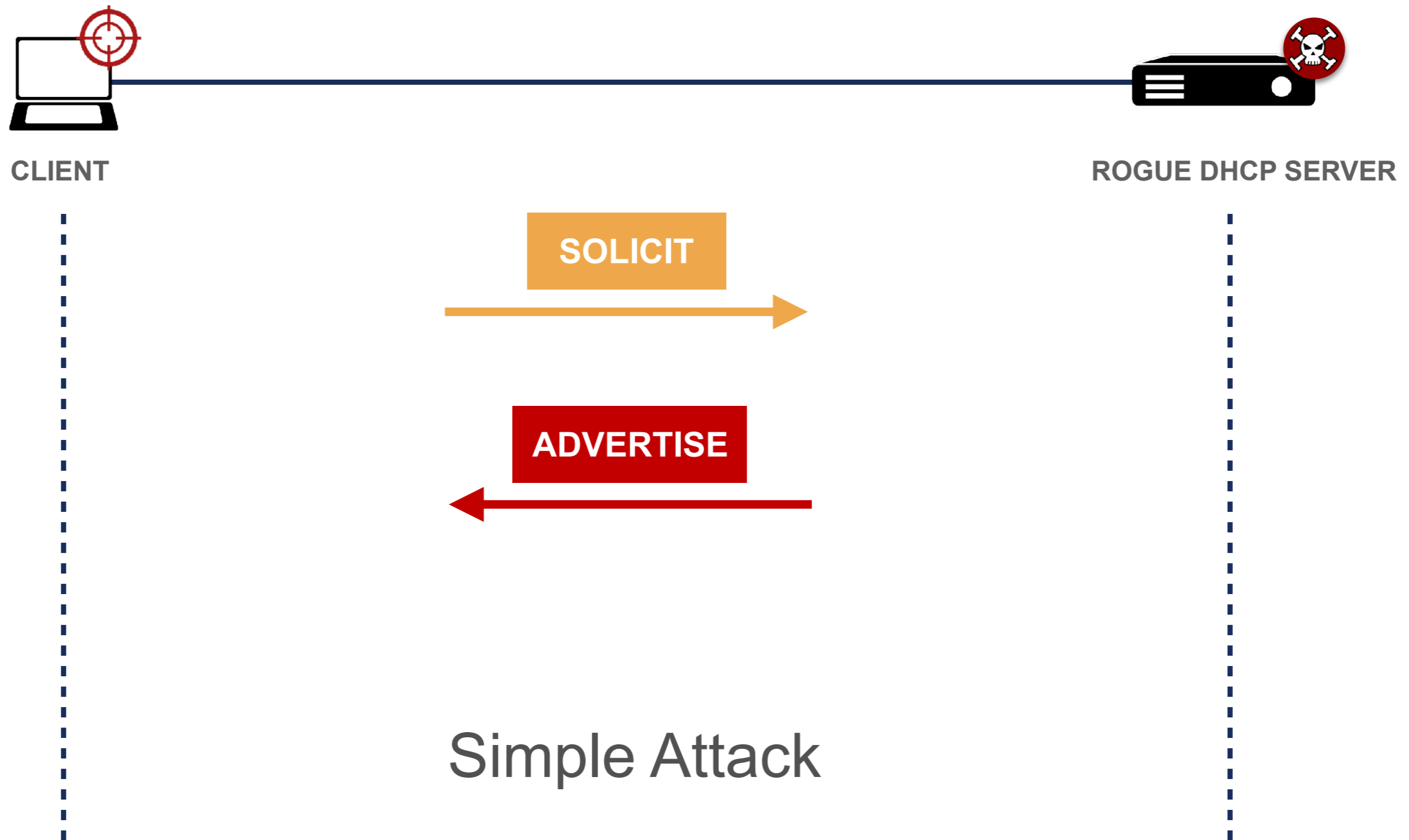
Rogue DHCP Server



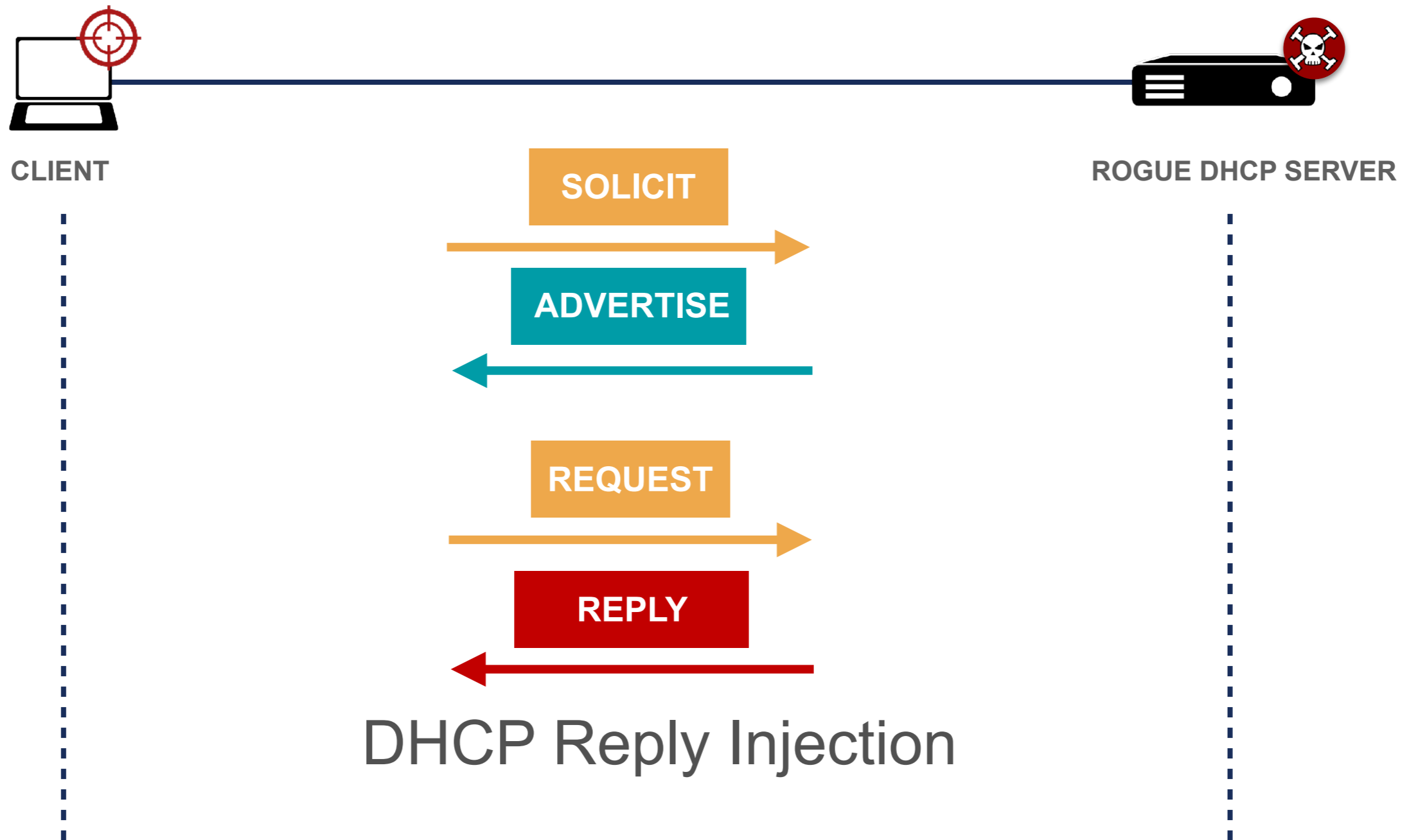
DHCP Exhaustion Attack



Rogue DHCP Server



Rogue DHCP Server



DHCPv6 Solutions



RFC8415 - Security Considerations

recommends ***RFC8213*** - IPSec with Encryption



DHCPv6 Solutions



Secure DHCPv6 (*with encryption*)

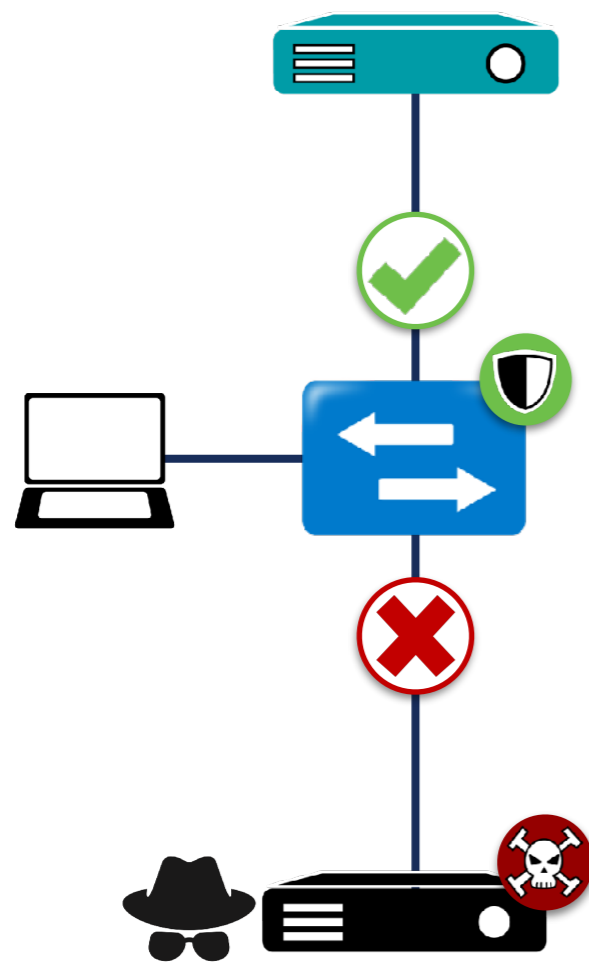


End-to-end encryption
Public key cryptography
Authentication



DHCPv6 Shield

RFC7610



- Protects **clients** only
- Implemented on **L2 switches**
- **DHCPv6 Guard** is vendor implementation



IPv6 Filtering

Section 4



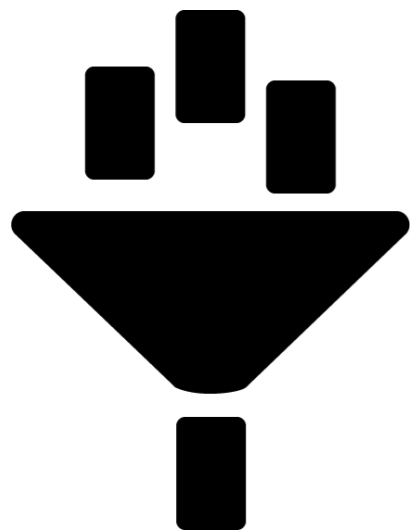
Filtering IPv6 Traffic

Section 4.1

Filtering in IPv6 is very Important!



- Global Unicast Addresses
- A good **addressing plan**



Easier filtering!

New Filters to Take Into Account



- ICMPv6
- IPv6 Extension Headers
- Fragments Filtering
- Transition mechanisms (TMs) / Dual-Stack

Filtering ICMPv6

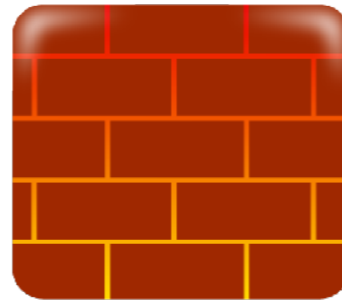


Type - Code	Description	Action
Type 1 - all	Destination Unreachable	ALLOW
Type 2	Packet Too Big	ALLOW
Type 3 - Code 0	Time Exceeded	ALLOW
Type 4 - Code 0, 1 & 2	Parameter Problem	ALLOW
Type 128	Echo Reply	ALLOW for troubleshoot and services. Rate limit
Type 129	Echo Request	ALLOW for troubleshoot and services. Rate limit
Types 131,132,133, 143	MLD	ALLOW if Multicast or MLD goes through FW
Type 133	Router Solicitation	ALLOW if NDP goes through FW
Type 134	Router Advertisement	ALLOW if NDP goes through FW
Type 135	Neighbour Solicitation	ALLOW if NDP goes through FW
Type 136	Neighbour Advertisement	ALLOW if NDP goes through FW
Type 137	Redirect	NOT ALLOW by default
Type 138	Router Renumbering	NOT ALLOW

More on RFC 4890 - <https://tools.ietf.org/html/rfc4890>



Filtering Extension Headers



- **Firewalls** should be able to:
 1. Recognise and filter some **EHs** (example: **RH0**)
 2. Follow the **chain of headers**
 3. Not allow **forbidden combinations** of headers



Filtering Fragments



Upper layer info
not in 1st fragment



Creates many tiny fragments to
go through filtering / detection

Fragments
inside fragments



Several fragment headers

Fragmentation
inside a tunnel



External header hides fragmentation



Filtering Fragments



Upper layer info
not in 1st fragment



All header chain should be in
the 1st fragment [RFC7112]

Fragments
inside fragments



Should not happen in IPv6.
Filter them

Fragmentation
inside a tunnel



FW / IPS / IDS should support
inspection of encapsulated traffic



Filtering TMs / Dual-stack



Technology	Filtering Rules
Native IPv6	EtherType 0x86DD
6in4	IP proto 41
6in4 (GRE)	IP proto 47
6in4 (6-UDP-4)	IP proto 17 + IPv6
6to4	IP proto 41
6RD	IP proto 41
ISATAP	IP proto 41
Teredo	UDP Dest Port 3544
Tunnel Broker with TSP	(IP proto 41) (UDP dst port 3653 TCP dst port 3653)
AYIYA	UDP dest port 5072 TCP dest port 5072

More on RFC 7123 - <https://tools.ietf.org/html/rfc7123>

IANA Protocol Numbers -

<https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml>

IPv6 Packet Filtering



Much more important in IPv6

+

Common IPv4 Practices

+

New IPv6 Considerations

End to End needs filtering

ICMPv6 should be wisely filtered

Filtering adapted to IPv6: EHs, TMs



Filtering IPv6 Traffic

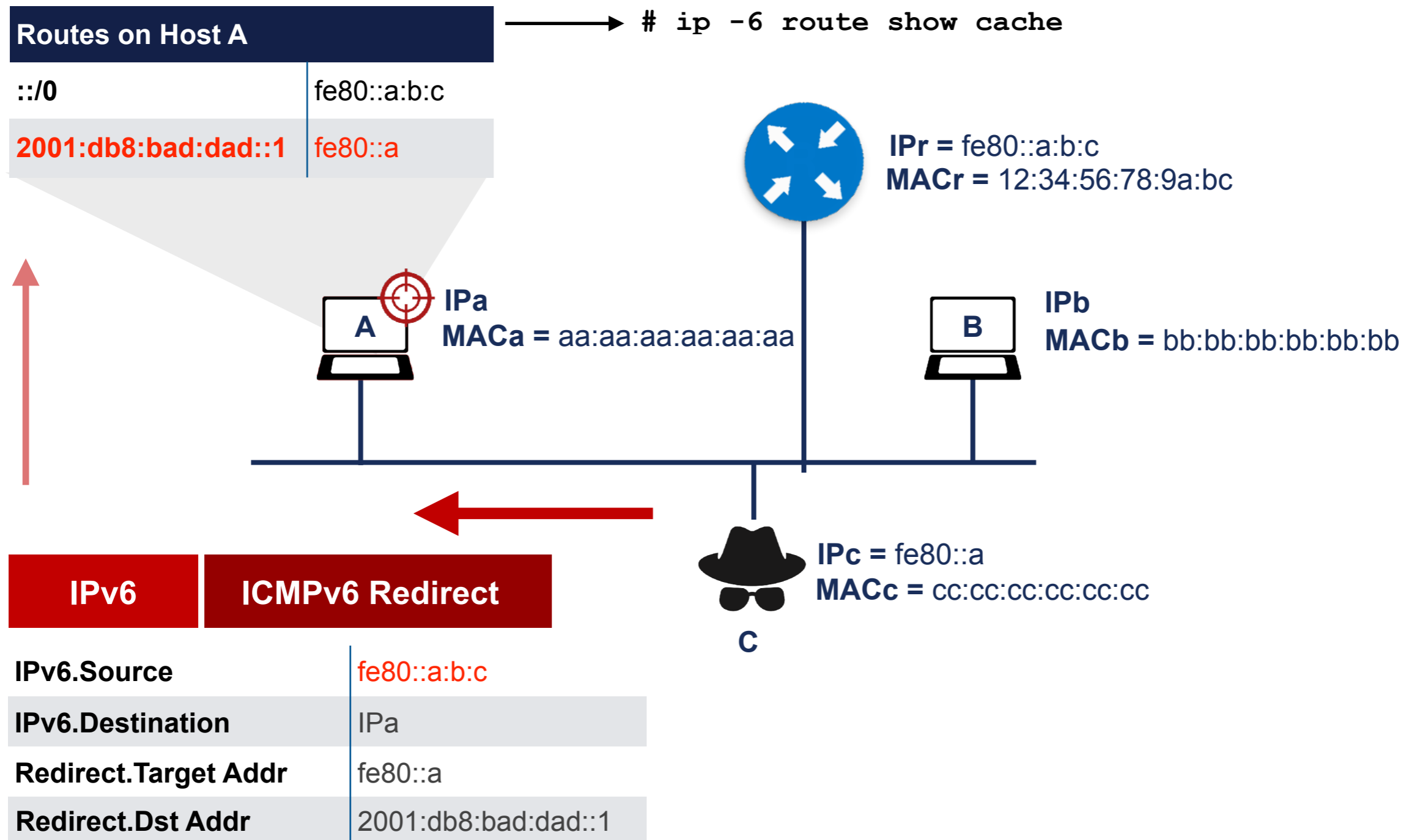
Exercise 4.1

Exercise 4.1 IPv6 Packet Filtering



- **Description:** Configure IPv6 packet filters
- **Goals:**
 - Understand IPv6 packet filtering
 - Learn how to use ip6tables on Linux hosts
- **Time:** 20 minutes
- **Tasks:**
 - Configure IPv6 packet filtering rules

4.1: IPv6 Packet Filtering - Redirect





Internet Wide IPv6 Security

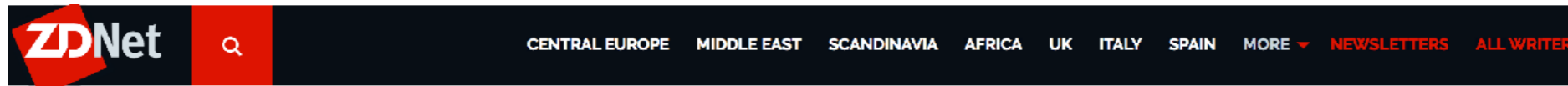
Section 5



DDoS

Section 5.1

DDoS attacks in IPv6?



JUST IN INTEL CHIP FLAW LETS HACKERS EASILY HIJACK FLEETS OF PCS

First IPv6 Distributed Denial of Service Internet attacks seen

You know IPv6 must finally be making it: The first IPv6 Distributed Denial of Service Internet attacks have been spotted in the wild.



By Steven J. Vaughan-Nichols for Networking February 20, 2012 - 14:48 GMT (14:48 GMT) | Topic: Networking



SIGN IN

The Register®



{* NETWORKS *}

It's begun: 'First' IPv6 denial-of-service attack puts IT bods on notice

Internet engineers warn this is only the beginning

Kieren McCarthy in San Francisco

Sat 3 Mar 2018 // 09:30 UTC

DDoS factors related with IPv6



Using lots of hosts



Using outdated firmware





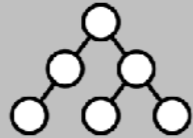


Poor (or no) security measures



DDoS factors related with IPv6



	Filter traffic Don't allow access to all IPv6 addresses
	Update firmware
	Use security measures for IPv6
	Ingress / Egress filtering and RPF
	Hierarchical IPv6 address assignment





IPv6 Transition Mechanisms

Section 5.2

Temporary solution...



With security risks!



- In IPv4-only infrastructure expect **dual-stack hosts**:
 - VPNs or tunnels
 - Undesired local IPv6 traffic
 - Automatic Transition Mechanisms
 - Problems with rogue RAs



Dual-stack



Bigger attack surface

GUA Addresses

Use one IP version to attack the other

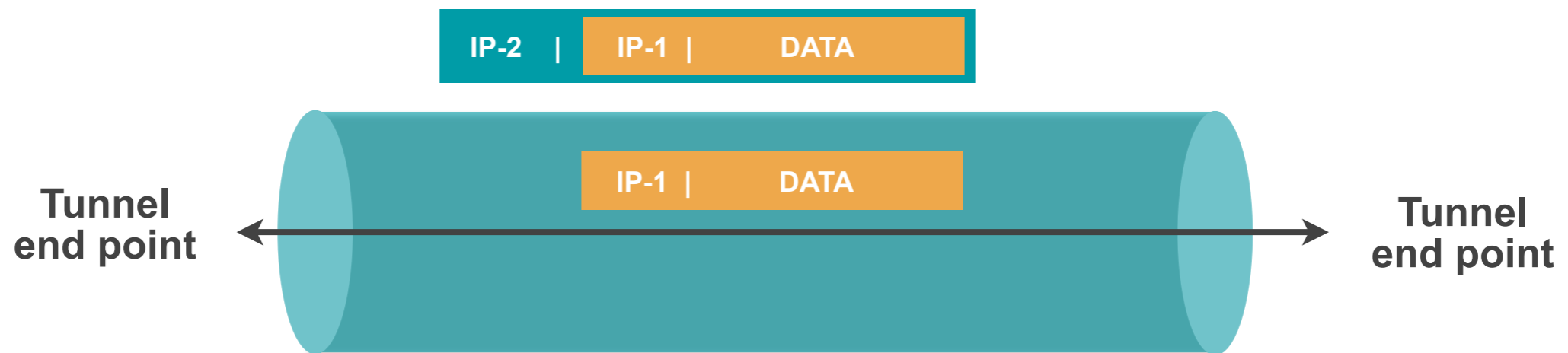


Protect IPv6 at the same level as IPv4

Filter end-to-end IPv6 properly

Don't trust "IPv4-only"

Tunnelling



Attackers need knowledge of

- Version of IP-1 and IP-2
- Tunnel end points addresses
- Tunneling protocol

To create tailor-made packets for

- Traffic Injection
- Unauthorised use
- Reflection attack
- Loop attack



Solutions

- Filtering
- Authentication

Translation



IPSec can't be used end-to-end

DNSSEC can't be used with DNS64

Reflection attack

IP pool depletion attack

**ALG (Application Level Gateway)
CPU Attack**



Must support filtering

**Implementations should protect
themselves against exhaustion
attacks**



IPv6 Security Tips and Tools

Section 6

Introduction



1

Best security tool is knowledge

2

IPv6 security is a moving target

3

IPv6 is happening: need to know about IPv6 security

4

Cybersecurity challenge: Scalability
IPv6 is also responsible for Internet growth

Tips



- IPv6 quite similar to IPv4, many reusable practices
- IPv6 security compared with IPv4:

No changes with IPv6

Changes with IPv6

New IPv6 issues

Up to date information



<i>Information category</i>	Standardisation Bodies	Vulnerabilities Databases	Security Tools	Cybersecurity Organisations	Vendors	Public Forums
<i>Sub-categories</i>	IETF, 3GPP, Broadband Forum		Vulnerability Scanners	CSIRTs / CERTs Gov. / LEAs		Mailing Lists Groups of Interest Security Events
<i>Information in this category</i>	Security considerations Protocol updates Security recommendations	Vulnerability ID (CVE-ID, other) Severity (CVSS, other) Description Affected systems Solutions and workarounds	Vulnerability ID (CVE-ID, other) Severity (CVSS, other) Description Affected systems Solutions and workarounds Affected devices in your network	Vulnerability ID (CVE-ID, other) Severity (CVSS, other) Description Affected systems Solutions and workarounds "0 Day" vulnerabilities	Vulnerability ID (CVE-ID, other) Severity (CVSS, other) Description Affected systems Solutions and workarounds "0 Day" vulnerabilities	"0 Day" vulnerabilities News Trends Lessons learned
<i>Examples</i>	RFCs, I-Ds	NVD, CVE	OpenVAS	CERT-EU ENISA EUROPOL/EC3	Cisco, Juniper, MS, Kaspersky, etc.	NOGs, IETF, IPv6 Hackers, Reddit, Troopers, etc.

Examples



Manual

CVE

cve.mitre.org/cve/search_cve_list.html

Search for: **ICMPv6 windows**

NVD

<https://nvd.nist.gov/vuln/search>

Search for: **CVE-2020-16899**

Go to vendor's link

Automated

OpenVAS

Name ▼		Status	Reports	Last Report	Severity
Windows Workgroup Test	↻	Stopped at 2 %	1		
Windows Domain Test	↻	Stopped at 2 %	1		
DMZ Mail Scan	↻	Container			
EulerOS Scan	↻	Stopped at 22 %	74	Thu, Dec 26, 2019 6:00 AM UTC	10.0 (High)
TLS Map Scan	✍️ ↻	Done	1	Fri, Dec 27, 2019 1:38 PM UTC	0.0 (Log)
Metasploitable Test - GSM Master	↻	Done	1	Fri, Jan 3, 2020 11:29 AM UTC	10.0 (High)
DMZ Mail Scan 2	↻	New			
system discovery	↻	Done	1	Fri, Dec 20, 2019 10:29 AM UTC	0.0 (Log)

Homework



Go to NVD: <https://nvd.nist.gov/vuln/search>

Search for IPv6 + your vendor

Security Tools



Type	Can be used for	Examples
Packet Generators	Assessing IPv6 security	Scapy, nmap, Ostinato, TRex
	Testing implementations	
	Learning about protocols	
	Proof of concept of attacks/protocols	
Packet Sniffers/ Analyzers	Understanding attacks and security measures	tcpdump, Scapy, Wireshark, termshark
	Learning about protocols and implementations	
	Troubleshooting	
Specialised Toolkits	Assessing IPv6 security	THC-IPV6, The IPv6 Toolkit, Ettercap
	Learning about protocols and implementations	
	Proof of concept of attacks/protocols	
	Learn about new attacks	
Scanners	Finding devices and information	nmap, OpenVAS
	Proactively protect against vulnerabilities	
IDS/IPS	Understanding attacks and security measures	Snort, Suricata, Zeek
	Learning about protocols and implementations	
	Assessing IPv6 security	
	Learn about new attacks	

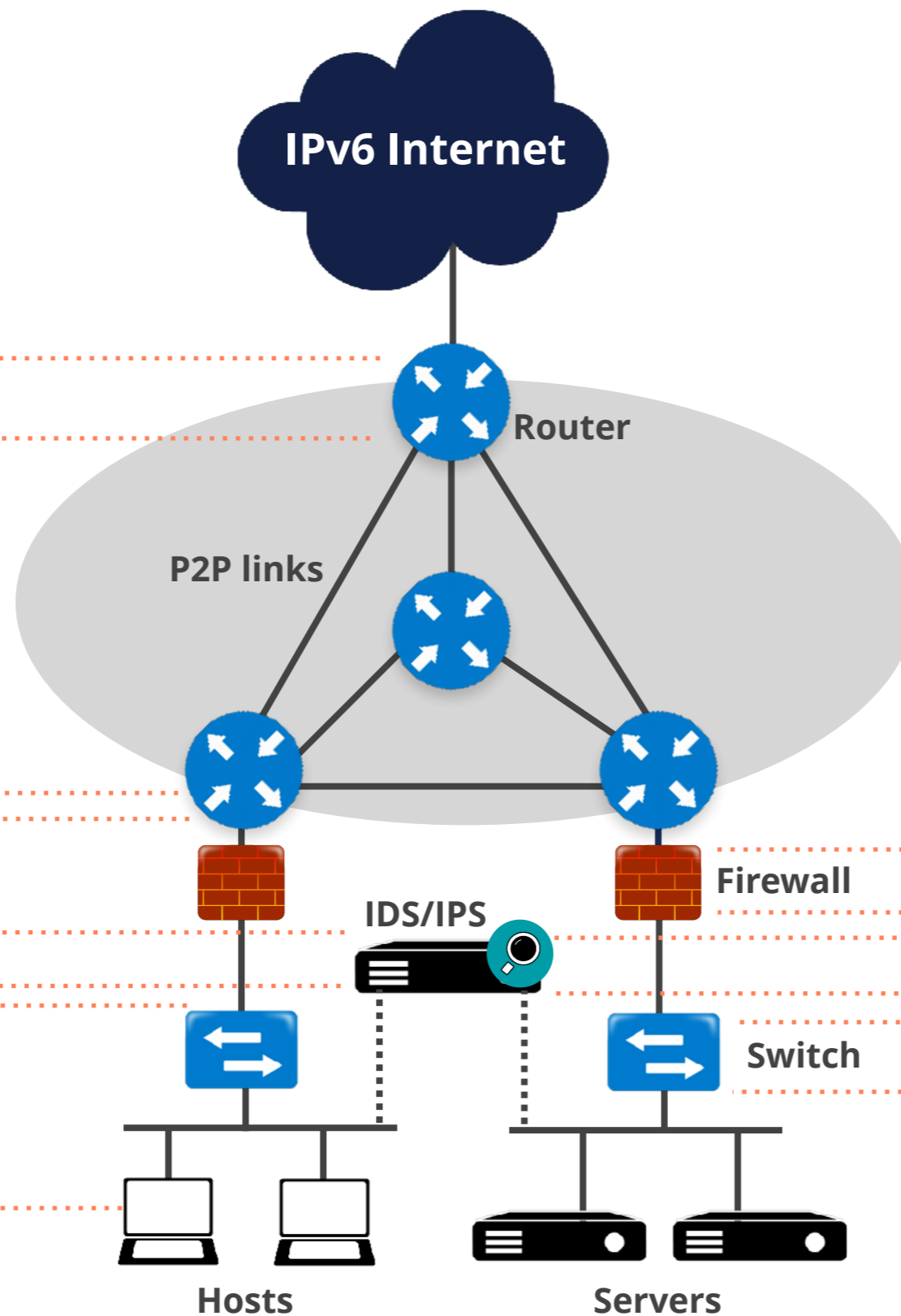
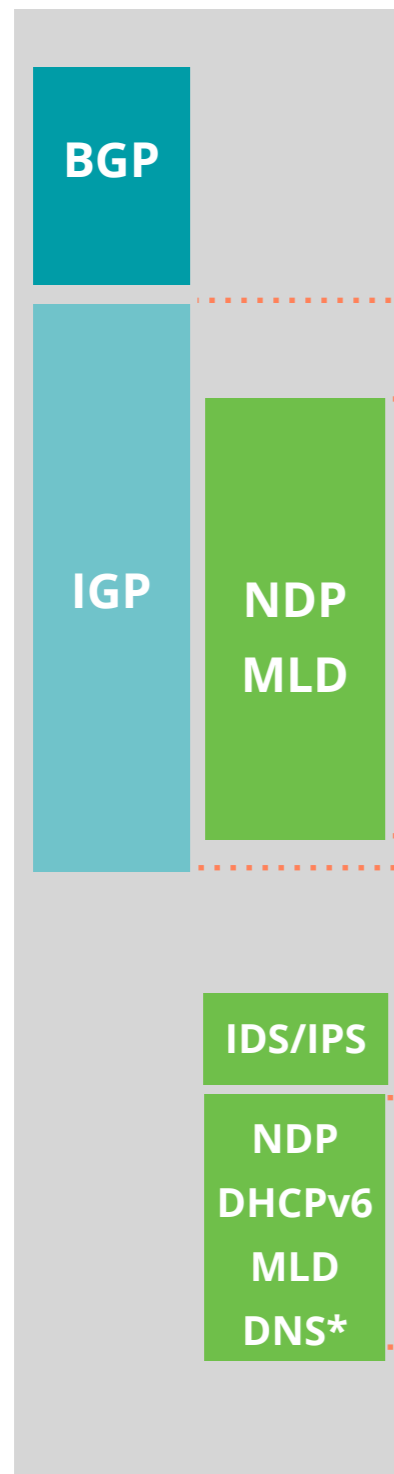


Devices Categories (RIPE-772)

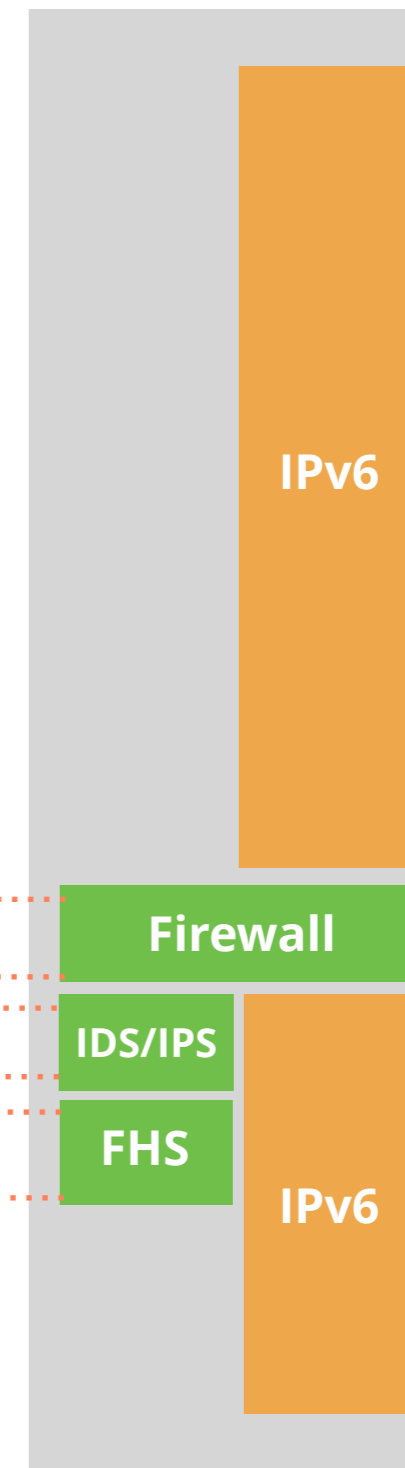
Host	Switch	Router	Security Equipment	CPE
IPSec (if needed)	HOST +	HOST +	HOST +	Router
RH0 [RFC5095]	IPv6 ACLs	Ingress Filtering and RPF	Header chain [RFC7112]	Security Equipment
Overlapping Frags [RFC5722]	FHS	DHCPv6 Relay [RFC8213]	Support EHs Inspection	DHCPv6 Server Privacy Issues
Atomic Fragments [RFC6946]	RA-Guard [RFC6105]	OSPFv3	ICMPv6 fine grained filtering	
NDP Fragmentation [RFC6980]	DHCPv6 guard	Auth. [RFC4552] or / and [RFC7166]	Encapsulated Traffic Inspection	
Header chain [RFC7112]	IPv6 snooping	IS-IS [RFC5310] or, less preferred, [RFC5304]	IPv6 Traffic Filtering	
Stable IIDs [RFC8064][RFC7217][RFC7136]	IPv6 source / prefix guard	MBGP		
Temp. Address Extensions [RFC8981]	IPv6 destination guard	TCP-AO [RFC5925]		
Disable if not used: LLMNR, mDNS, DNS-SD, transition mechanisms	MLD snooping [RFC4541]	MD5 Signature Option [RFC2385] <i>Obsoleted</i>		
	DHCPv6-Shield [RFC7610]	MBGP Bogon prefix filtering		



Control Plane Security



Forwarding Plane Security



* All Name resolution related protocols

What's Next in IPv6



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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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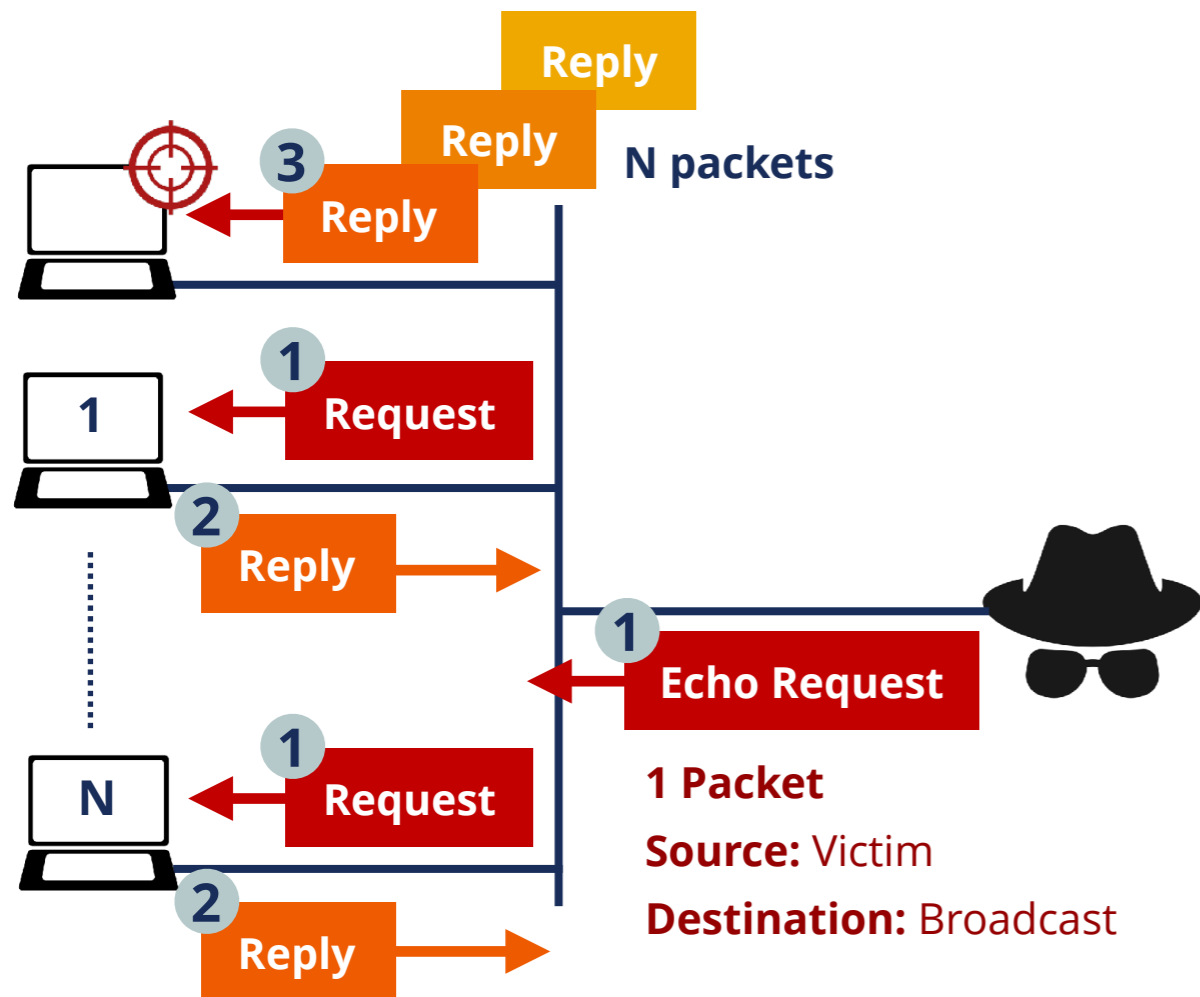
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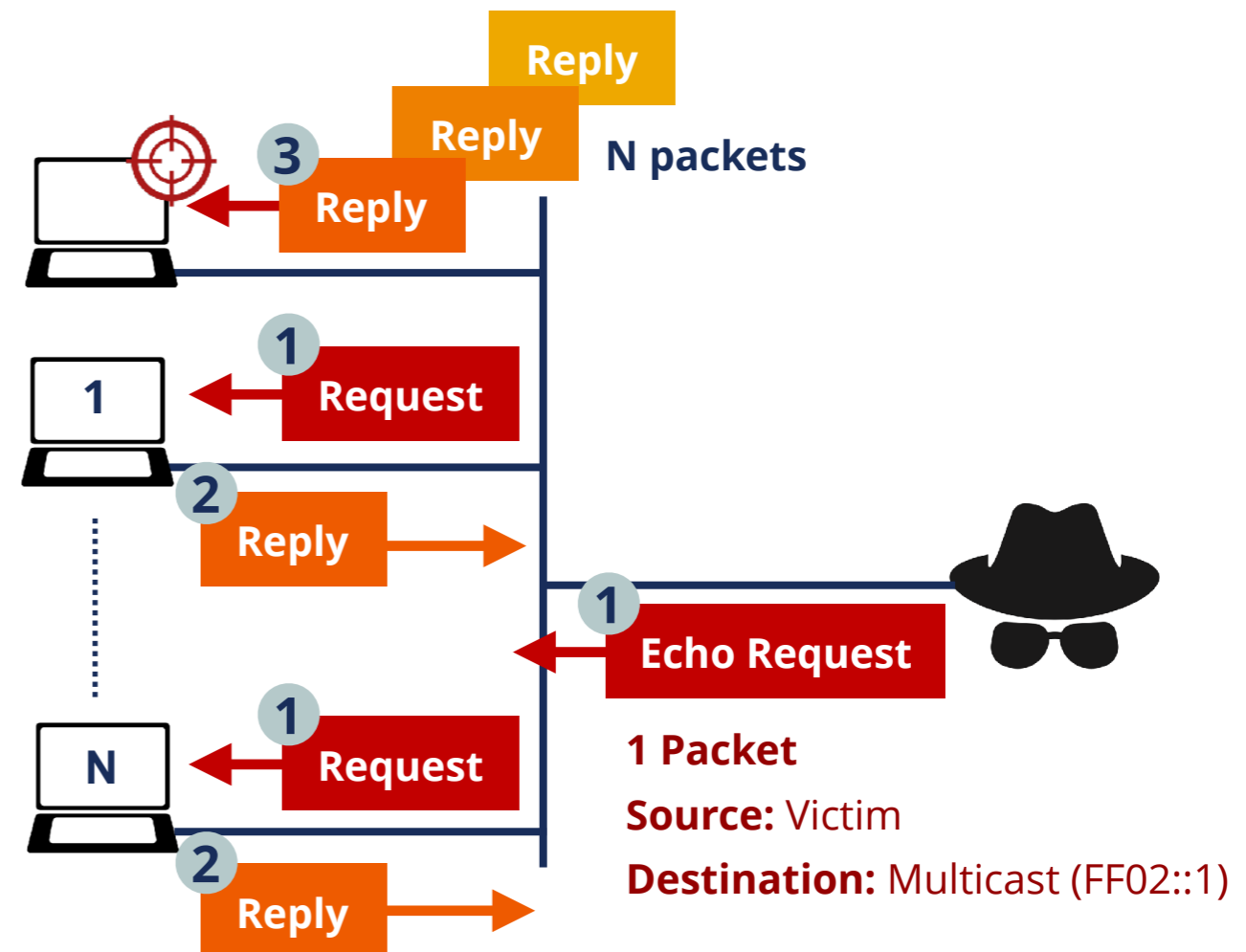




Extra: Smurf Attack



IPv4



IPv6

Extra: DoS / DDoS



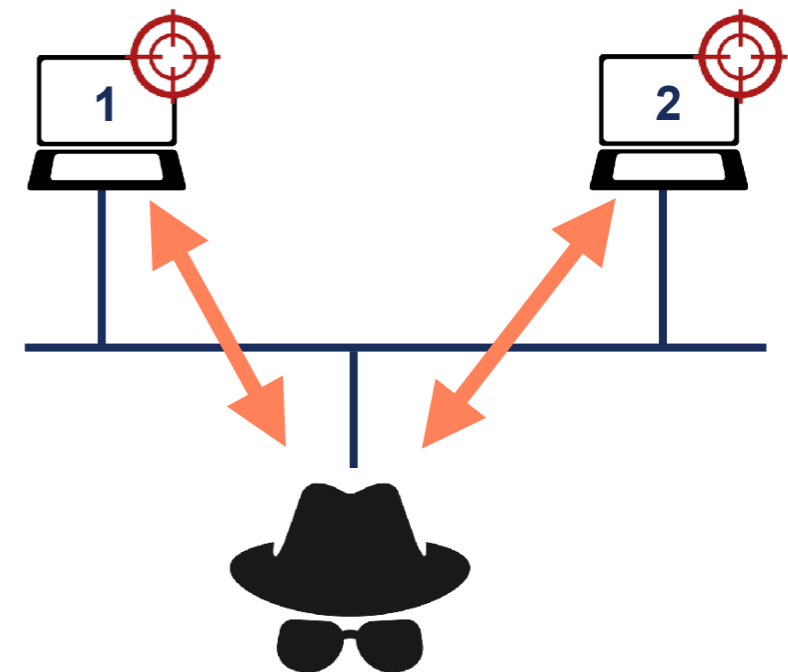
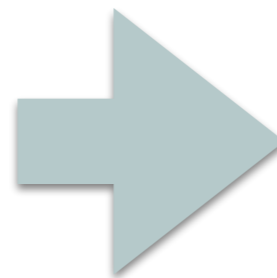
- **DoS** (Denial of Service): Type of attack that is able to make a service or protocol to stop working.
- **DDoS** (Distributed DoS): Is a type of DoS attack that is performed from several devices.
- Example: send too much traffic to a link, so that the routers can't handle it, overloading them



Extra: MITM



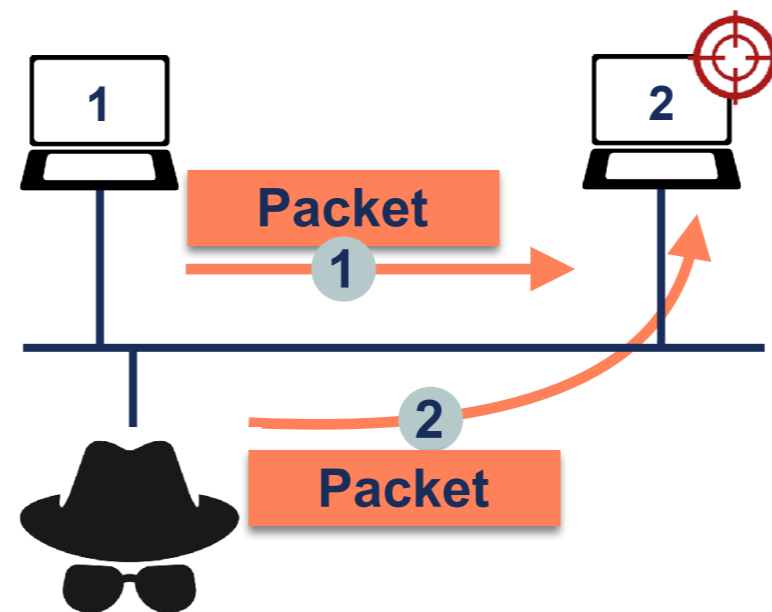
- Man-In-The-Middle attack:
 - The attacker is able to be on the path of the packets



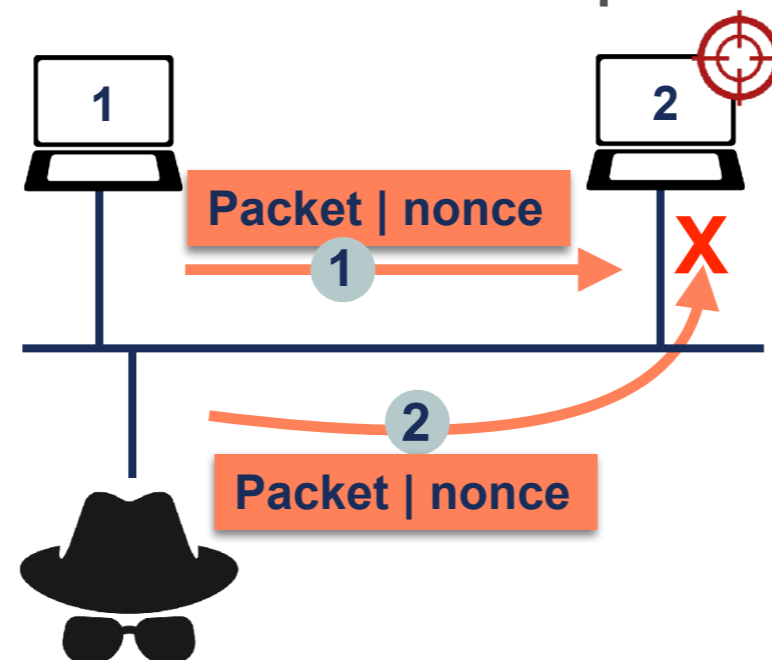
Extra: Replay Attacks



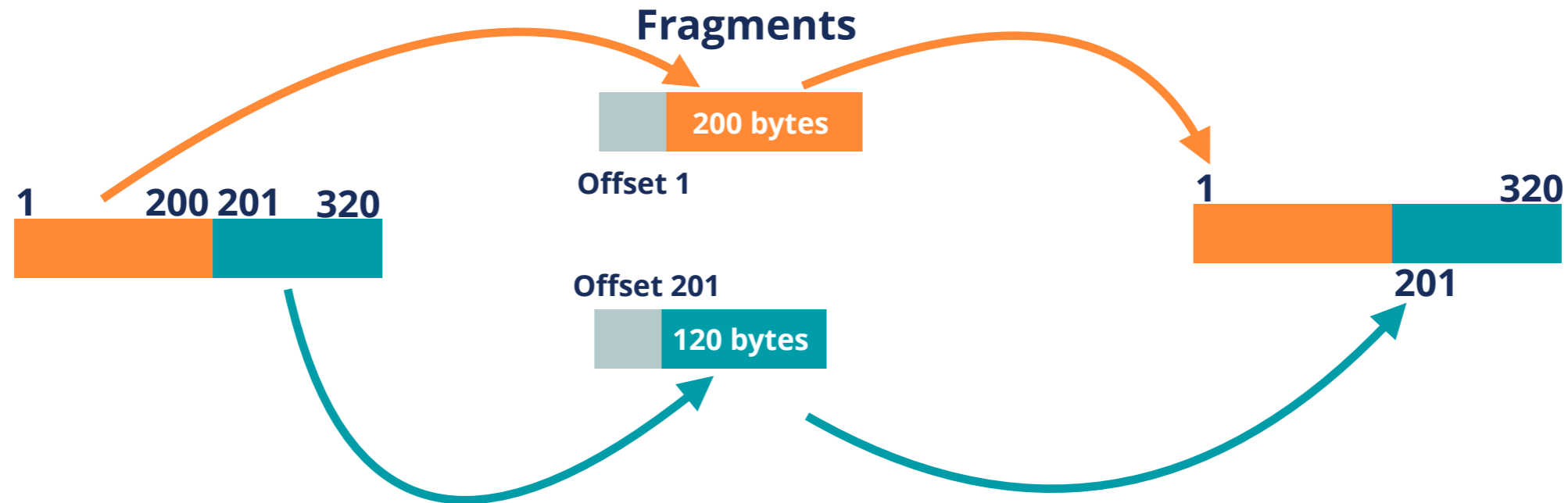
- Replay Attacks consist in sending again a previous packet



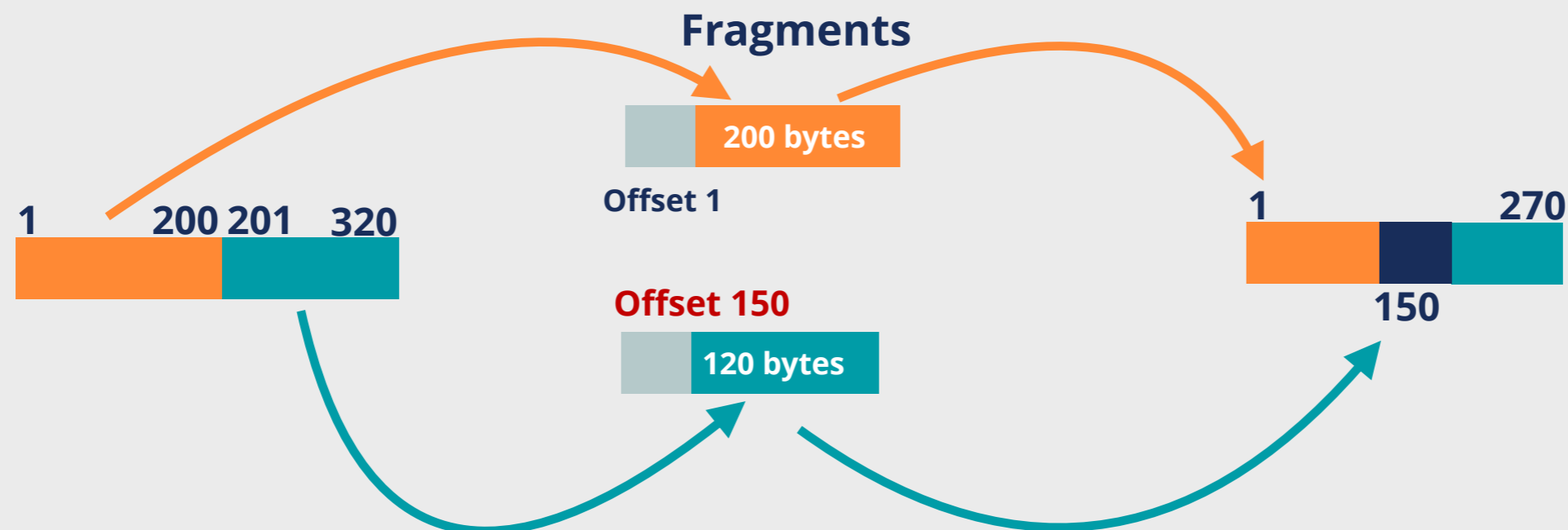
- Solution: nonce or timestamp (makes packet unique)



Extra: Overlapping Fragments



Normal fragments offset say where the data goes

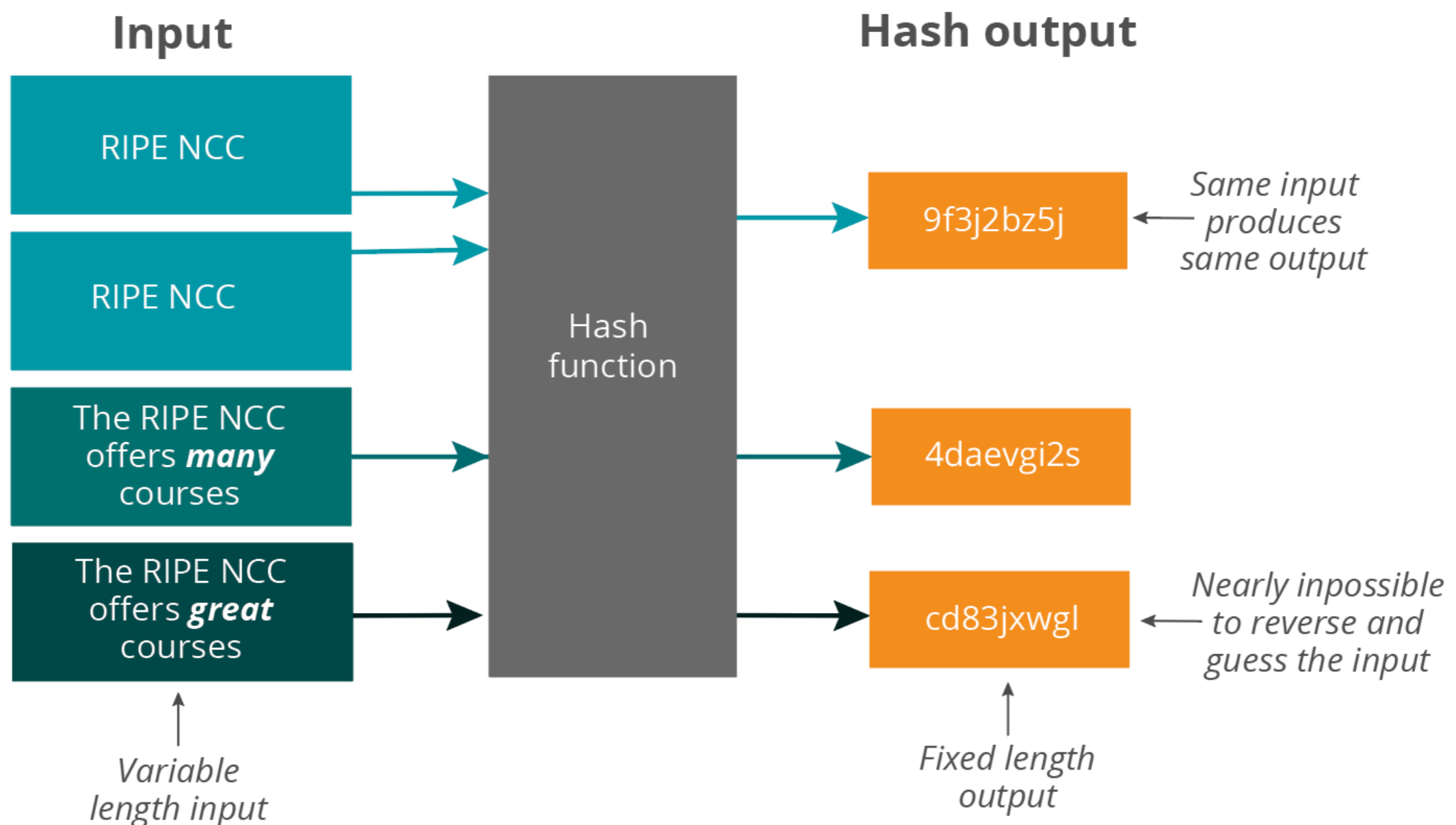


Overlapping fragments have wrong offset values



Extra: Hash Function

- **Input:** Variable length bit string, for example a text
- **Output:** Fixed length bit string, represented by a series of characters





Extra Reference Slides



IPv6 Associated Protocols Security

Section 3



IPv6 Routing protocols

Section 3.6



THIS SECTION

Authentication of
neighbors/peers

Securing routing
updates

NOT COVERED

Route filtering

SAME AS IPv4

Router Hardening



Neighbors/Peers Authentication



	Authentication Options	Comments
RIPng	<ul style="list-style-type: none">— No authentication— IPsec (general recommendation)	<ul style="list-style-type: none">— RIPv2-like MD5 no longer available— IPsec not available in practice
OSPFv3	<ul style="list-style-type: none">— IPsec [RFC4552]— Authentication Trailer [RFC7166]	<ul style="list-style-type: none">— ESP or AH. Manual keys— Hash of OSPFv3 values. Shared key
IS-IS	<ul style="list-style-type: none">— HMAC-MD5 [RFC5304]— HMAC-SHA [RFC5310]	<ul style="list-style-type: none">— MD5 not recommended— Many SHA, or any other hash
MBGP	<ul style="list-style-type: none">— TCP MD5 Signature Option [RFC2385]— TCP-AO [RFC5925]	<ul style="list-style-type: none">— Protects TCP. Available. Obsoleted— Protects TCP. Recommended

Securing Routing Updates



- IPsec is a general solution for IPv6 communication
 - In practice not easy to use
- OSPFv3 specifically states [RFC4552]:
 1. ESP **must** be used
 2. Manual Keying
- Other protocols: **No options available**



Conclusions



- Security options available for IPv6 routing protocols
- Try to use them:
 - Depending on the protocol you use
 - At least at the same level as IPv4



IPv6 Filtering

Section 4



Filtering IPv6 Routing Information

Section 4.2

IPv6 BGP Bogon Prefix Filtering



Use	Prefix
Default	::/0
Unspecified Address	::/128
Loopback Address	::1/128
IPv4-mapped Addresses	::ffff:0.0.0.0/96
IPv4-compatible Addresses (deprecated)	::/96
Link-local Addresses	fe80::/10
Site-local Addresses (deprecated)	fec0::/10
Unique-local addresses	fc00::/7
Multicast Addresses	ff00::/8
Documentation addresses	2001:db8::/32
6Bone Addresses (deprecated)	3ffe::/16, 5f00::/8
ORCHID	2001:10::/28

Team Cymru: <https://team-cymru.com/community-services/bogon-reference/>



MANRS (www.manrs.org)



- Secure and Resilient Internet is a **collaborative** effort
- **Concrete actions** for: network operators, IXPs, CDN/Cloud providers
- **IPv6** and **IPv4** BGP



MANRS Network Operators Actions



	Facilitate Global Coordination	Keep contact information updated: RIPE DB, LIR Portal, PeeringDB		
	Facilitate Routing Information Validation	Route Objects	RPKI	Document Policy
	Prevent IP Spoofing	uRPF	Ingress Filtering [RFC2827][RFC3704]	
	Prevent Incorrect Routing Information	Define Routing Policy	Check BGP Announcements (RPKI / ROAs)	
		BGP Bogon Filtering	BGPsec (?)	



Internet Wide IPv6

Security

Section 5



BGP Hijacking

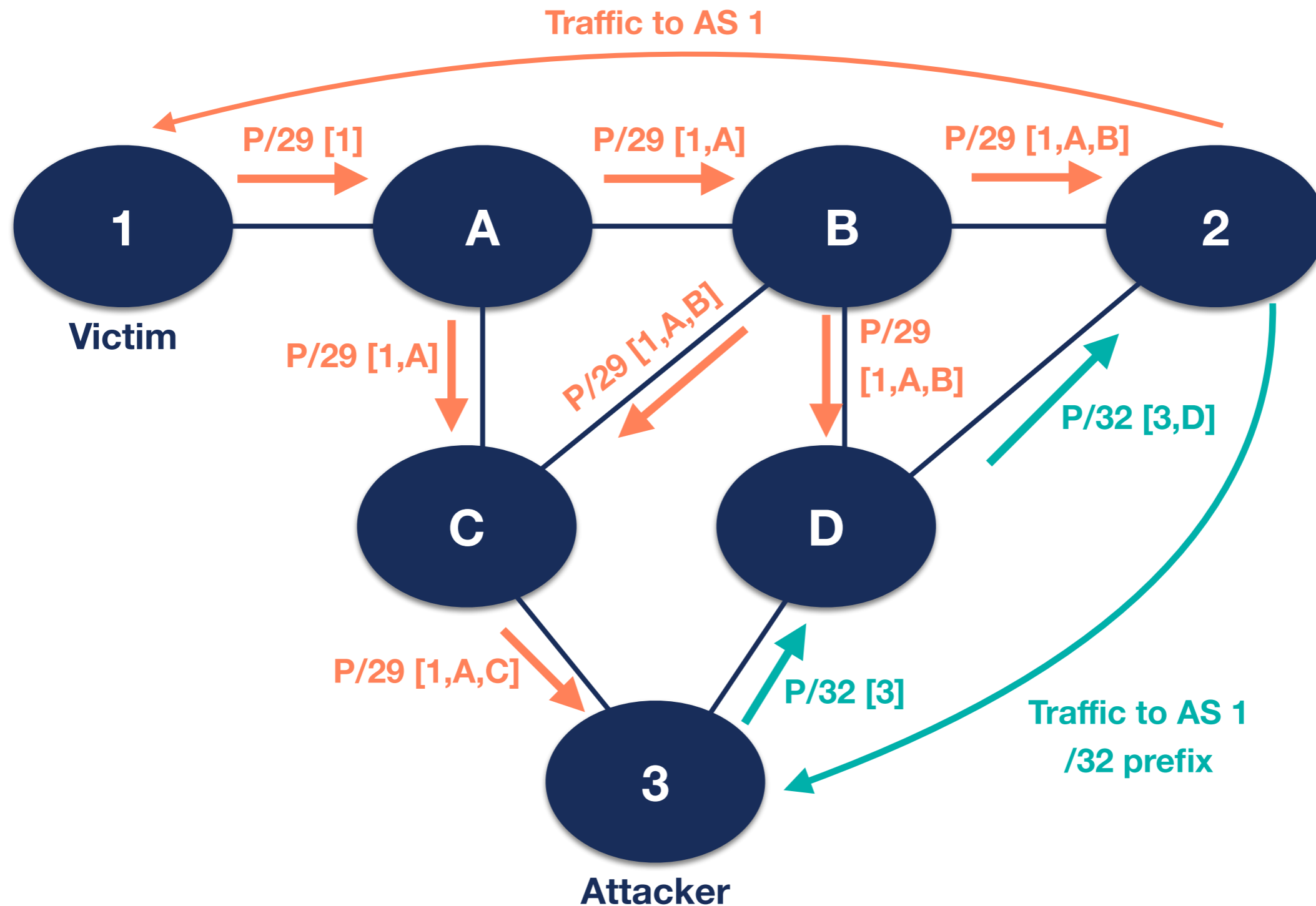
Section 5.3

Introduction

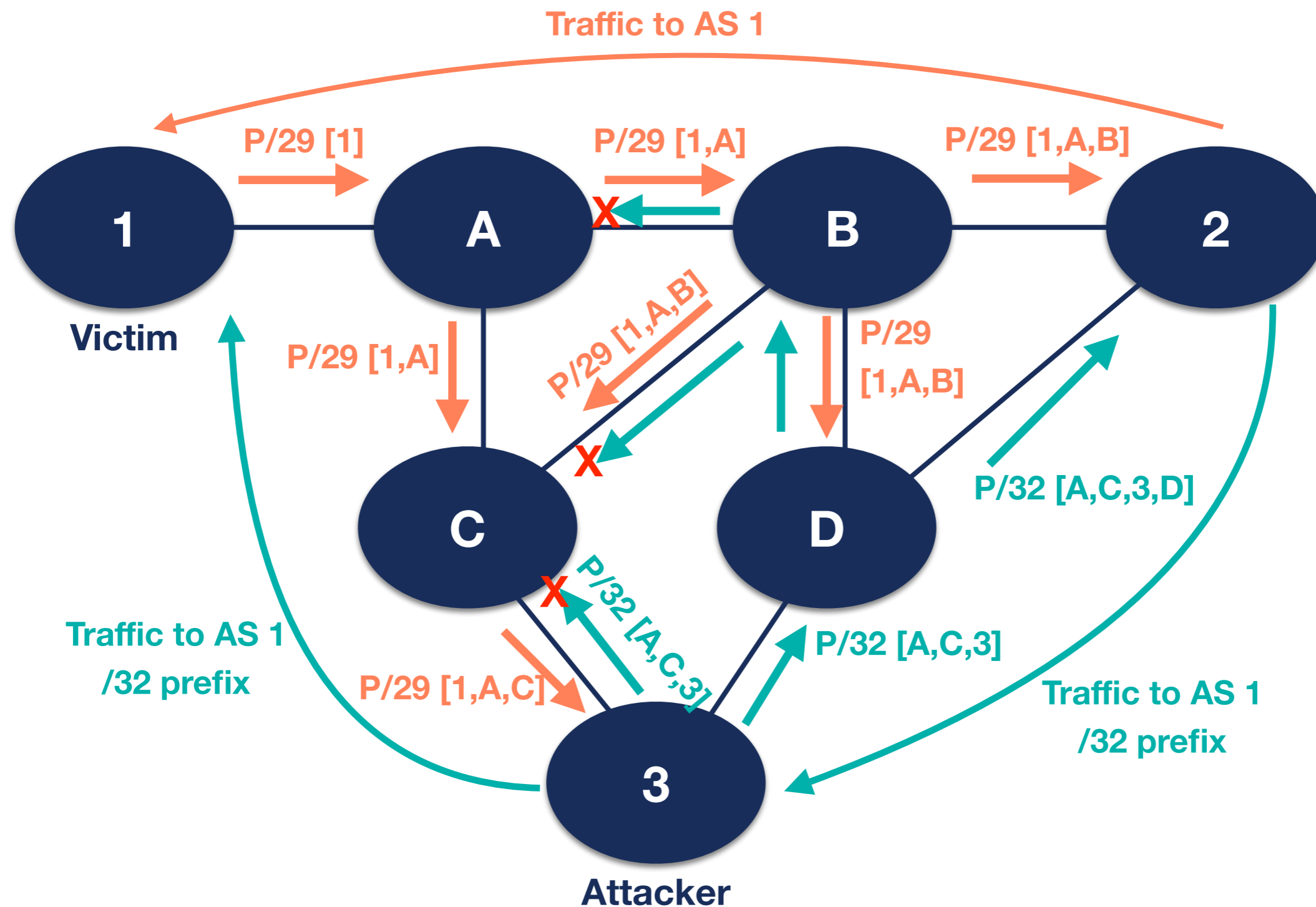


- BGP is a control plane protocol (application level)
- Hijack techniques same in IPv6 and IPv4
- Protection techniques as well

BGP Prefix Hijack - Fake Origin



BGP MITM - Fake AS-path



BGP Hijack: Solutions



- To secure BGP for IPv6:
 1. Route Filtering
 2. RPKI
 3. BGPsec (in the future)
- Temporary: More specific announcement

