RIPE NCC

RIPE NETWORK COORDINATION CENTRE

IPv6 Security Course Preview

RIPE 76

Alvaro Vives - Marseille - 14 May 2018

Overview

IPv6 Security Myths

Basic IPv6 Protocol Security

(Extension Headers, Addressing)

IPv6 Associated Protocols Security

(NDP, MLD)

Legend

Learning/ understanding

Attacker

Protecting

IPv6 Security Myths

IPv6 Security Myths

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 6434 - IPv6 Node Requirements: IPsec SHOULD
- IPSec available. Used for security in IPv6 protocols

IPv6 Security Myths

1 2 3 4 5 6 7 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 Myths

1 2 3 4 5 6 7 8

- 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 Myths

1 2 3 **4** 5 6 7 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 Myths

1 2 3 4 **5** 6 7 8

- 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 Myths

1 2 3 4 5 6 7 8

- It supports IPv6

Reason:

- Q: “Does it support IPv6?”
- A: “Yes, it supports IPv6”

Reality:

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

IPv6 Security Myths

1 2 3 4 5 6 7 8

- My network is IPv4 only
- IPv6 is not a security problem

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 Myths

1 2 3 4 5 6 7 **8**

- It’s 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

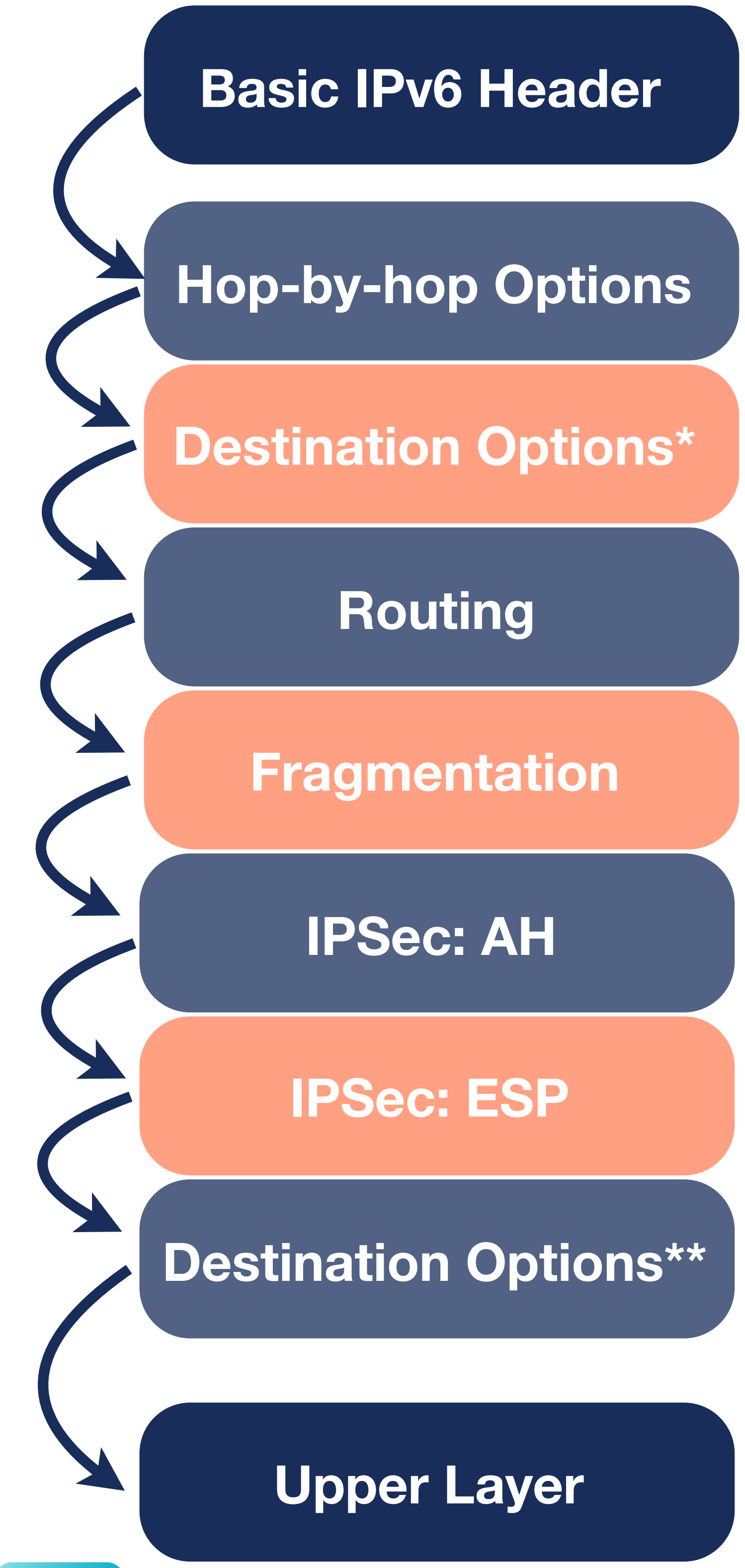
Conclusions

- 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

IPv6 Extension Headers

IPv6 Extension Headers (1)



Basic IPv6 Header

Hop-by-hop Options

Destination Options*

Routing

Fragmentation

IPSec: AH

IPSec: ESP

Destination Options**

Upper Layer

- Fixed: Types and order
- Flexible use
- Processed only at endpoints
  - Exceptions: Hop-by-hop (and Routing)
- Only appear once
  - Exception: Destination Options

* Options for IPs in routing header

** Options for destination IP

IPv6 Extension Headers (2)

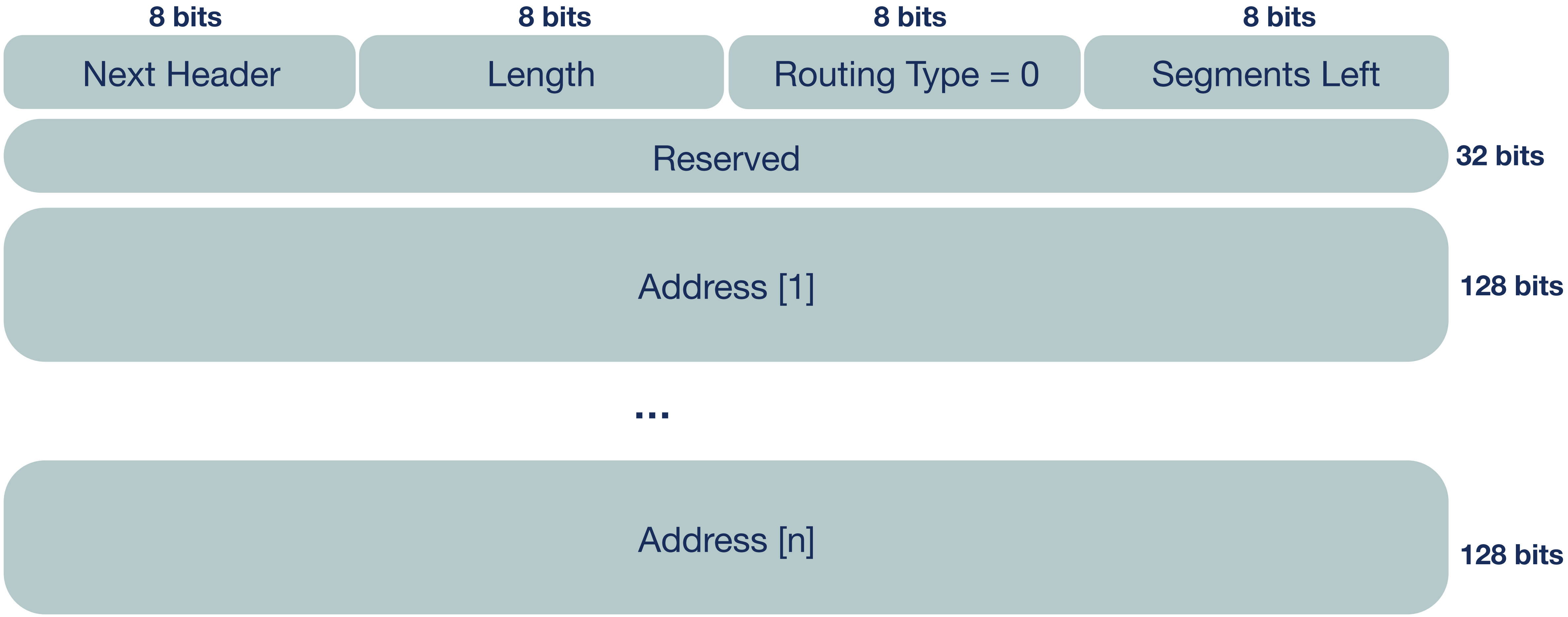
- Flexibility means complexity for security

- Security devices/software should be able to process the full chain of headers

- Firewalls:
  - Must deal with standard EHs
  - Able to filter based on EH

Extension Headers Threats (1)

- **Routing Header (Type 0)**: RH0 can be used for traffic amplification over a remote path
- **RH0 Deprecated** [RFC 5095]
  - RH1 deprecated, RH2 (MIPv6) & RH3 (RPL) still valid



8 bits | 8 bits | 8 bits | 8 bits

Next Header | Length | Routing Type = 0 | Segments Left

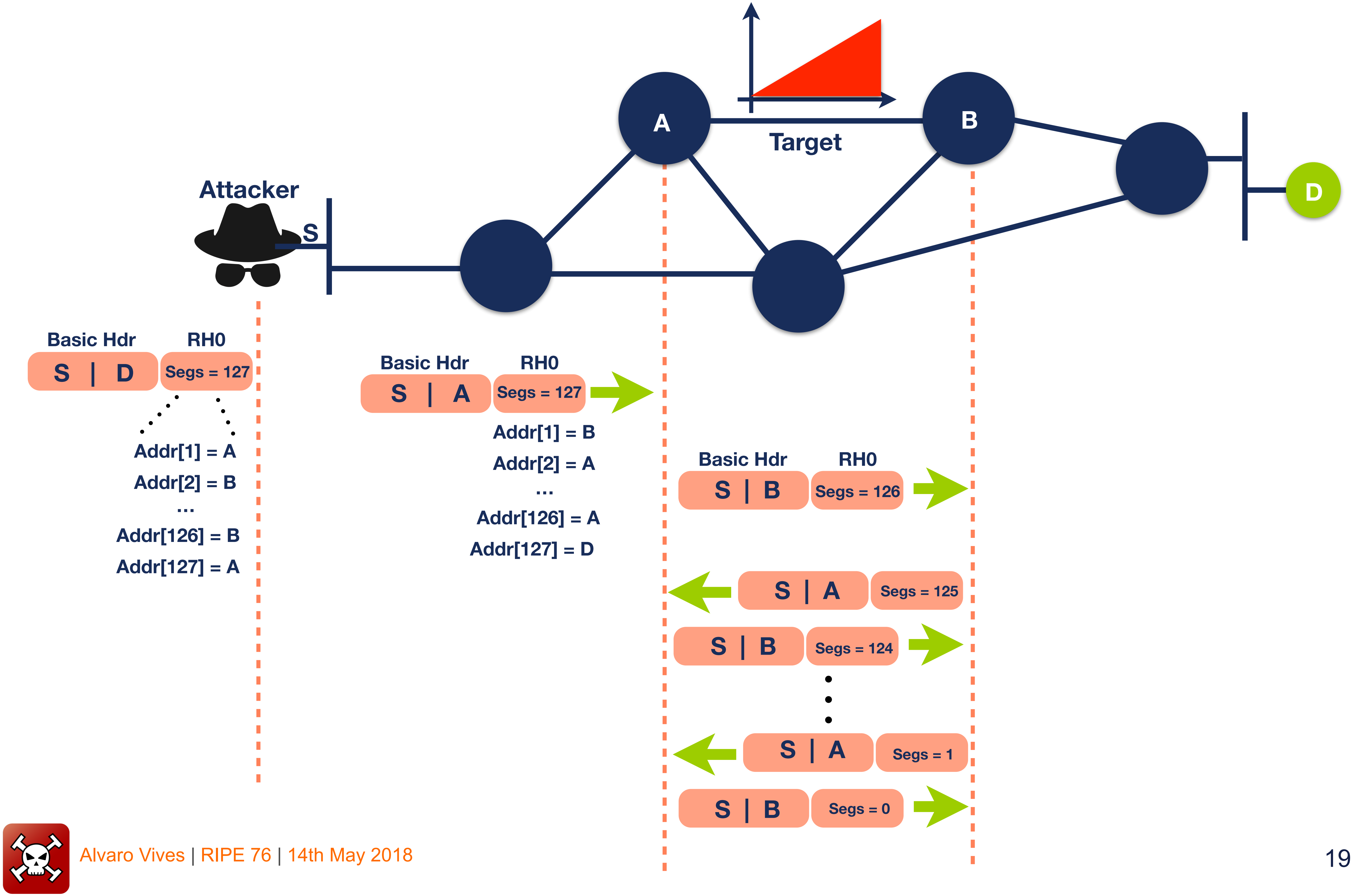
Reserved — 32 bits

Address [1] — 128 bits

...

Address [n] — 128 bits

Extension Headers Threats (2)



Basic Hdr RH0

S | D Segs = 127

Addr[1] = A

Addr[2] = B

...

Addr[126] = B

Addr[127] = A

Basic Hdr RH0

S | A Segs = 127

Addr[1] = B

Addr[2] = A

...

Addr[126] = A

Addr[127] = D

Basic Hdr RH0

S | B Segs = 126

S | A Segs = 125

S | B Segs = 124

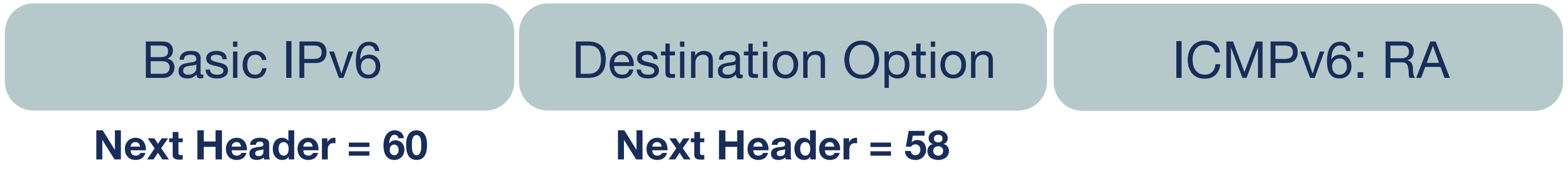
S | A Segs = 1

S | B Segs = 0

Extension Headers Threats (3)

- Trying to bypass security mechanisms
  - Example: fooling RA filtering (RA-Guard)

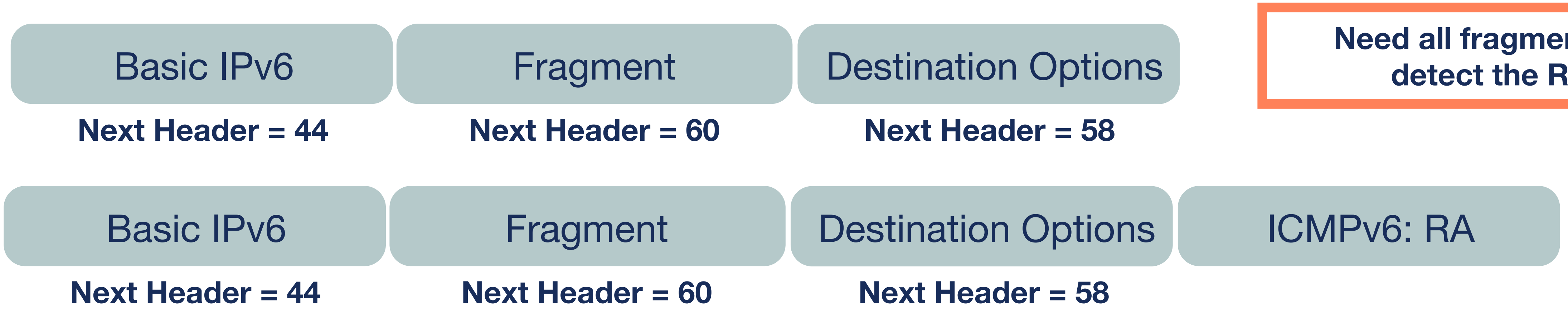
- Any EH



Basic IPv6	Destination Option	ICMPv6: RA
Next Header = 60	Next Header = 58	

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

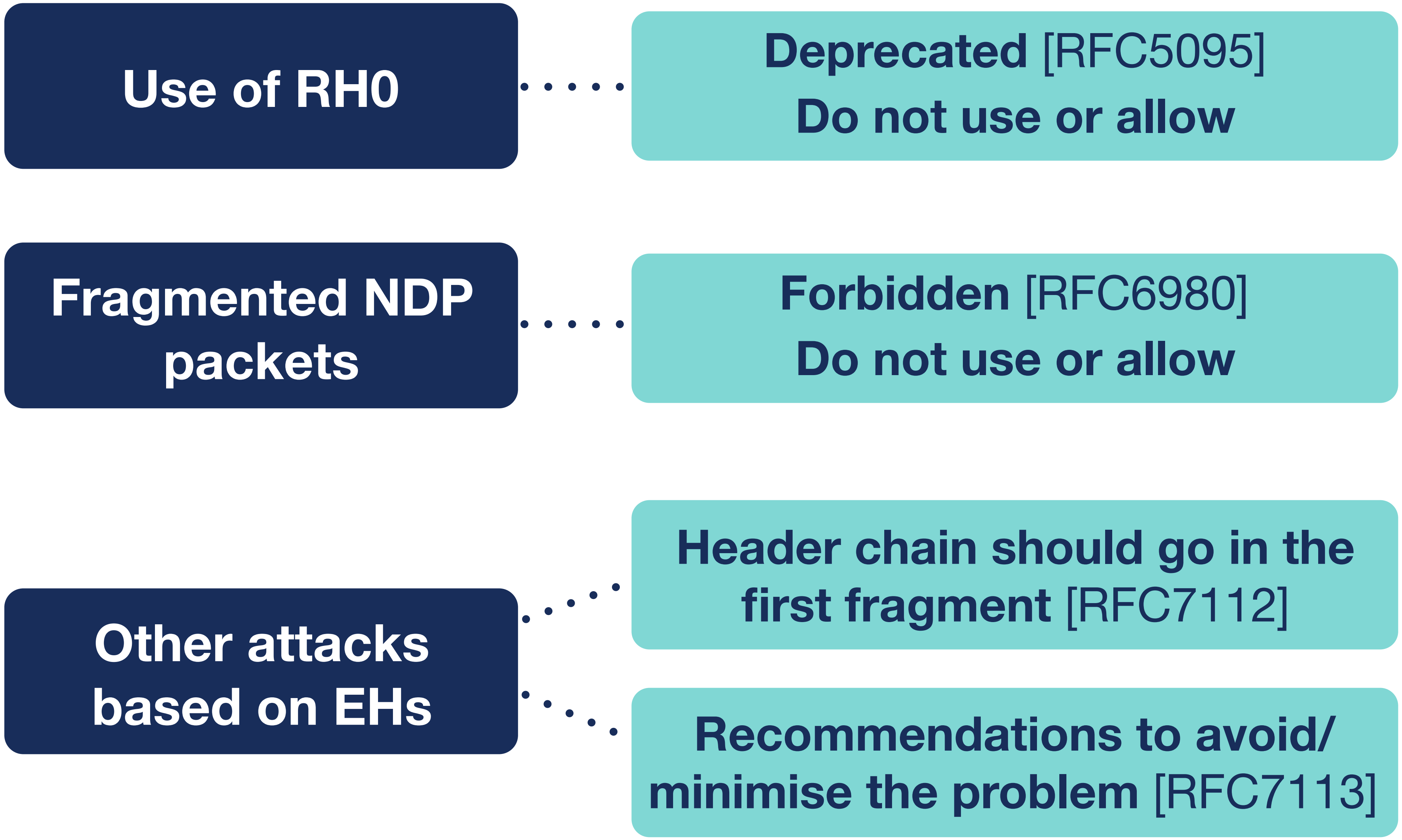
- Fragment EH



Basic IPv6	Fragment	Destination Options	
Next Header = 44	Next Header = 60	Next Header = 58	
Basic IPv6	Fragment	Destination Options	ICMPv6: RA
Next Header = 44	Next Header = 60	Next Header = 58	

Need all fragments to detect the RA

Extension Headers Solutions



Use of RH0

Deprecated [RFC5095]
Do not use or allow

Fragmented NDP packets

Forbidden [RFC6980]
Do not use or allow

Other attacks based on EHs

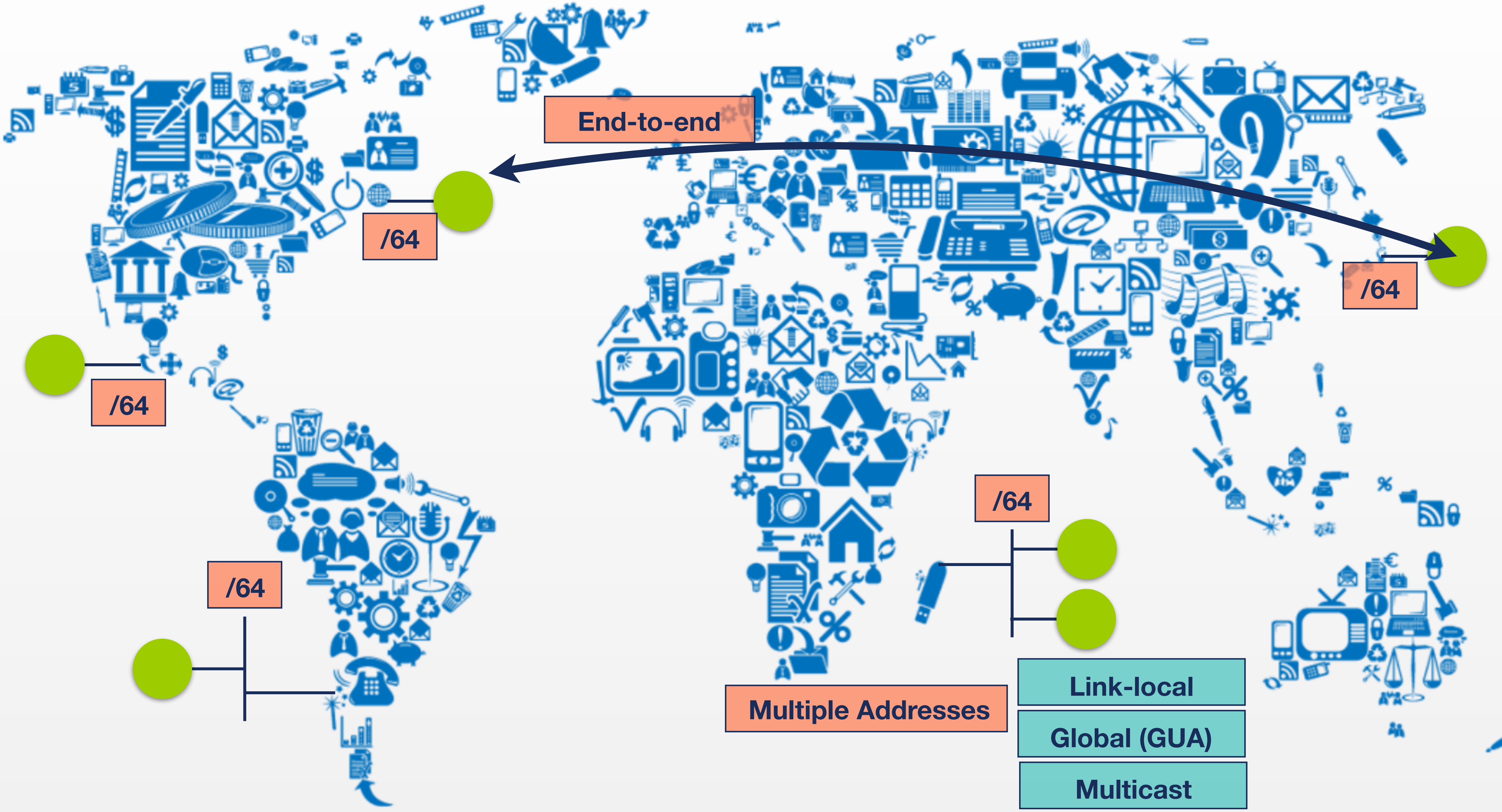
Header chain should go in the first fragment [RFC7112]

Recommendations to avoid/ minimise the problem [RFC7113]

- Require security tools to inspect Header Chain properly

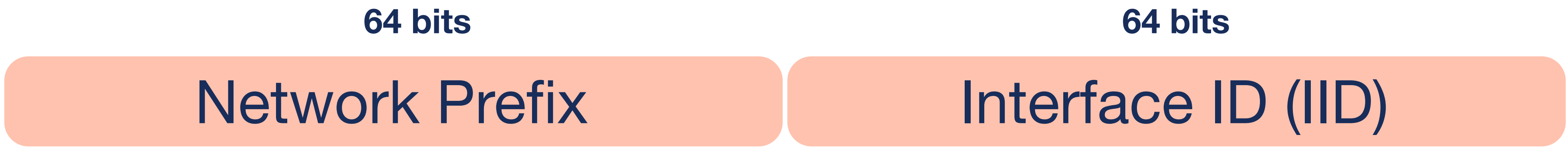
IPv6 Addressing Architecture

Introduction



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

IPv6 Network Scanning (1)



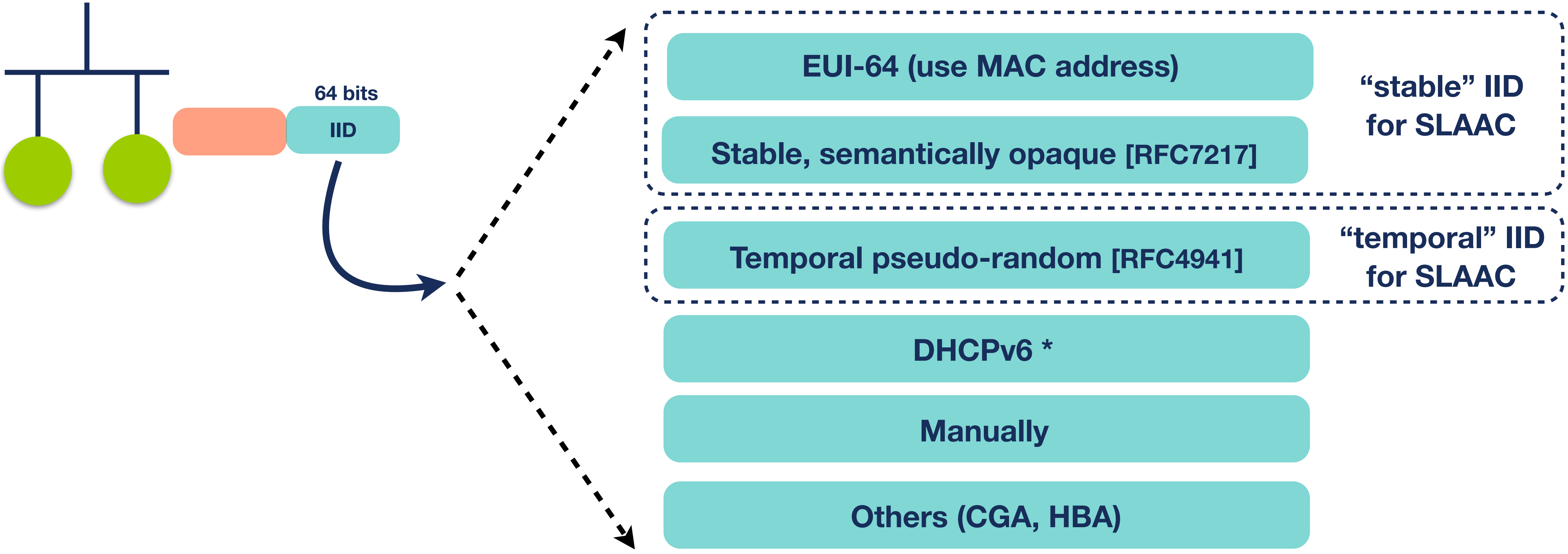
64 bits | 64 bits

Network Prefix | Interface ID (IID)

- Network Prefix determination (64 bits)
  - Common patterns in addressing plans
  - DNS direct and reverse resolution
  - Traceroute

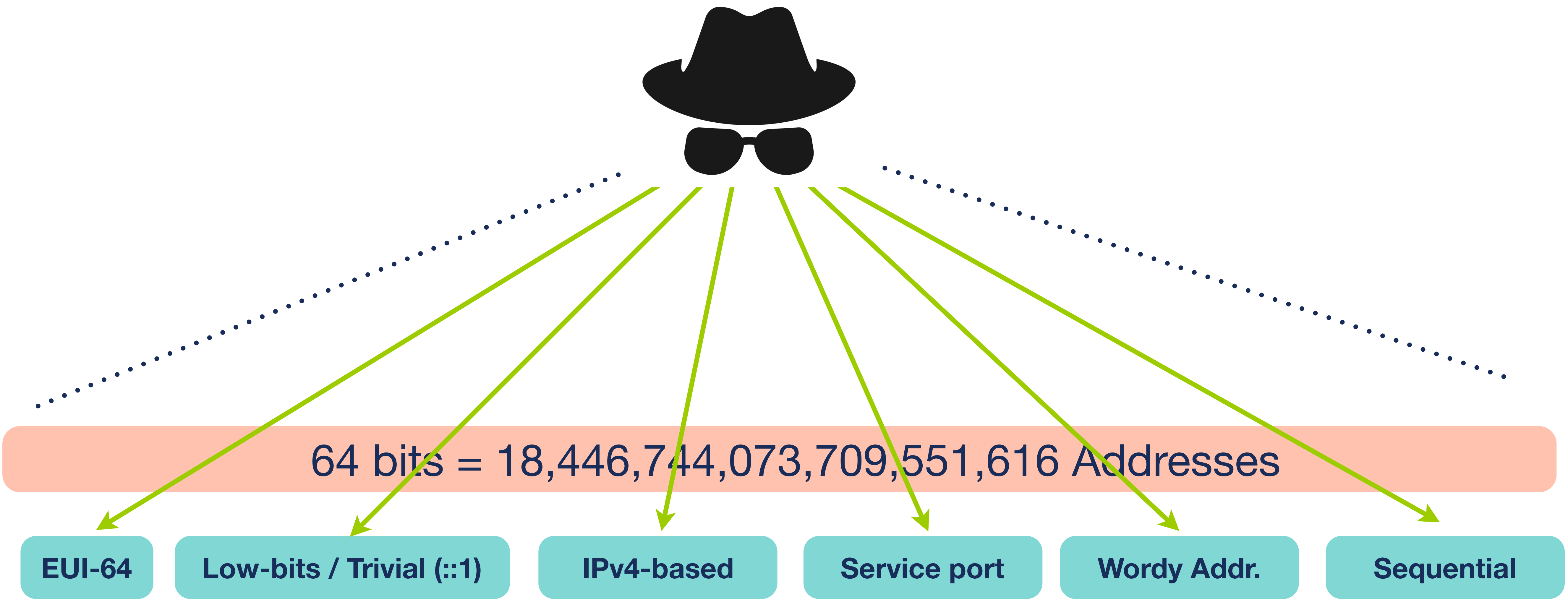
- IID determination (64 bits)
  - “brute force” no longer possible

IPv6 Network Scanning (2)



- IID generated by the node (* except DHCPv6)
- Consider IID bits “opaque”, no value or meaning [RFC7136]
  - How to generate [RFC7217]
  - This method is widely used and standardised [RFC8064]

IPv6 Network Scanning (3)



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

EUI-64

Low-bits / Trivial (::1)

IPv4-based

Service port

Wordy Addr.

Sequential

OUI: 24 bits
FFFE: 16 bits

2001:db8:1::10.0.0.5

2001:db8:1::80

2001:db8::bad:cafe

Security Tips

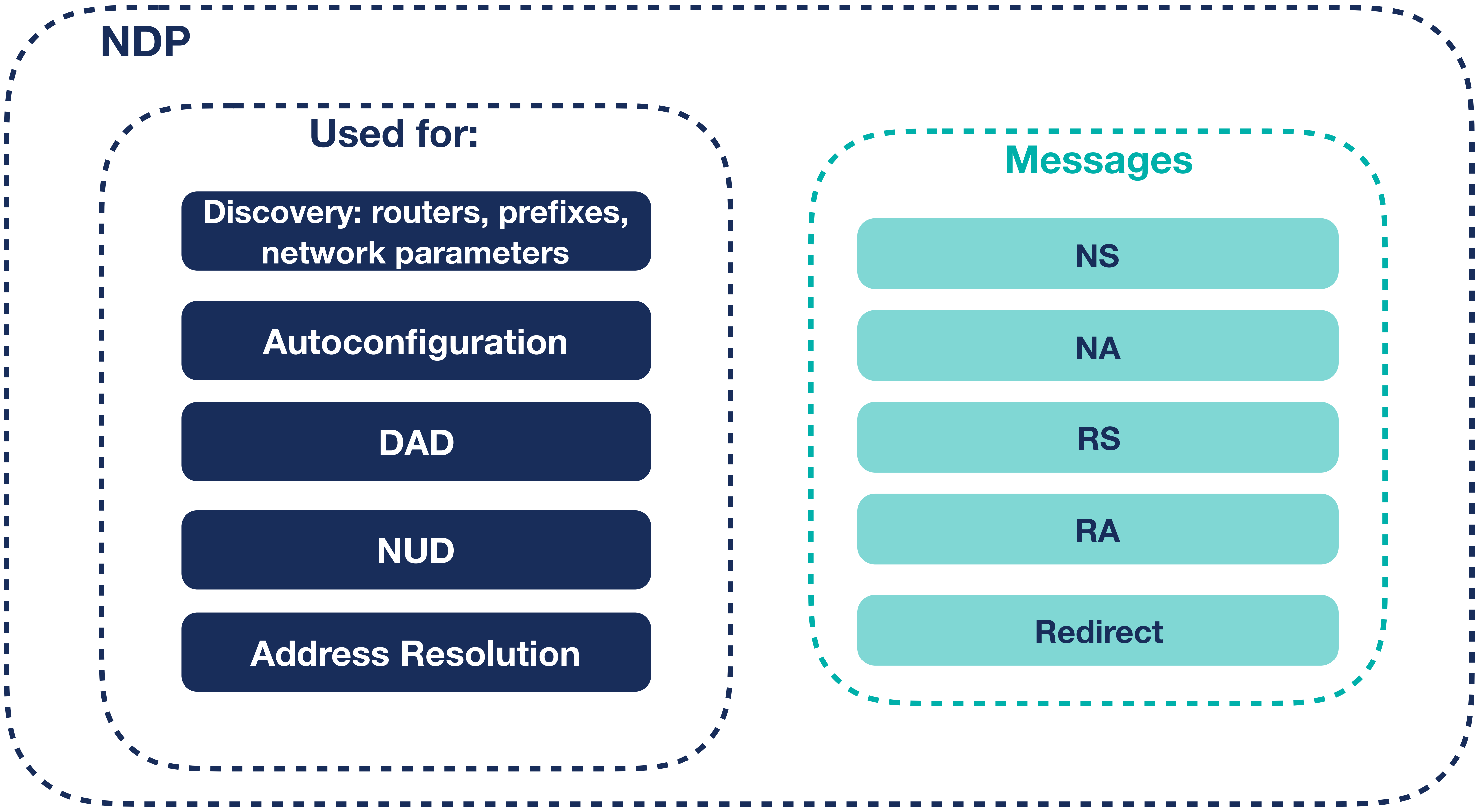
- Use hard to guess IIDs
  - RFC 7217 better than EUI-64
  - RFC 8064 establishes RFC 7217 as the default
- Use IPS/IDS to detect scanning
- Filter packets where appropriate
- Use "default" /64 size IPv6 subnet prefix

IPv6 Associated Protocols Security

NDP

Introduction (1)

- NDP [RFC4861] is used on a link



NDP

Used for:

- Discovery: routers, prefixes, network parameters
- Autoconfiguration
- DAD
- NUD
- Address Resolution

Messages

- NS
- NA
- RS
- RA
- Redirect

Introduction (2)

- Hop Limit = 255, if not, discard

- NDP has vulnerabilities
  - [RFC3756] [RFC6583]

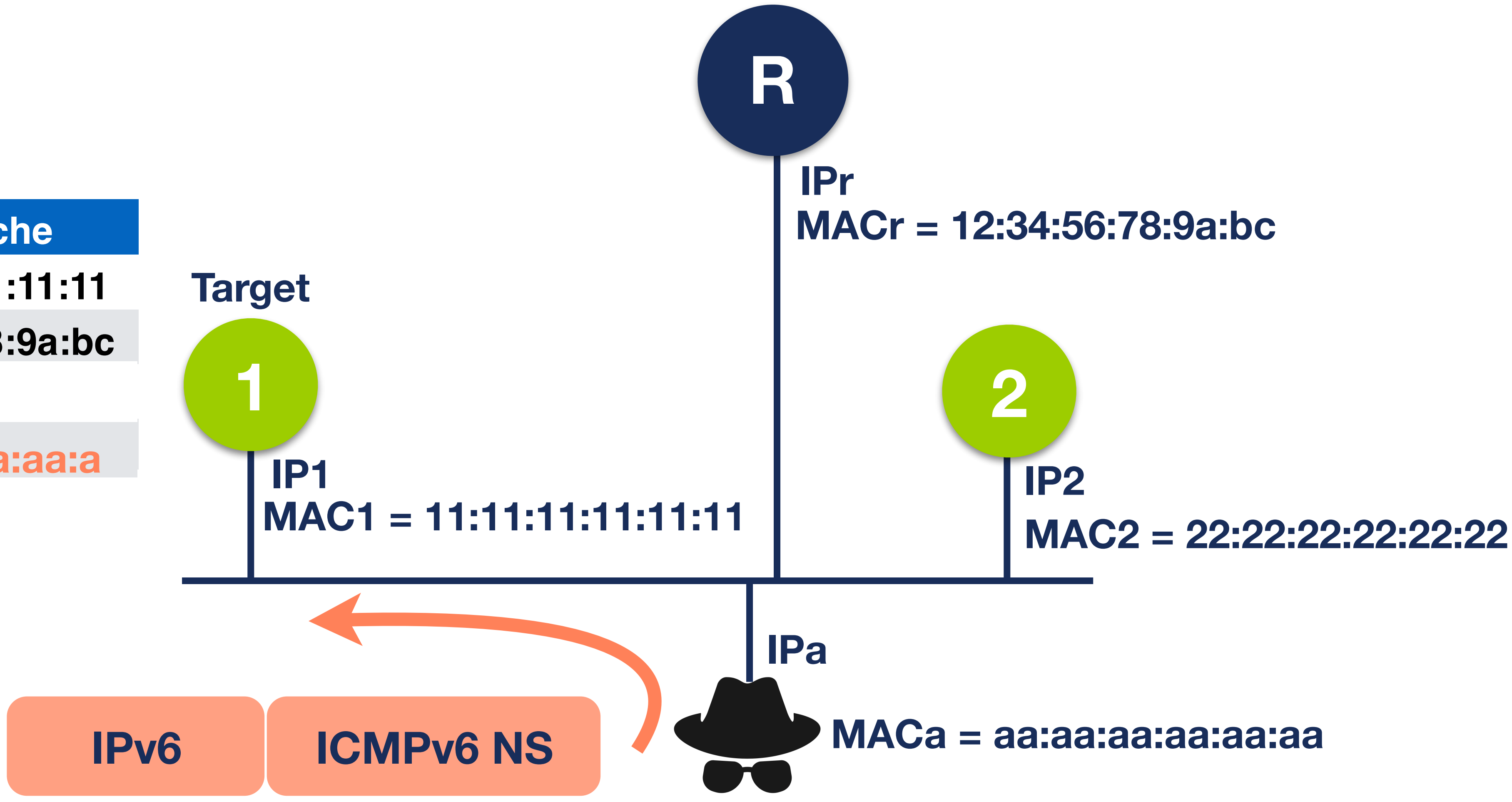
- NDP specification: use IPsec -> impractical, not used

- SEND (SEcure Neighbour Discovery): Not widely available
  - [RFC3971]

NDP Threats (1)

- NS: 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.Source IPv6: IP2

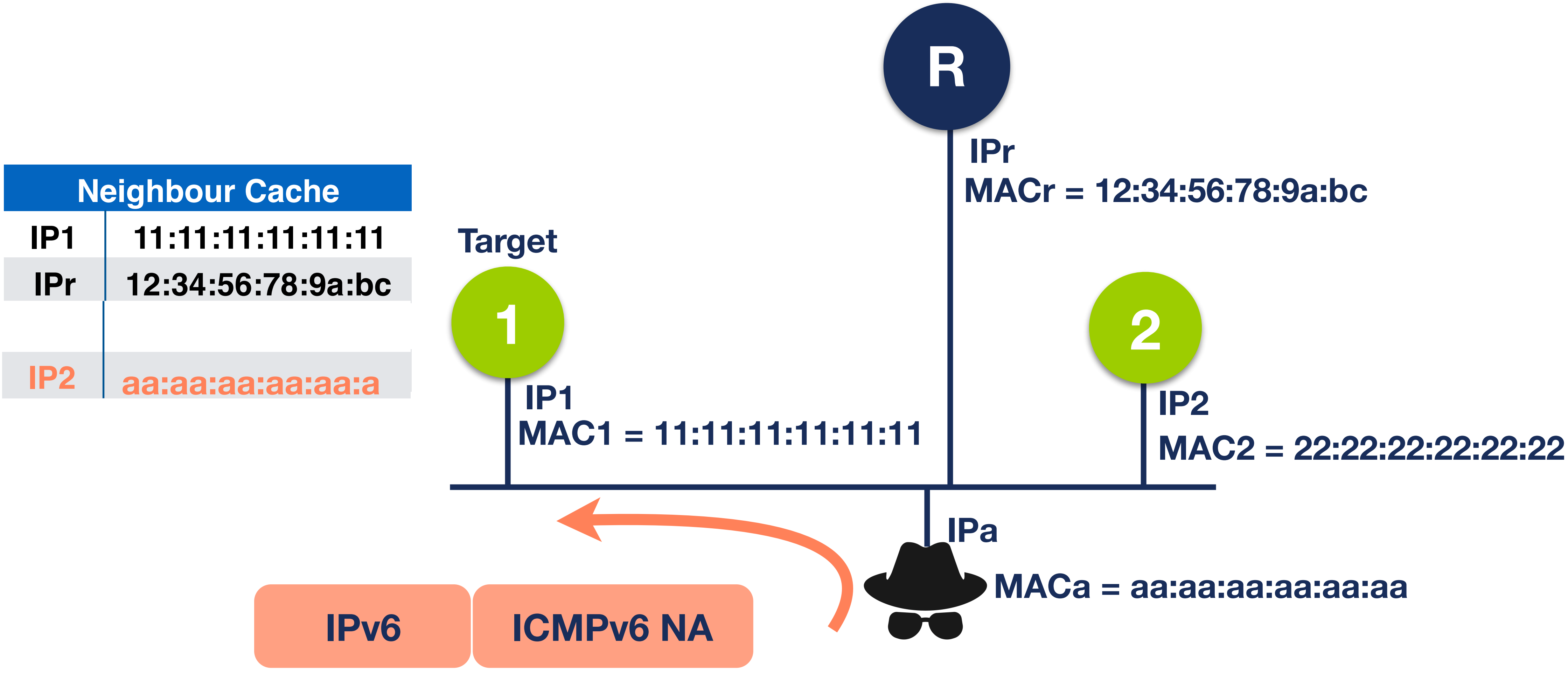
IPv6.Destination IPv6: IP1

NS.Target Addr: IP1

NS.Src Link-layer Addr: aa:aa:aa:aa:aa:aa

NDP Threats (2)

- Unsolicited NA: Redirection / DoS



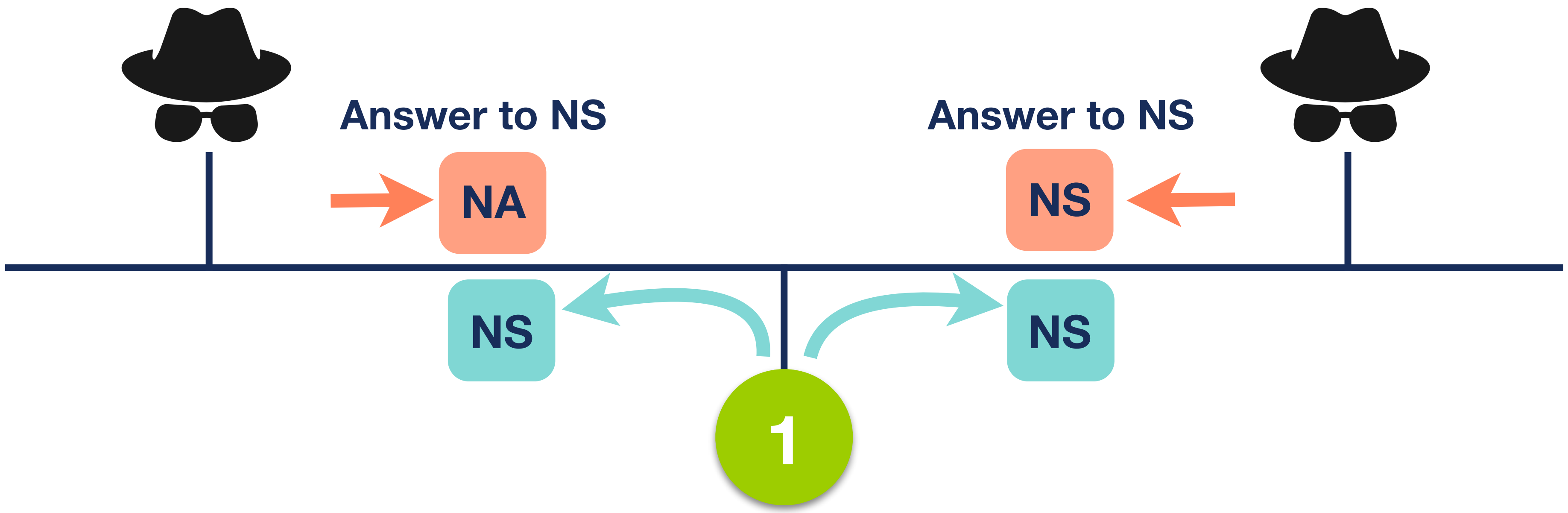
Neighbour Cache	
IP1	11:11:11:11:11:11
IPr	12:34:56:78:9a:bc
IP2	aa:aa:aa:aa:aa:a

NA.Target Addr.: IP2

NA.Target Link-layer Addr.: aa:aa:aa:aa:aa:aa

NDP Threats (3)

- DAD DoS Attack

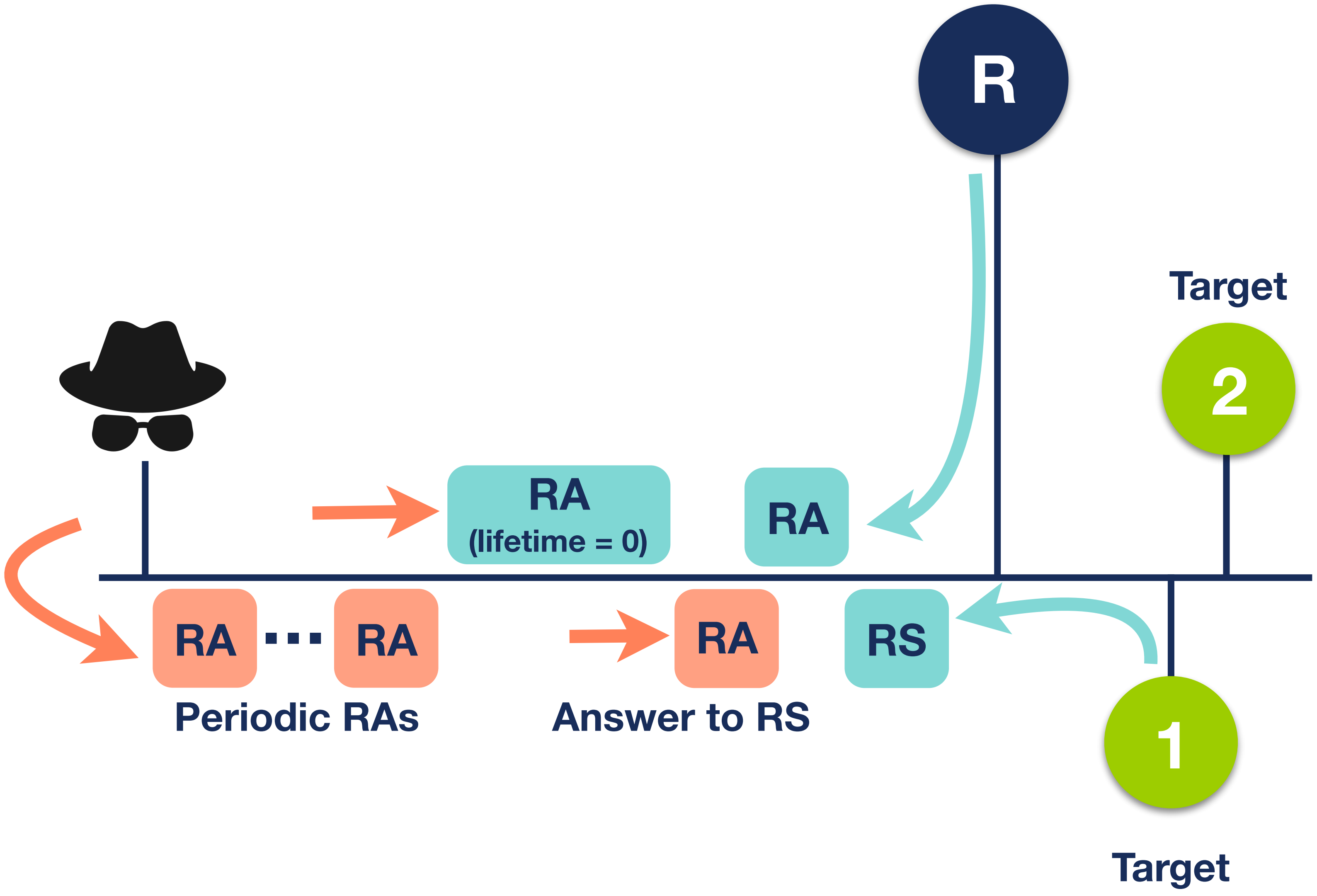


Target

DAD for IP1 before configuring it

NDP Threats (4)

- Malicious Last Hop Router



NDP Threats (5)

- **Bogus Address Configuration Prefix**

- Attacker sends RA with prefix for SLAAC
- Hosts using SLAAC will auto-configure an address using that prefix

- Return packets never reach the host

- DoS attack

NDP Threats (6)

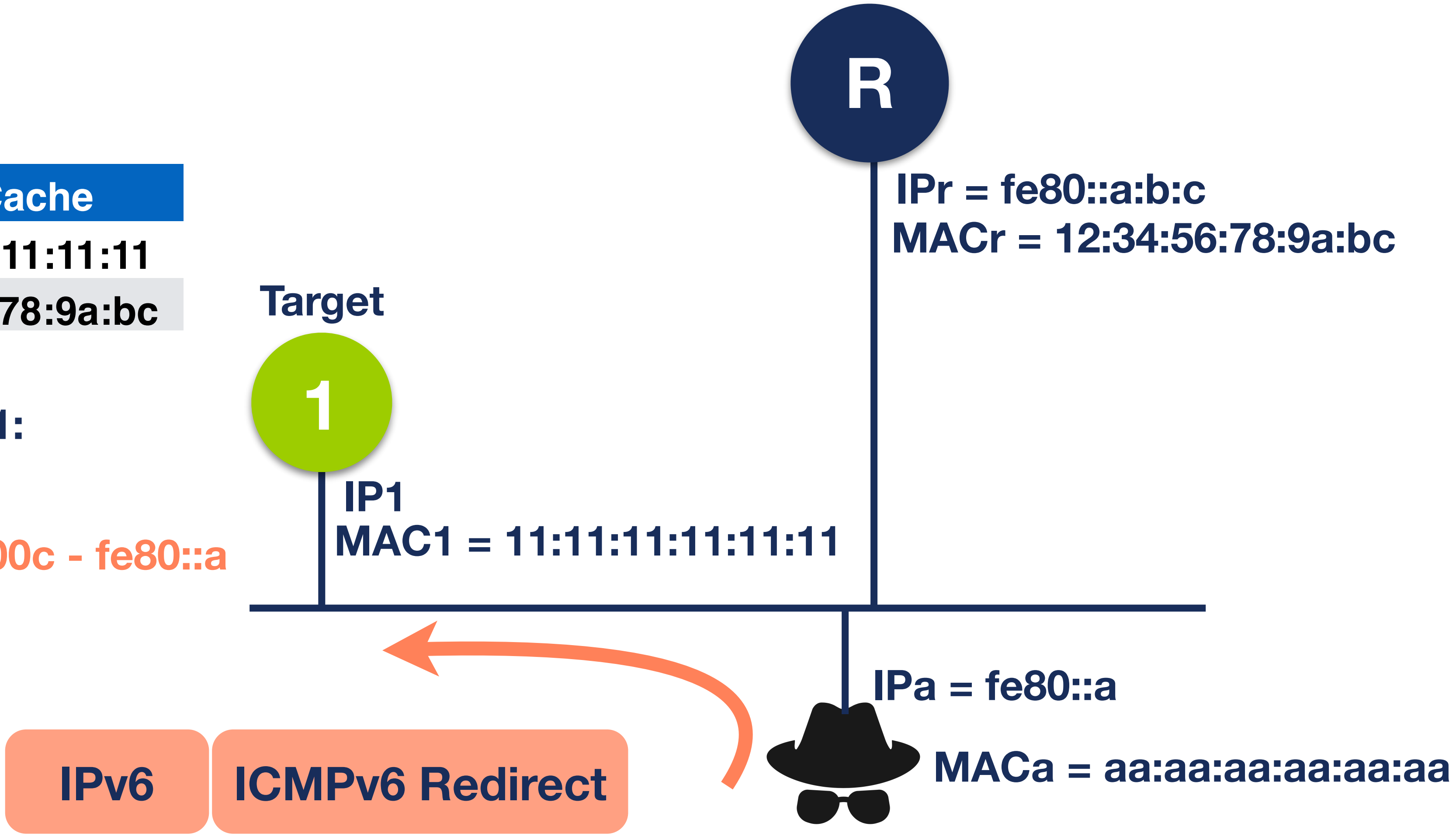
- Spoofed Redirect Message

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



IPv6.Source: IPr = fe80::a:b:c

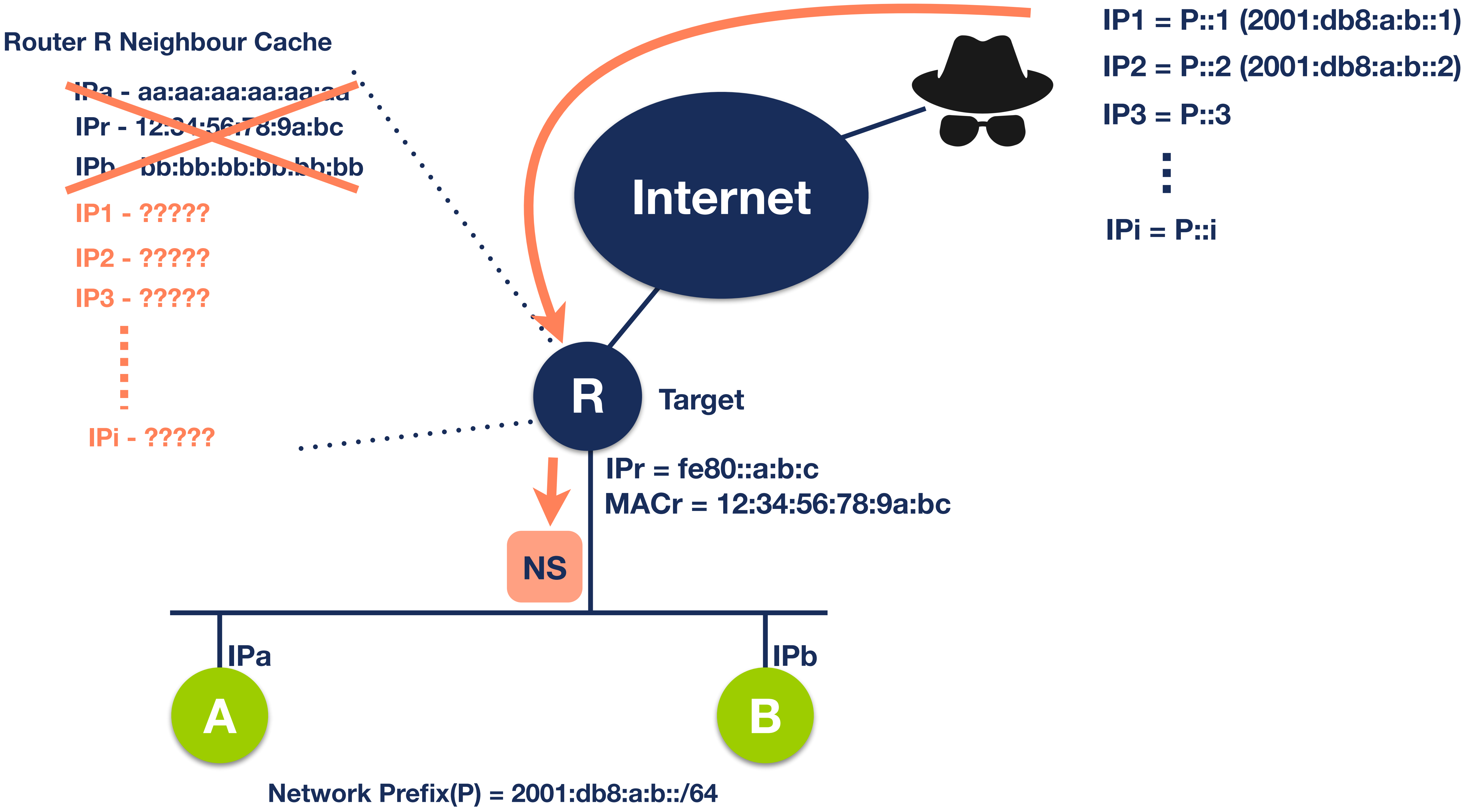
IPv6.Destination: IP1

Redirect.Target Addr.: IPa = fe80::a

Redirect.Dst Addr.: 2001:db8::face:b00c

NDP Threats (7)

- Neighbour Discovery DoS Attack



Router R Neighbour Cache

~~IPa - aa:aa:aa:aa:aa:aa~~

~~IPr - 12:34:56:78:9a:bc~~

~~IPb - bb:bb:bb:bb:bb:bb~~

IP1 - ?????

IP2 - ?????

IP3 - ?????

IPi - ?????

IP1 = P::1 (2001:db8:a:b::1)

IP2 = P::2 (2001:db8:a:b::2)

IP3 = P::3

IPi = P::i

Internet

R

Target

IPr = fe80::a:b:c

MACr = 12:34:56:78:9a:bc

NS

IPa

IPb

A

B

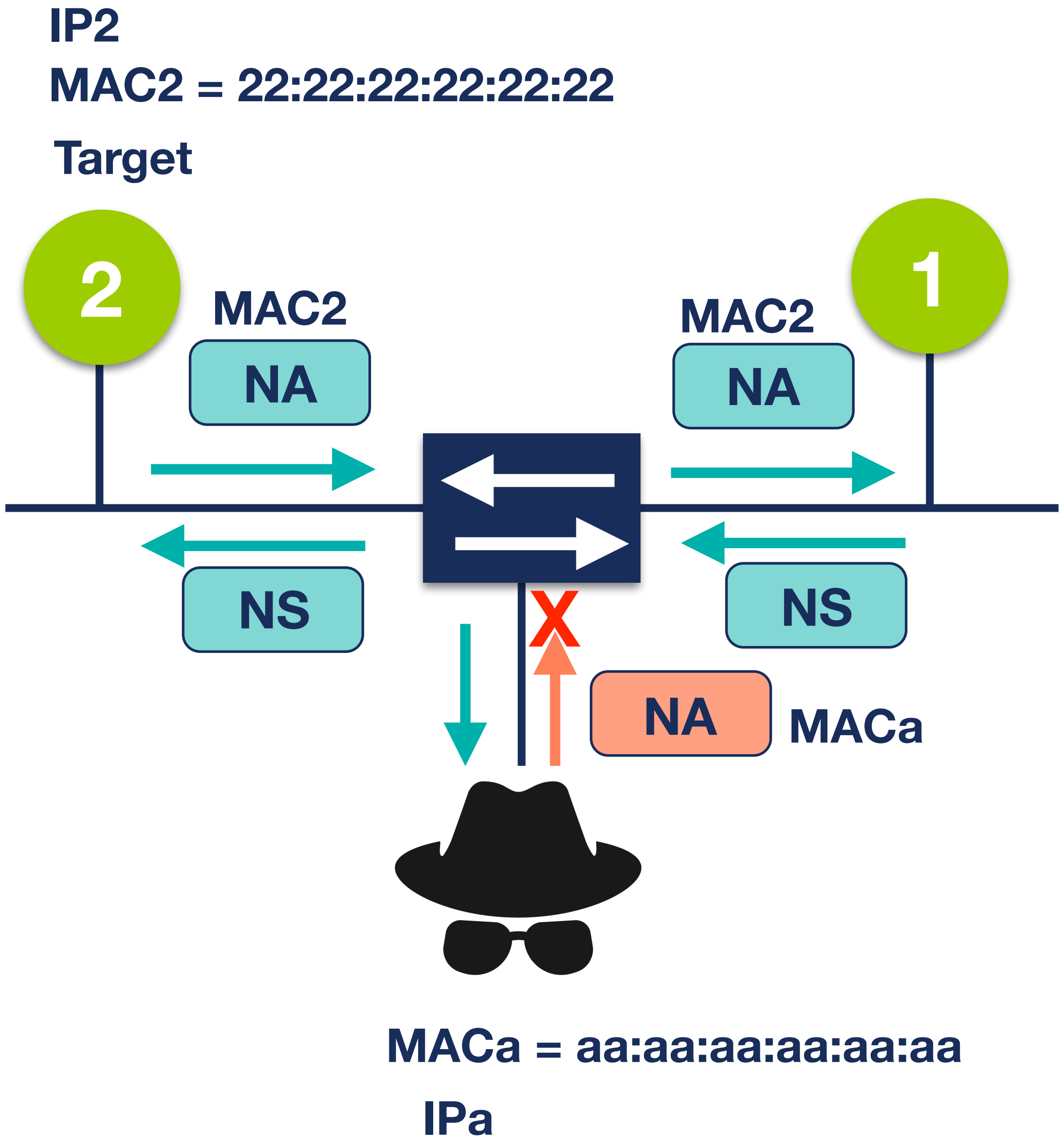
Network Prefix(P) = 2001:db8:a:b::/64

First Hop Security (1)

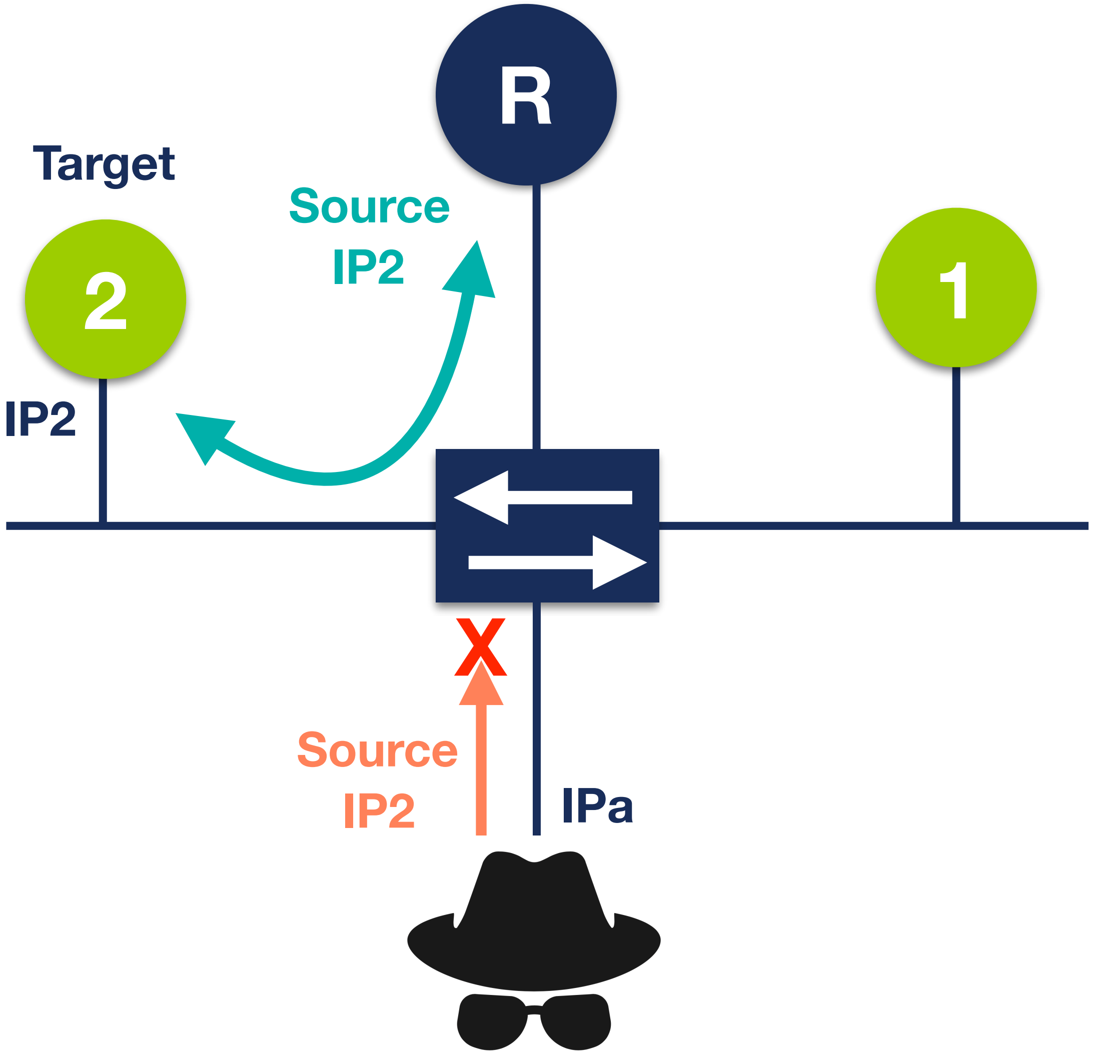
- Security implemented on switches

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

First Hop Security (2)



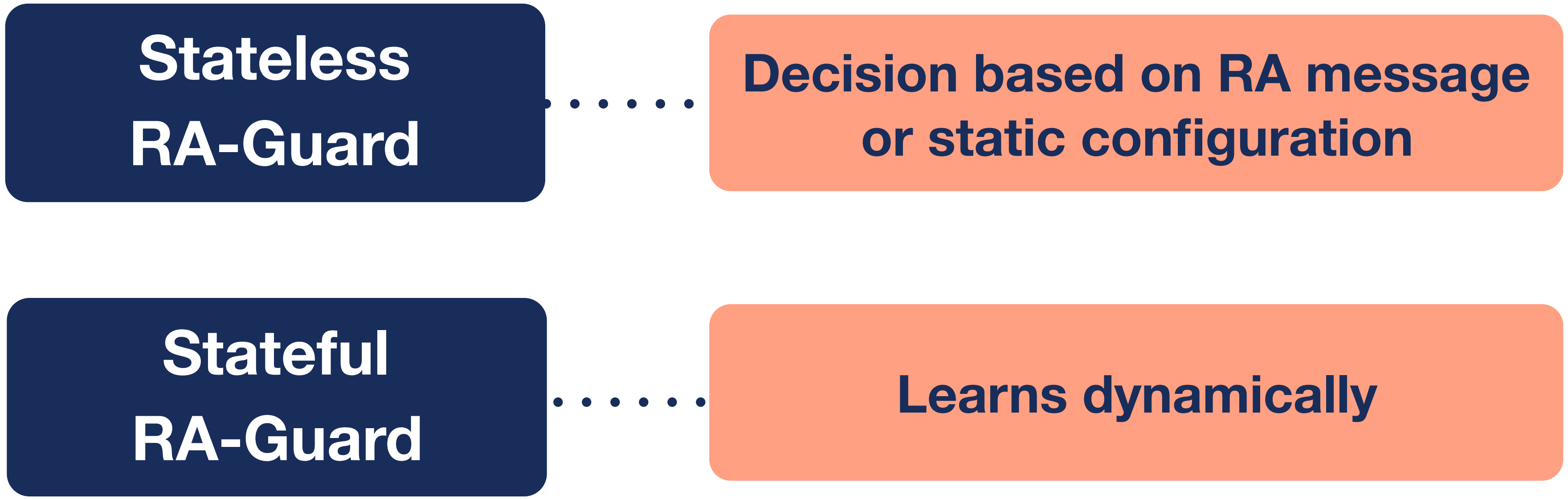
IPv6 Snooping



IPv6 Source/ Prefix Guard

RA-GUARD

- RA-GUARD [RFC6105] easiest and available solution
- Only allows RAs on legitimate port(s) on L2 switches



Stateless RA-Guard

Decision based on RA message or static configuration

Stateful RA-Guard

Learns dynamically

- Requires support on switches
- EHs were used to go through RA-Guard [RFC7113]

Conclusions / Tips

- NDP is an important, powerful and vulnerable protocol

- Some solutions are available to protect NDP

- Recommended: use available ones
  - Check availability and configure them

- Detection (IDS/IPS) could be easier and recommended

Multicast Listener Discovery (MLD)

Introduction

- Multicast Listener Discovery (MLD) 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

- Mandatory for all IPv6 nodes (MUST)

QUERY

Router asks for Listeners

General

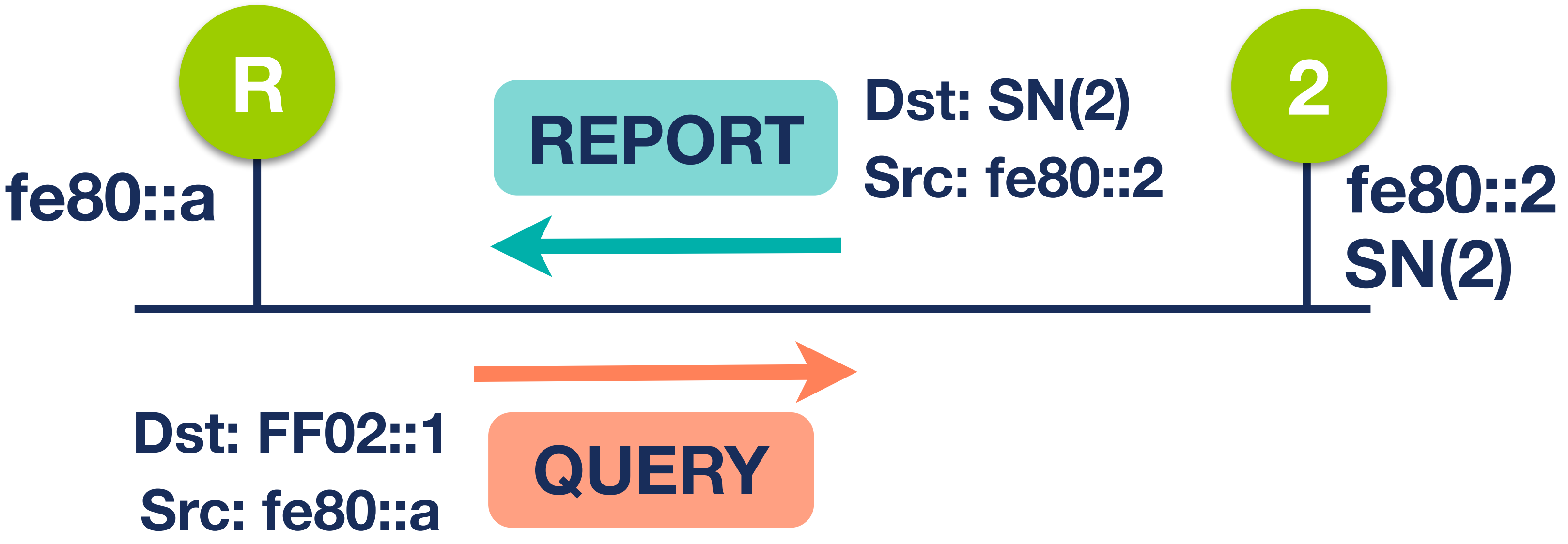
Specific

REPORT

Listeners report themselves

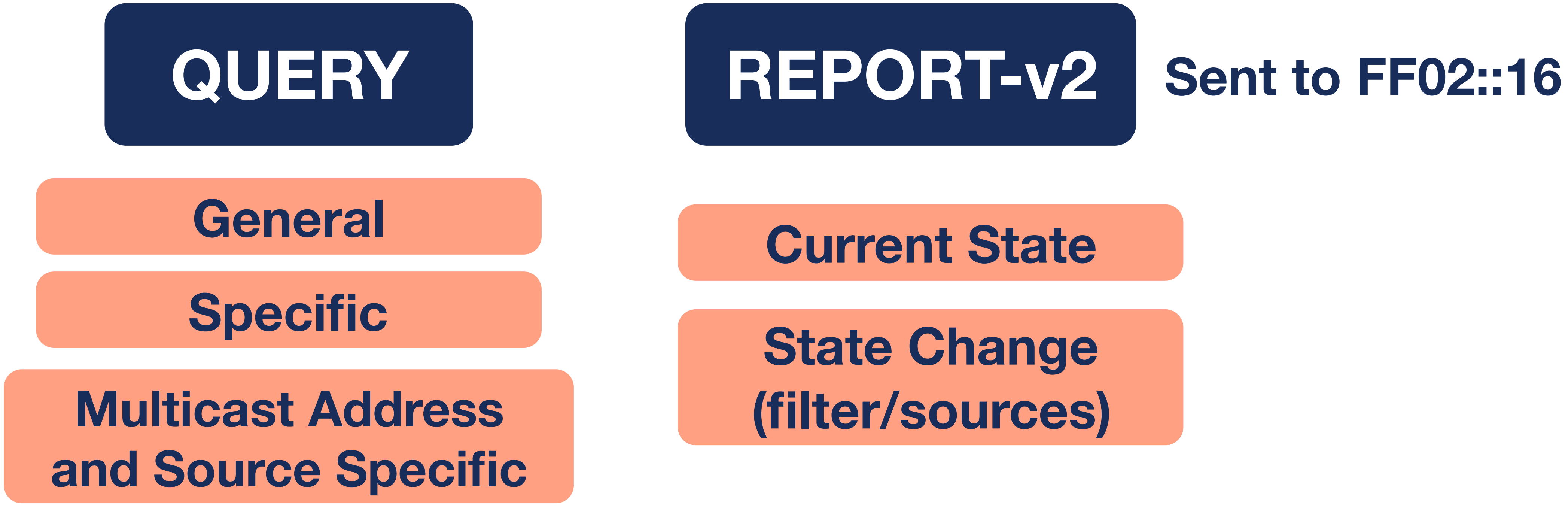
DONE

Listeners indicate they're done



MLDv2

- Strongly recommended for all IPv6 hosts (SHOULD)
- Interoperable with MLDv1
- Adds Source-Specific Multicast filters:
  - Only accepted sources; or
  - All sources accepted except specified ones



QUERY

General

Specific

Multicast Address and Source Specific

REPORT-v2

Sent to FF02::16

Current State

State Change (filter/sources)

MLD Threats (1)

- Flooding of MLD messages

Solutions

Lots of REPORTs

RAM Exhaustion

CPU Exhaustion

Rate limit MLD states

Rate limit MLD messages

Disable MLD (if not needed)

- Traffic Amplification

Spoofed QUERY

Hosts send REPORTs

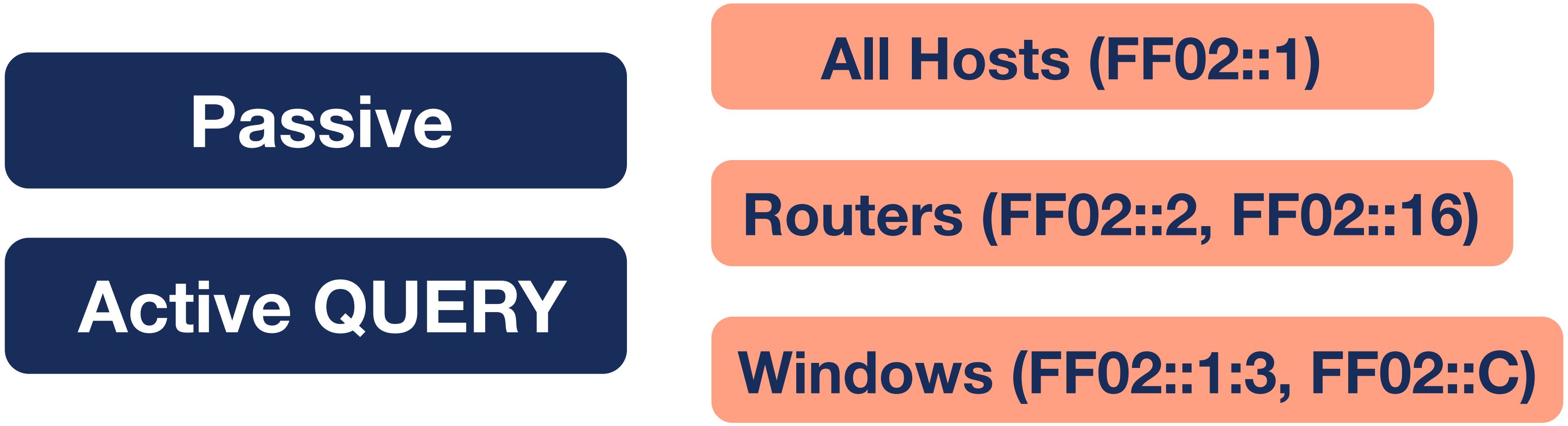
Several for each Addr.

Windows 8.1 = 8 Msgs.

Rate limit MLD messages

MLD Threats (2)

- Network scanning



Passive

Active QUERY

All Hosts (FF02::1)

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

Windows (FF02::1:3, FF02::C)

MLD Solutions (1)

- MLD built-in security

Link-local source address

Hop Limit = 1

Router Alert option in Hop-by-Hop EH

Discard non compliant messages

- MLD Snooping [RFC4541]

Switch listens to REPORTs

MLD Table: maps multicast groups to ports that requested

Only allow multicast traffic on ports with listeners

MLD Solutions (2)

- Only allow QUERIES on router’s port
  - Kind of MLD-Guard

```
deny icmp any any mld-query
```

- Protecting routers
  - Rate limit REPORTs from each host
  - Disable multicast/MLD functionality if not using inter-domain multicast routing

IPv6 Security Tips

Introduction

- Best security tool is knowledge
- IPv6 security is a moving target, keep updated
- IPv6 is happening: need to know about IPv6 security
- IPv6 quite similar to IPv4, many reusable practices

Overview: Devices

- Different categories (from RIPE-554):

Host

- IPSec (if needed)
- RH0 [RFC5095]
- Overlapping Frags [RFC5722]
- Atomic Fragments [RFC6946]
- NDP Fragmentation [RFC6980]
- Header chain [RFC7112]
- Stable IIDs [RFC8064][RFC7217] [RFC7136]
- **Disable if not used:** LLMNR, mDNS, DNS-SD, IPv6 DNS Autodiscovery, transition mechanisms

Switch

- HOST +
- IPv6 ACLs
- FHS
  - RA-Guard [RFC6105]
  - DHCPv6 guard
  - IPv6 snooping
  - IPv6 source / prefix guard
  - IPv6 destination guard
  - MLD snooping [RFC4541]
  - DHCPv6-Shield [RFC7610]

Router

- HOST +
- Ingress Filtering and RPF
- DHCPv6 Relay [RFC8213]
- OSPFv3
  - Auth. [RFC4552]
  - or/and [RFC7166]
- IS-IS
  - [RFC5310]
  - or, less preferred, [RFC5304]
- MBGP
  - TCP-AO [RFC5925]
  - Obsoleted MD5 Signature Option [RFC2385]
  - MBGP Bogon prefix filtering

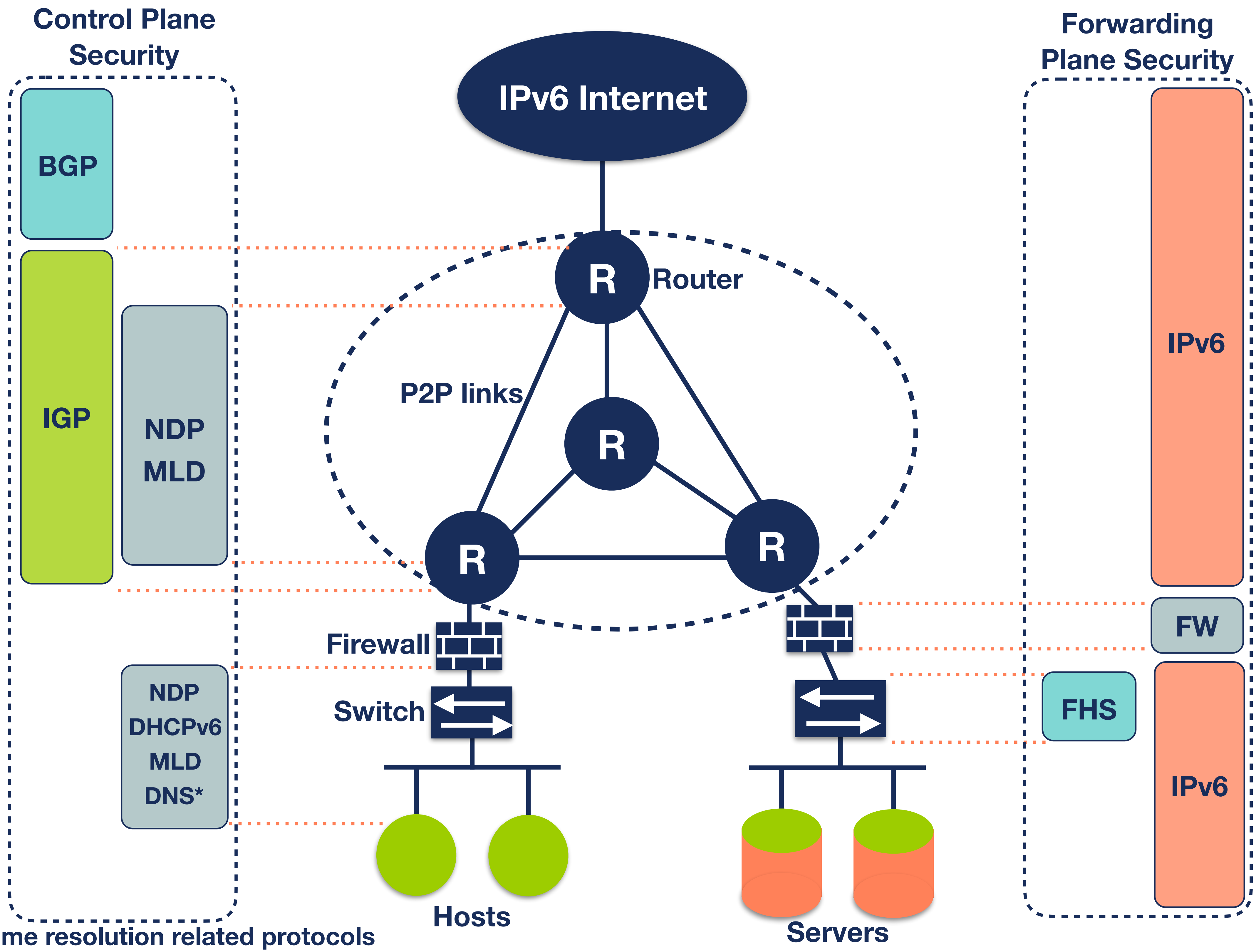
Security Equipment

- HOST +
- Header chain [RFC7112]
- Support EHs Inspection
- ICMPv6 fine grained filtering
- Encapsulated Traffic Inspection
- IPv6 Traffic Filtering

CPE

- Router
- Security Equipment
- DHCPv6 Server Privacy Issues

Overview: Network Example



* All Name resolution related protocols

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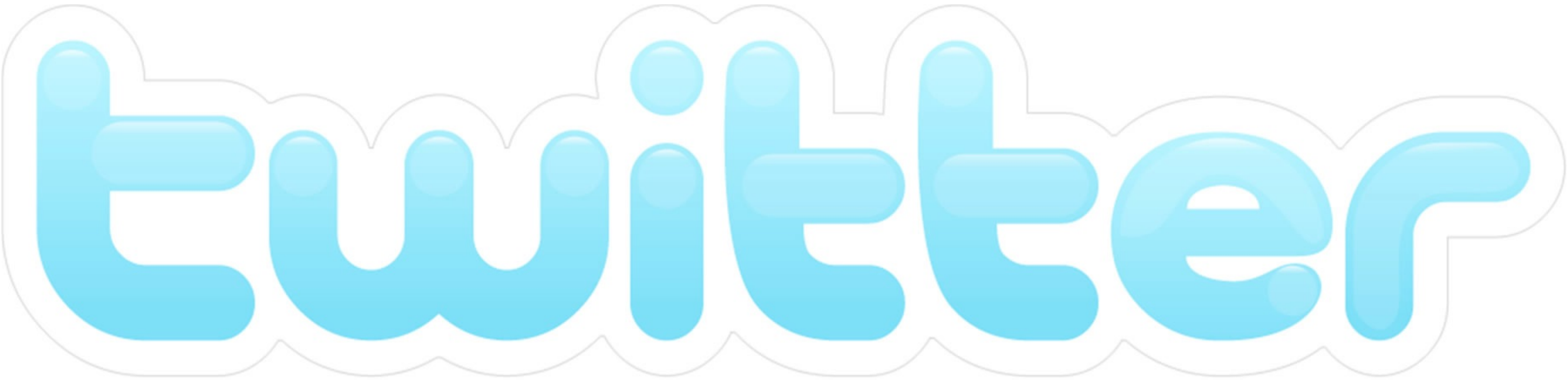

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Questions ?