RIPE NCC
RIPE NETWORK COORDINATION CENTRE

Basic IPv6 Protocol Security

Webinar

April 2025

RIPE NCC Learning & Development

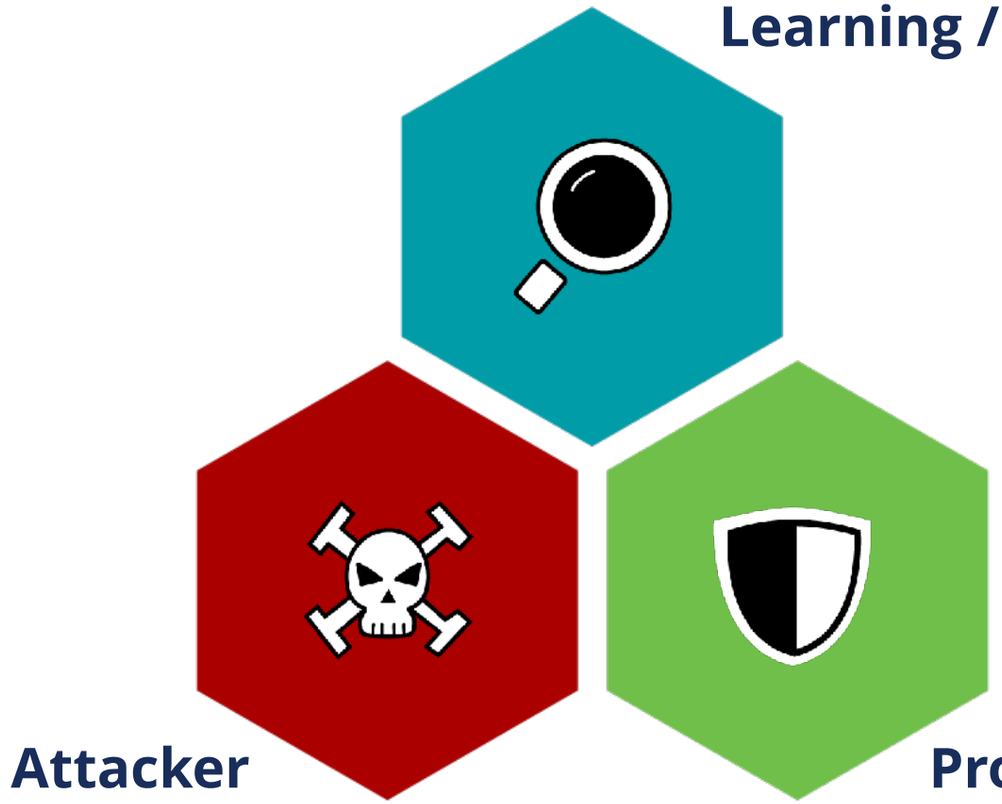
This webinar is being recorded

Basic IPv6 Protocol Security

IPv6 Basic header and Extension Headers

IPSec

IPv6 Security Addressing Architecture


Learning / Understanding
Attacker
Protecting

Tell us about you!

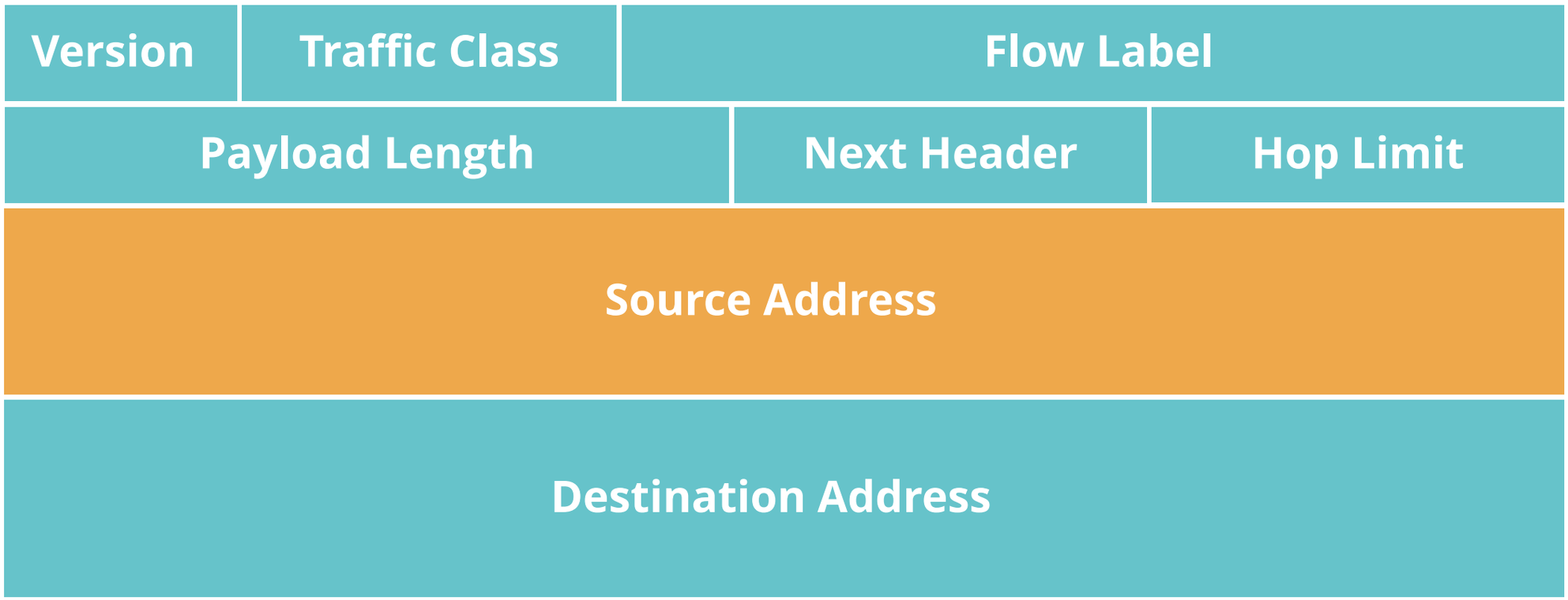
Please answer the polls

2 min.

IPv6 Basic Header and Extension Headers

Section 1

Basic IPv6 Header: Threat #1



Basic IPv6 Header: Threat #1

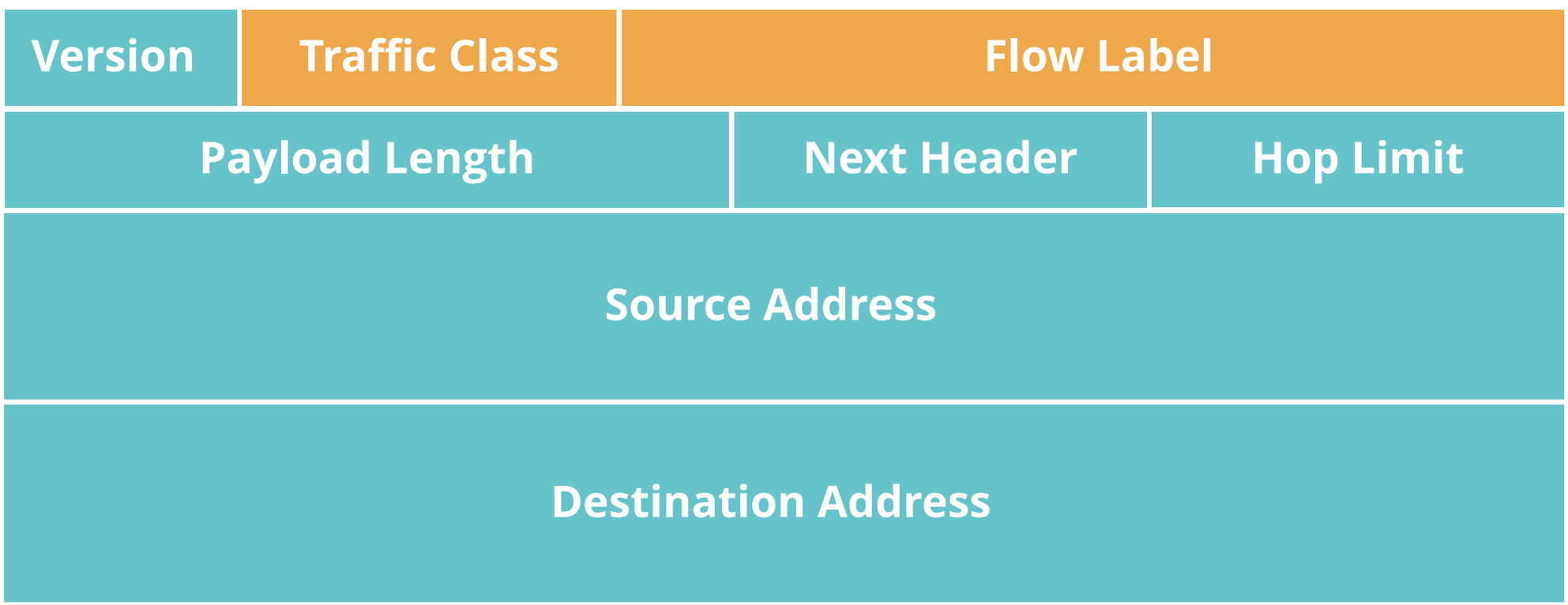
IP spoofing:

Using a fake IPv6 source address

Solution:

ingress filtering and RPF (*reverse path forwarding*)

Basic IPv6 Header: Threat #2



Basic IPv6 Header: Threats #2

Covert Channel:

Using Traffic Class and/or Flow Label

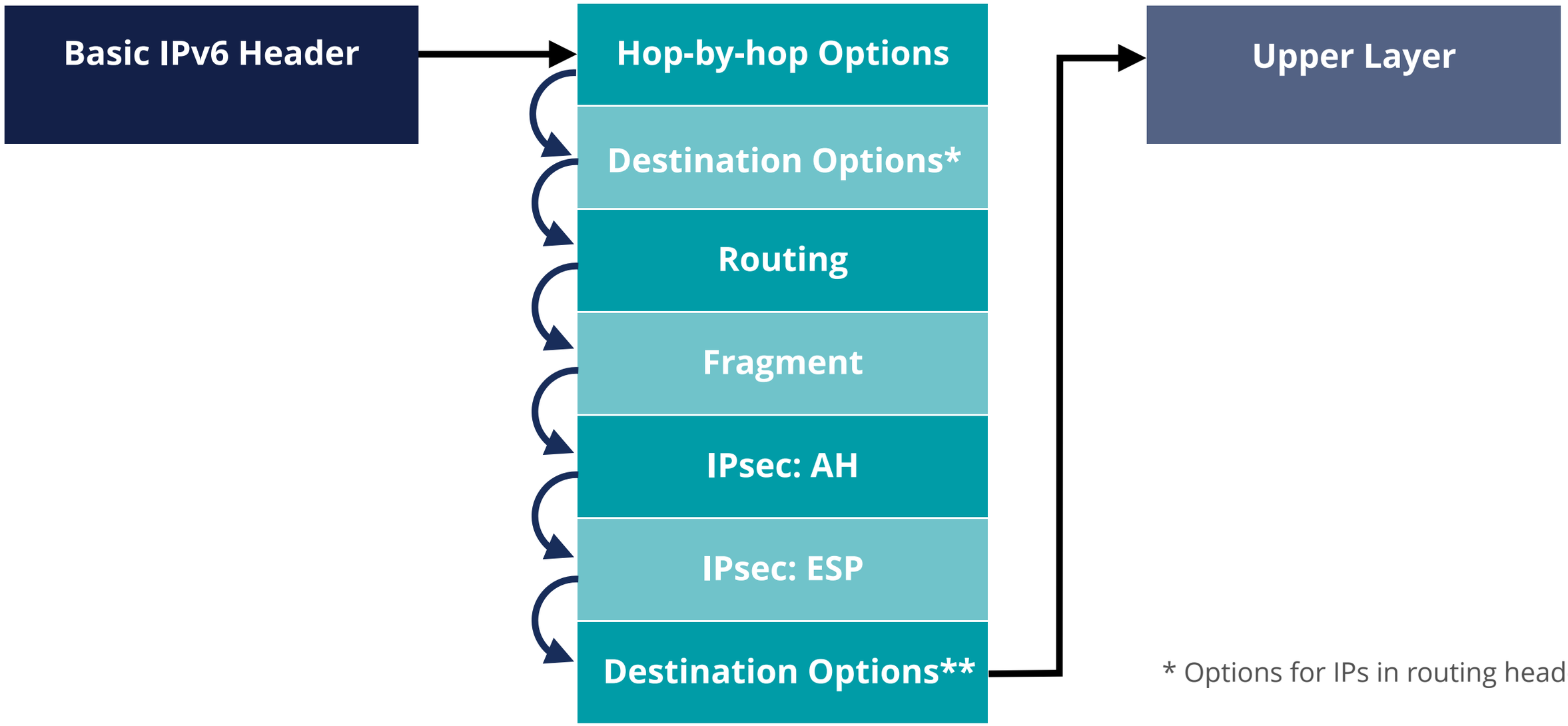
Solution:

Inspect packets (IDS / IPS)

Expected values:

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

IPv6 Extension Headers



* Options for IPs in routing header

** Options for destination IP

Extension Headers Properties

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

- Flexibility means **complexity**

- Security devices / software must process the **full chain of headers**

- Firewalls must be able to filter based on **Extension Headers**

Questions

Routing Header

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

- Processed by the **visited routers**

8 bits	8 bits	8 bits	8 bits
Next Header	**Length**	**Routing Type**	**Segments Left**
Specific data of that Routing Header type			

Routing Header Threat

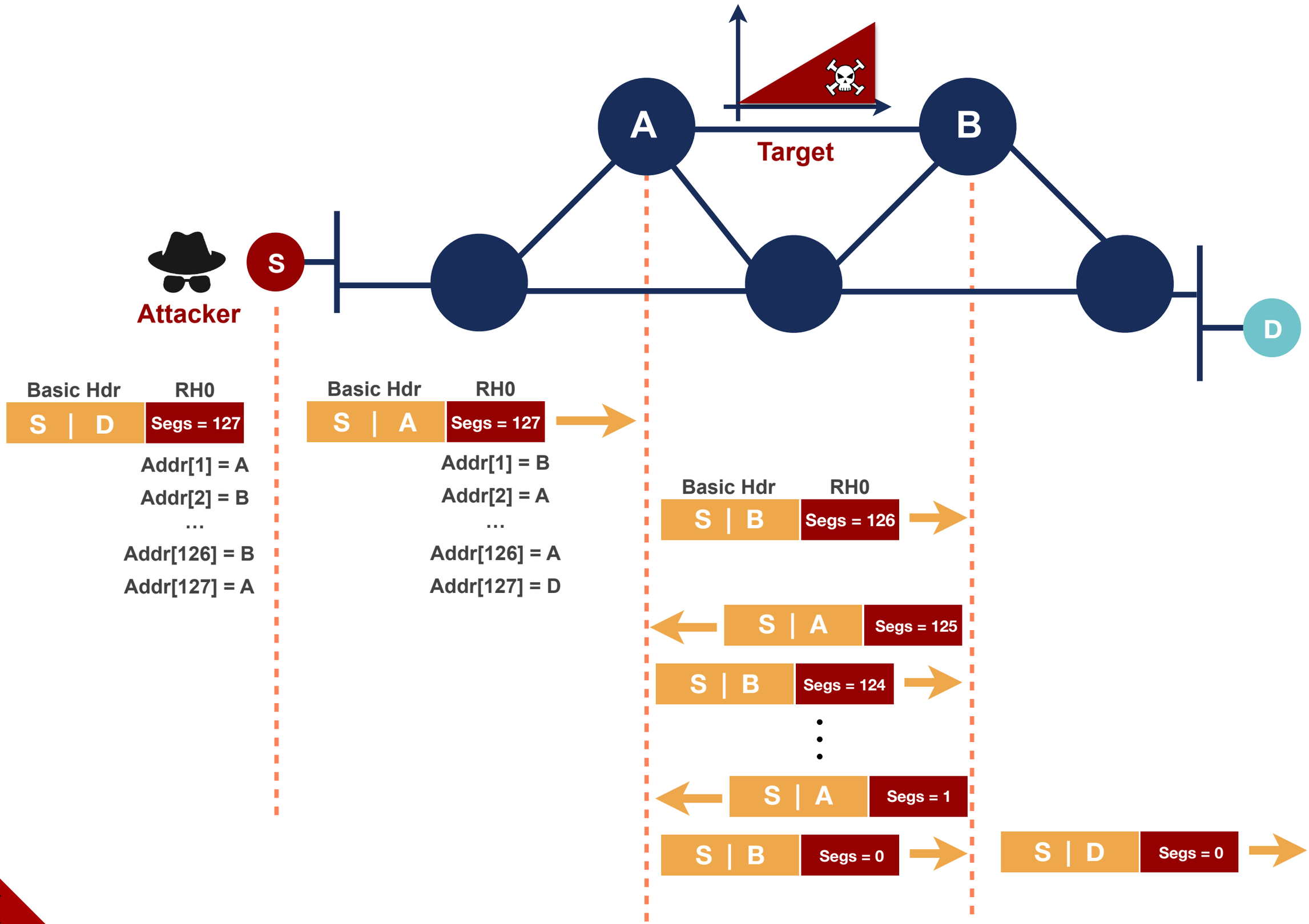
- **Routing Header** (**Type 0**):
  - RH0 can be used for traffic amplification over a remote path
- **RH0 Deprecated** [*RFC5095*]
  - RH1 deprecated. RH2 (MIPv6), RH3 (RPL) and RH4 (SRH) are valid

Take the poll!

What can **RH0** be used for?

Something bad?

2 min.

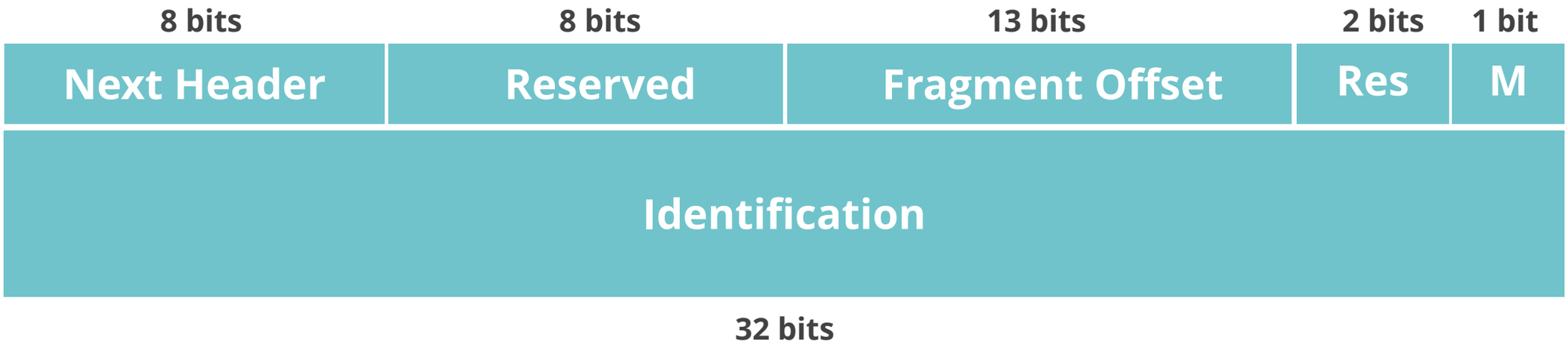

A
B
Target
S
Attacker
D
Basic Hdr
RH0
S | D
Segs = 127
Addr[1] = A
Addr[2] = B
...
Addr[126] = B
Addr[127] = A
Basic Hdr
RH0
S | A
Segs = 127
Addr[1] = B
Addr[2] = A
...
Addr[126] = A
Addr[127] = D
Basic Hdr
RH0
S | B
Segs = 126
S | A
Segs = 125
S | B
Segs = 124
S | A
Segs = 1
S | B
Segs = 0
S | D
Segs = 0

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

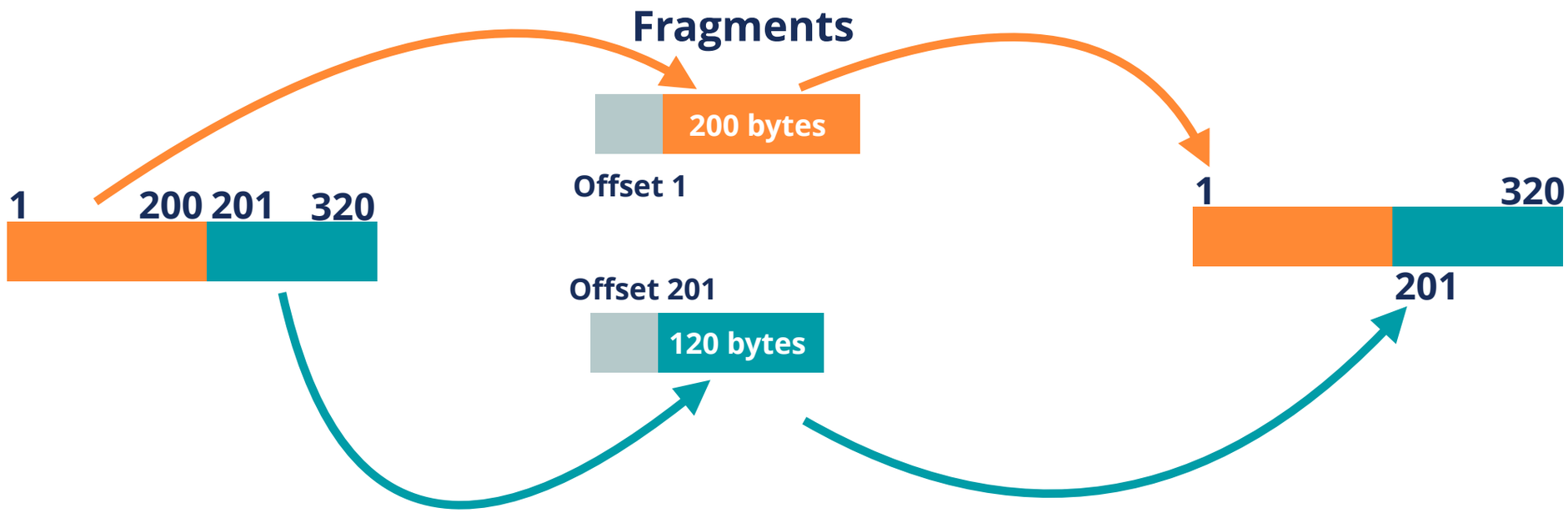
EH Threats: Fragmentation

Take the poll!

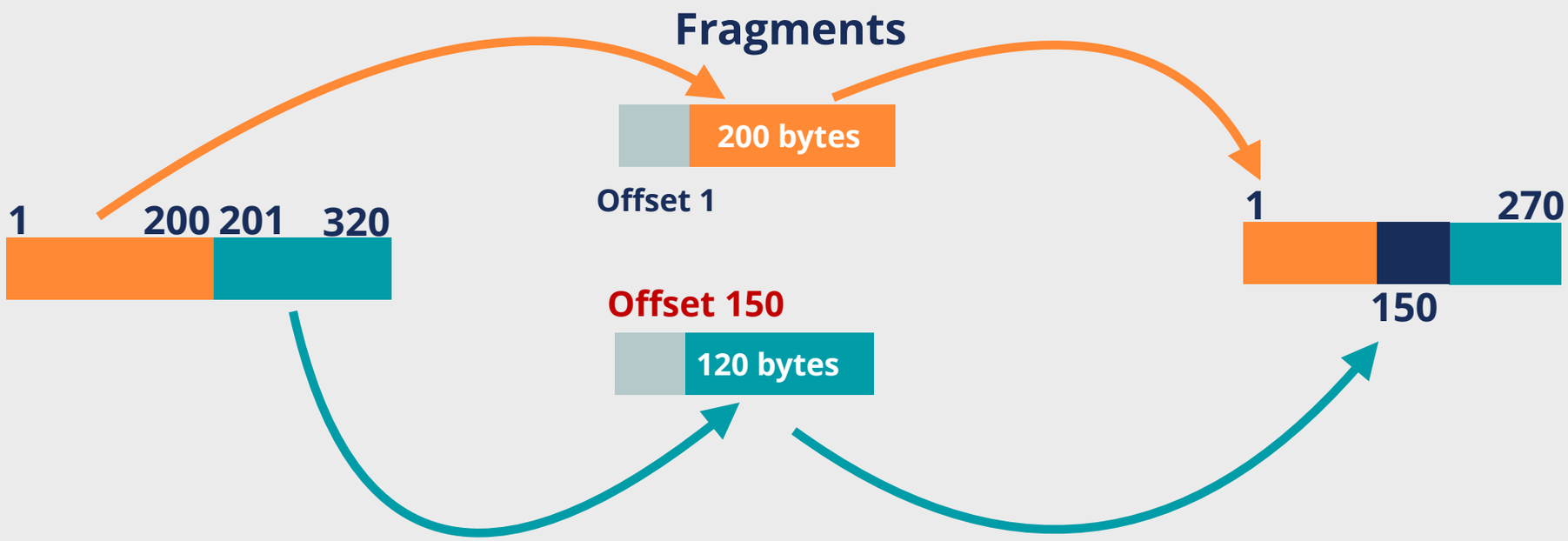
Do you know how **Overlapping Fragments** works?

2 min.

Overlapping Fragments

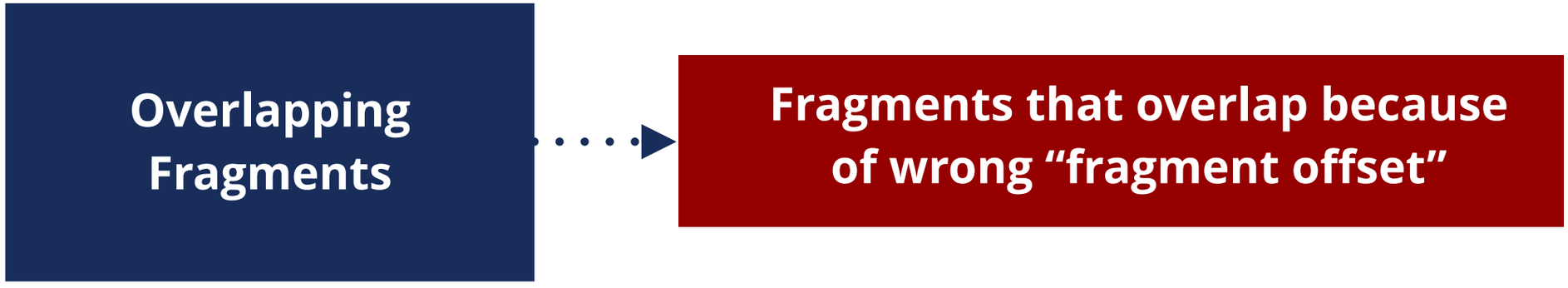


Normal fragments offset say where the data goes



Overlapping fragments have wrong offset values

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]**

Take the poll!

For what other malicious attacks can **Extension Headers** be used for?

2 min.

Bypassing RA Filtering/RA-Guard

Using **any** Extension Header

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

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
Next Header = 44	*Next Header = 60*	*Next Header = 58*

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

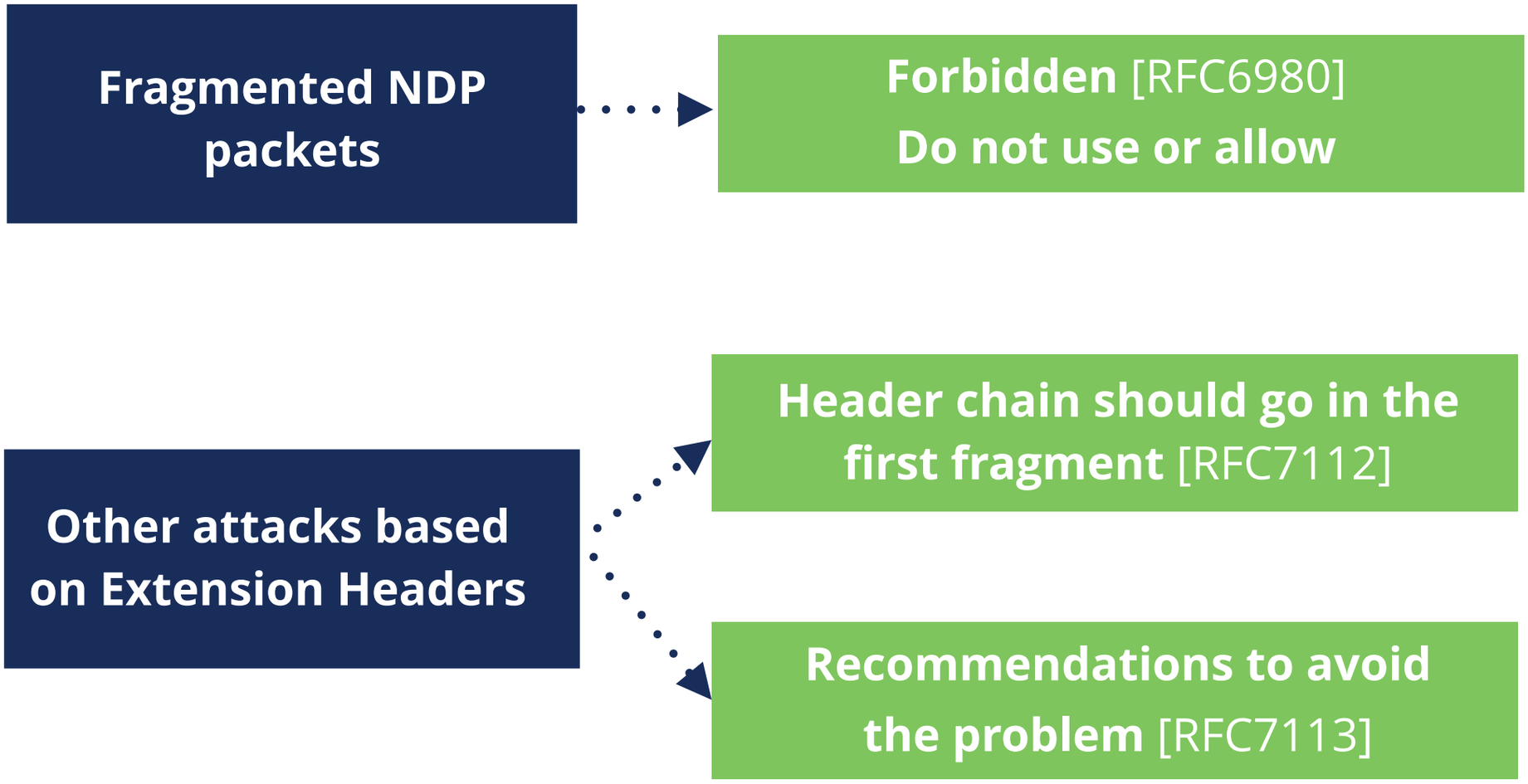
Needs all fragments to detect the RA

Take the poll!

How would you change IPv6 to **avoid** the **bypass using fragment header**?

2 min.

Extension Headers Solutions



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

Questions

- Is it possible to **generate** all those weird packets?

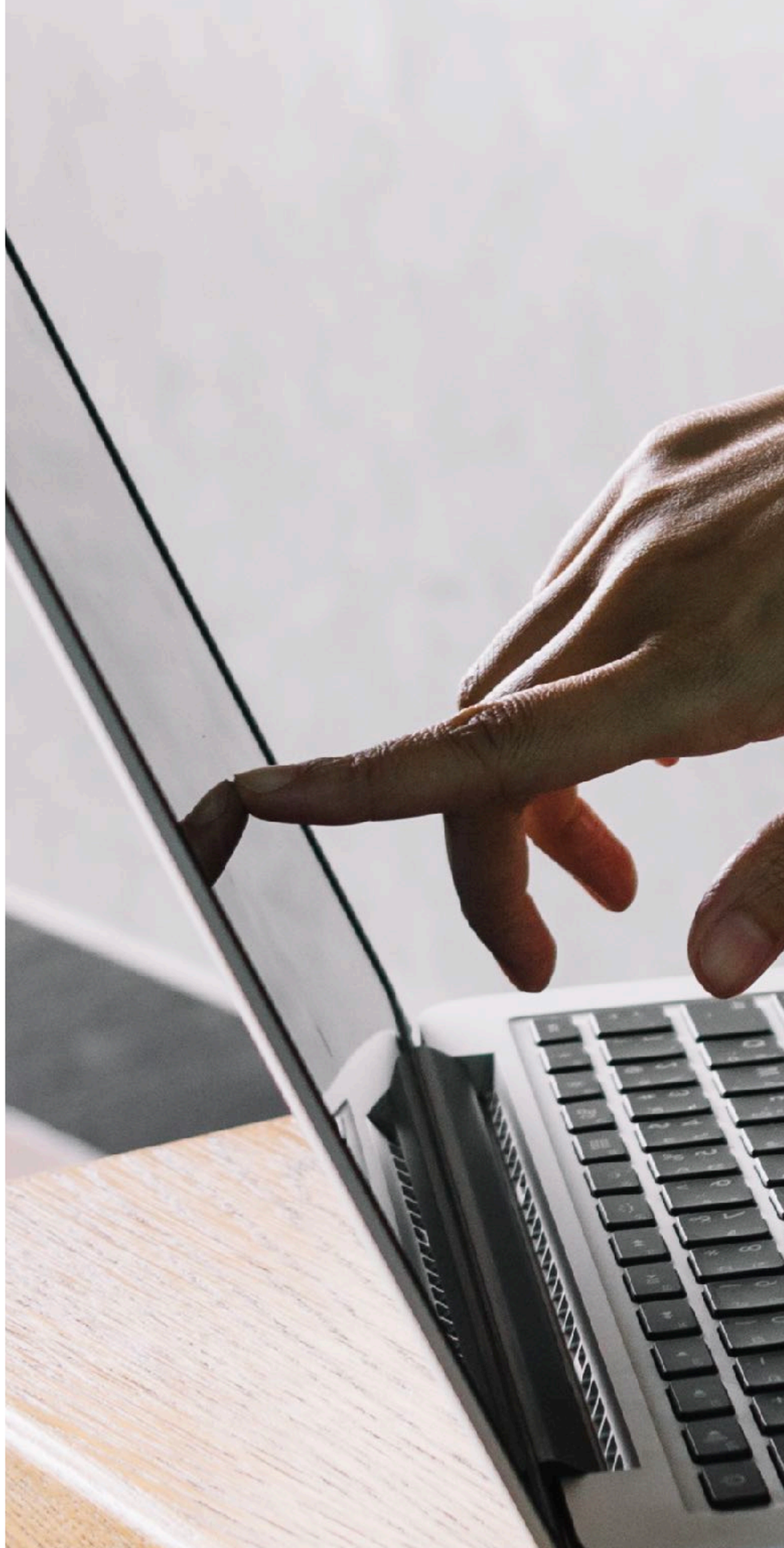
- How can I check if my devices/ software are **ready to resist** specific attacks? (Security assessment)?

Demo 1

IPv6 Packet Generation

Demo time!

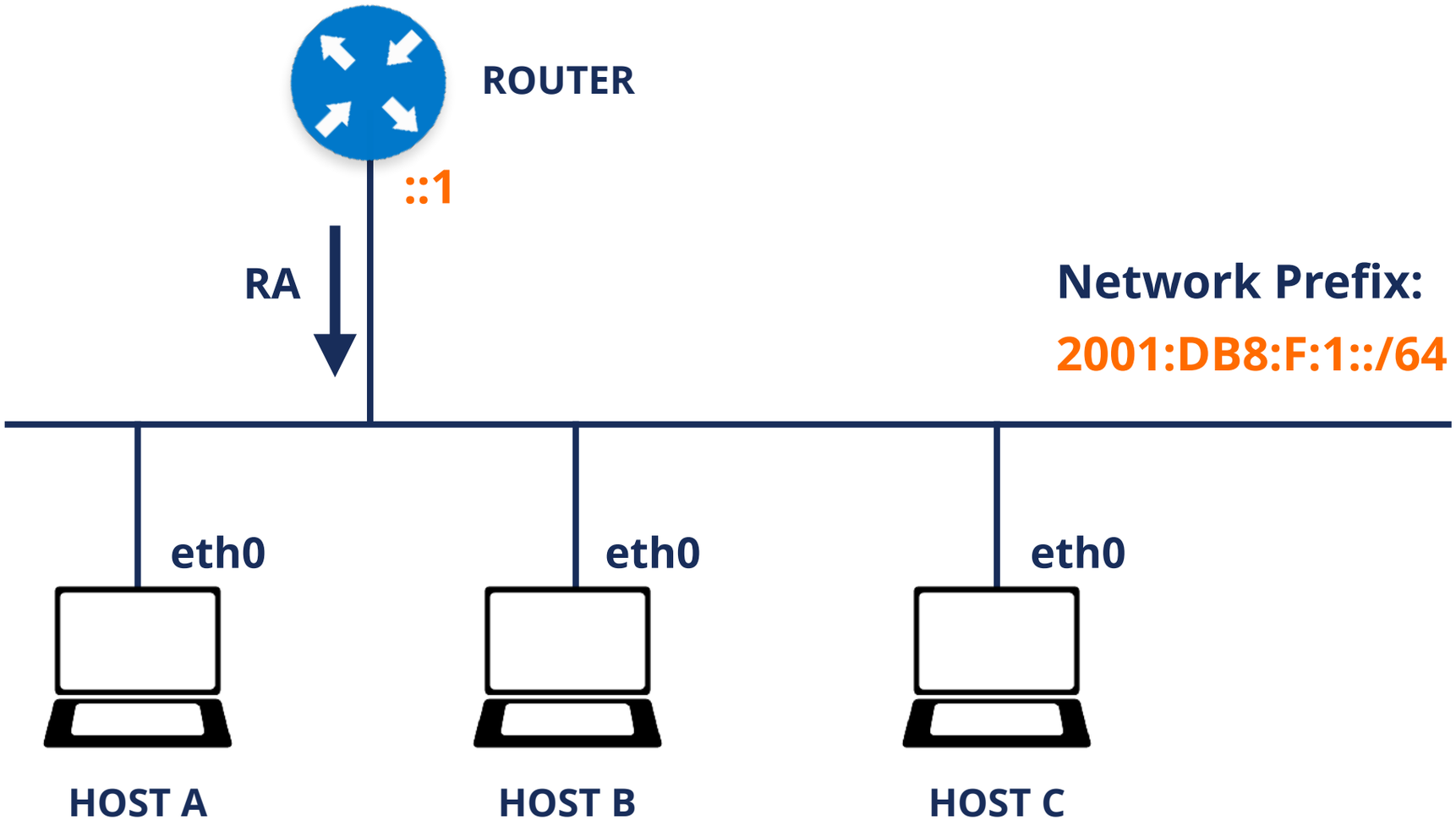
We will demo the activity on the screen.
Watch what we do.



Demo 1: IPv6 Packet Generation

- **Description**: Use **Scapy** to generate IPv6 packets
- **Goals**:
  - Know about the Scapy tool (http://secdev.org/projects/scapy/)
  - Learn about some of the capabilities of Scapy
- **Time**: 10 minutes
- **Demo**:
  - Generate IPv6 packets
  - Send and receive IPv6 packets

Demo 1 Lab Network



Network Prefix:

2001:DB8:F:1::/64

Demo 1: IPv6 Packet Generation

```
>>> a=IPv6()

>>> a
<IPv6  |>

>>> a.dst="2001:db8:a:b::123:321:101"

>>> a.src="2001:db8:1::A101"

>>> a.show()
###[ IPv6 ]###
  version= 6
  tc= 0
  fl= 0
  plen= None
  nh= No Next Header
  hlim= 64
  src= 2001:db8:1::a101
  dst= 2001:db8:a:b:0:123:321:101
```

Demo 1: IPv6 Packet Generation

```
>>> b=IPv6(src="2001:db8:5::5",dst="ff02::1")/ICMPv6ND_NA()

>>> b.show()
###[ IPv6 ]###
  version= 6
  tc= 0
  fl= 0
  plen= None
  nh= ICMPv6
  hlim= 255
  src= 2001:db8:5::5
  dst= ff02::1
###[ ICMPv6 Neighbor Discovery - Neighbor Advertisement ]###
     type= Neighbor Advertisement
     code= 0
     cksum= None
     R= 1
     S= 0
     O= 1
     res= 0x0
     tgt= ::
```

Demo 1: IPv6 Packet Generation

```
>>> c=IPv6(dst="2001:db8:F:1::1")/ICMPv6EchoRequest()

>>> ans,unans = sr(c)
Begin emission:
....Finished to send 1 packets.
*
Received 3 packets, got 1 answers, remaining 0 packets

>>> ans.summary()
IPv6 / ICMPv6 Echo Request (id: 0x0 seq: 0x0) ==> IPv6 / ICMPv6
Echo Reply (id: 0x0 seq: 0x0)

>>> ans[0][1].show()
```

Demo 1: IPv6 Packet Generation

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

Questions

Let’s take a **5 minutes** break!

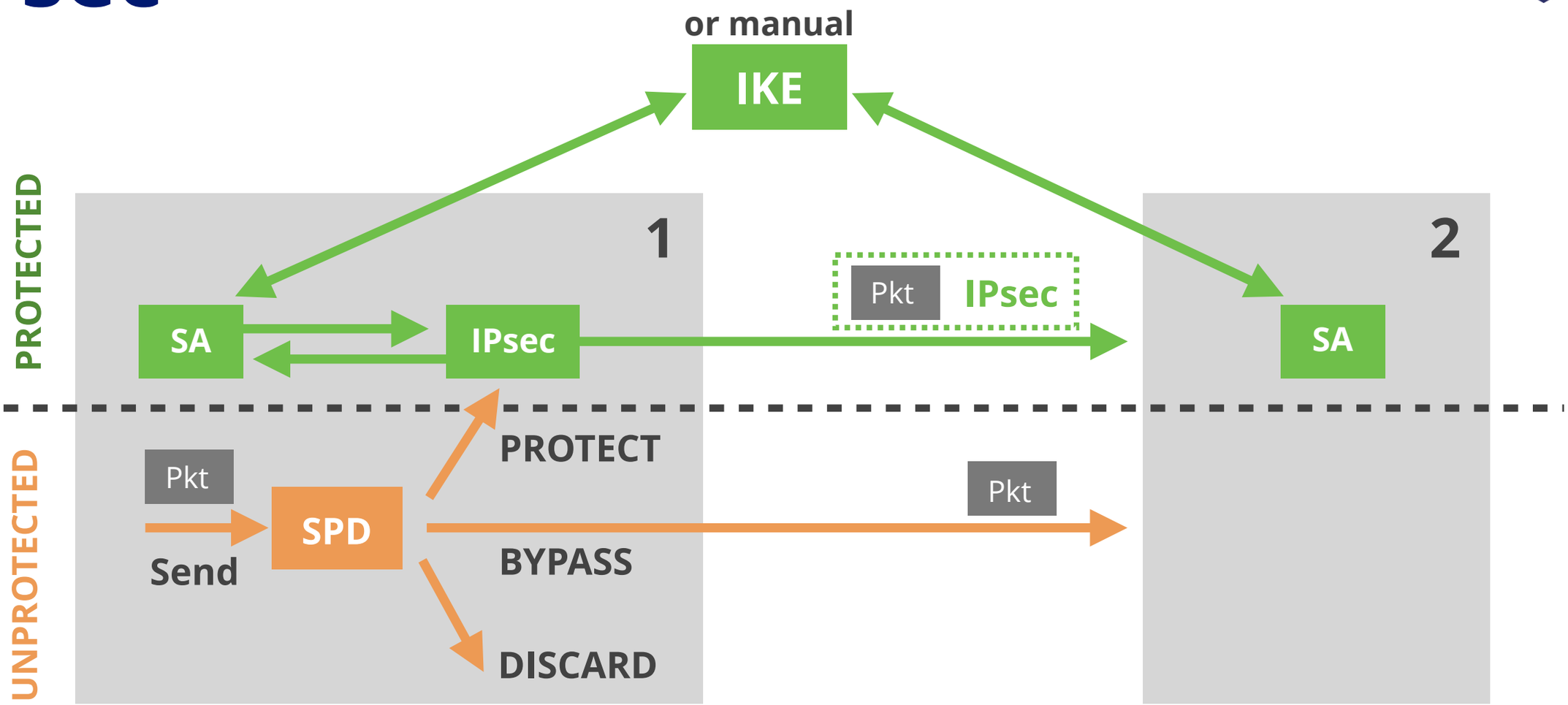

WELCOME
WE ARE
OPEN
PLEASE COME IN

IPSec

Section 2

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

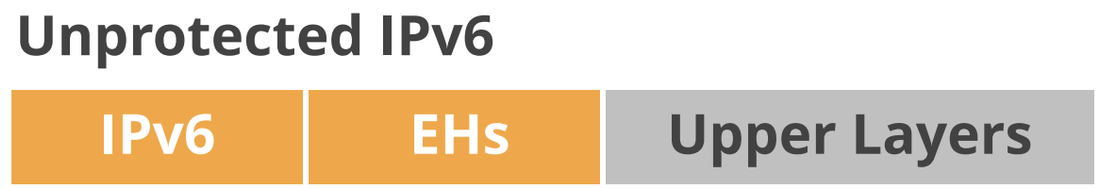
IKE **Internet Key Exchange** allows automatic creation of SAs

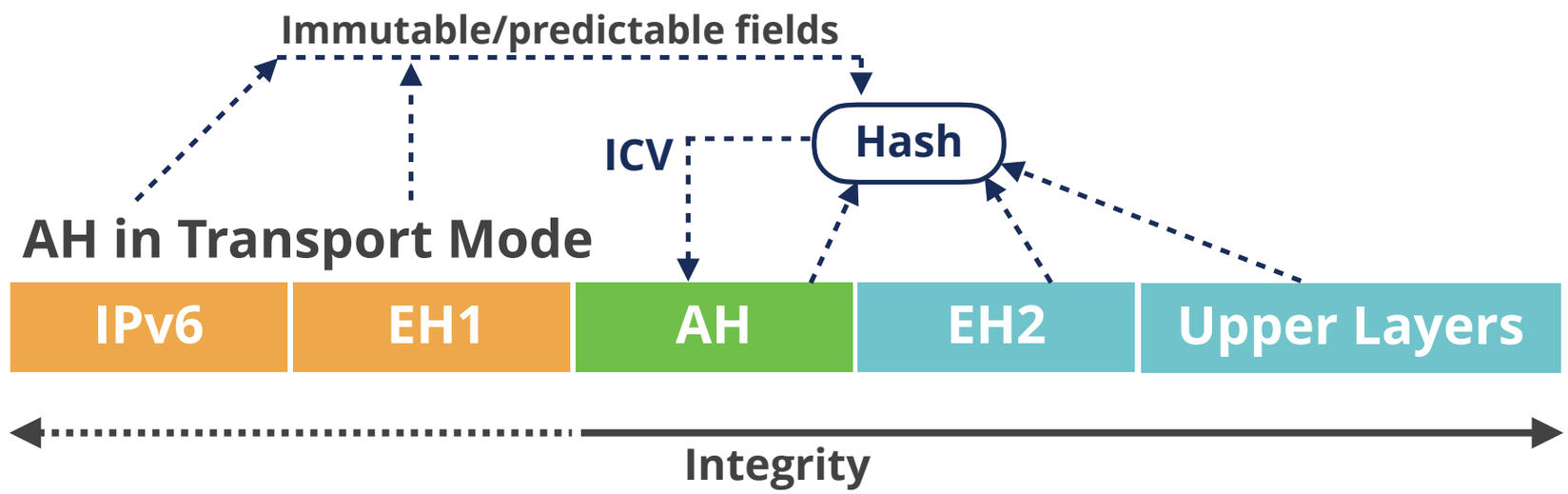
IPsec Modes

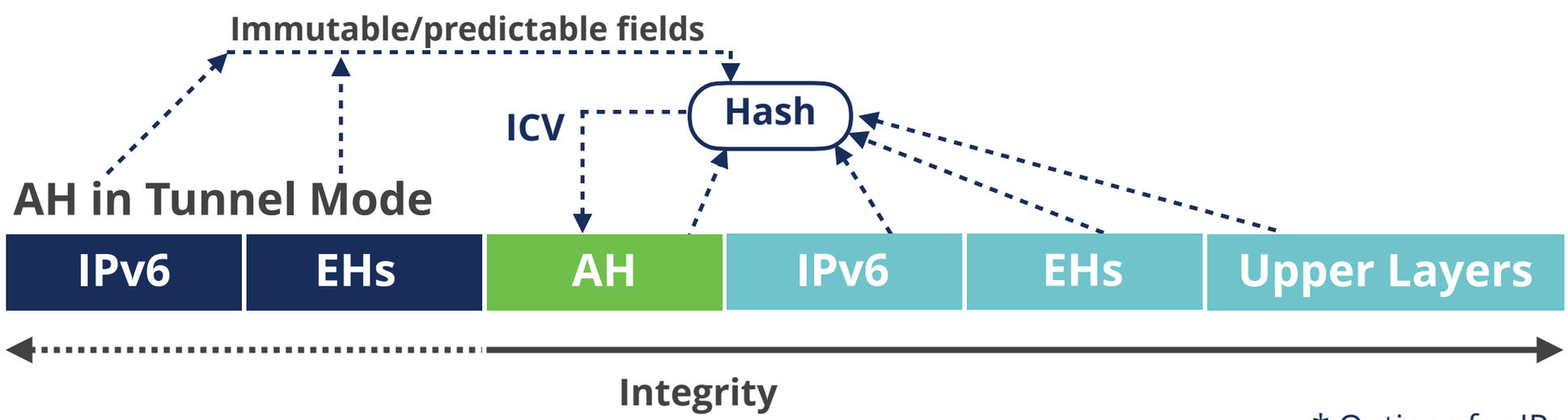
Transport Mode

Tunnel Mode

IPsec: Authentication Header







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

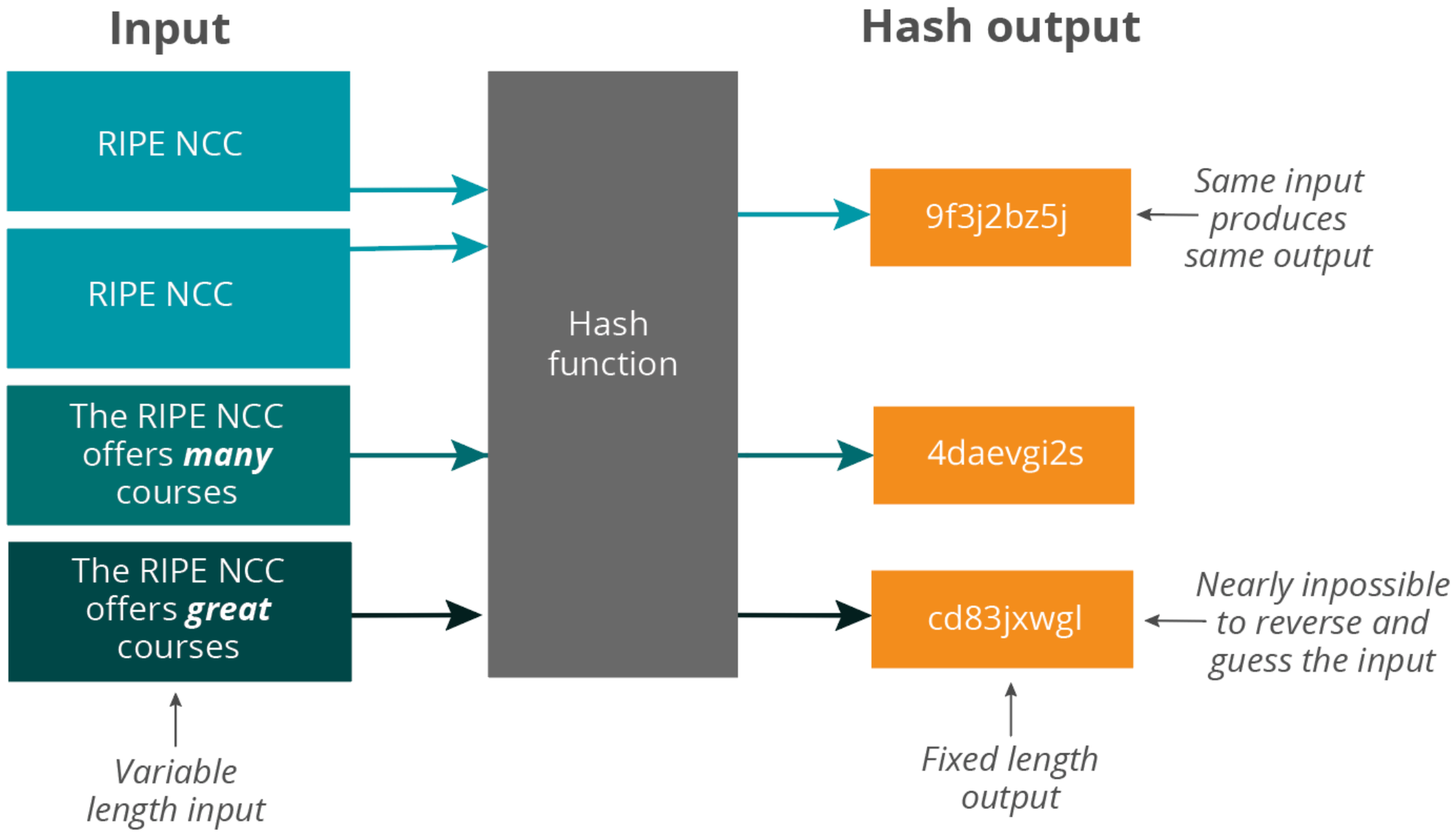
EH2 = Destination Options**

* Options for IPs in routing header

** Options for destination IP

Hash Function

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



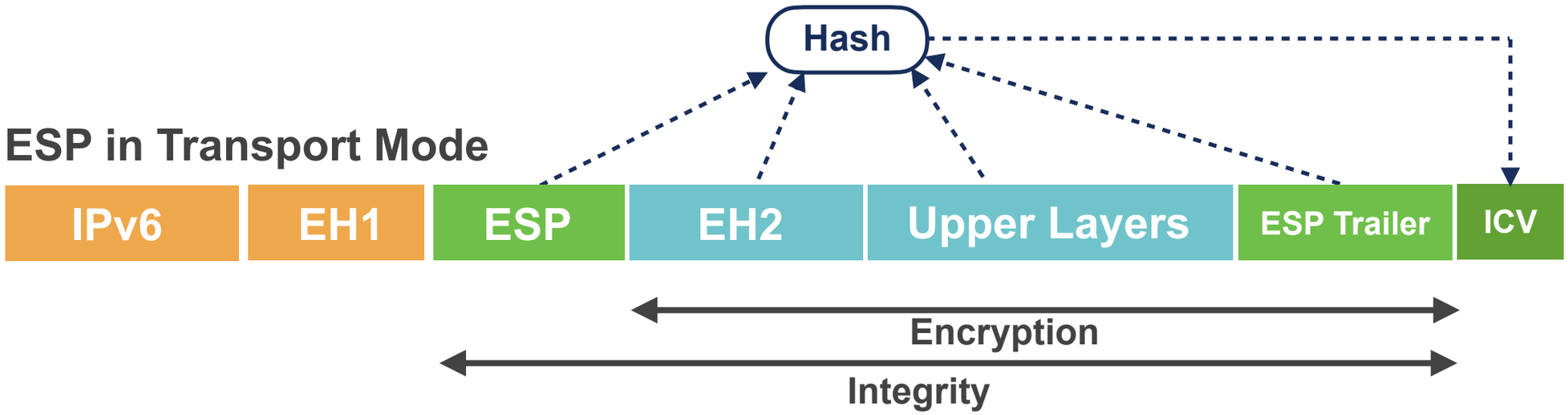
IPsec: ESP

Unprotected IPv6

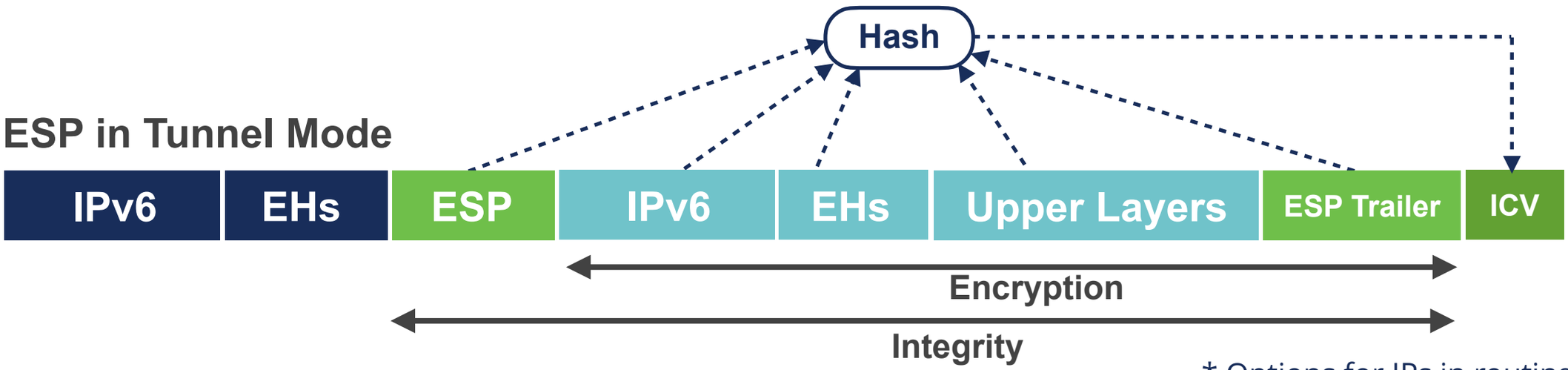
EH1 = Hop-by-Hop,
Dest. Options*,
Routing, Fragment

EH2 = Destination Options**

ESP in Transport Mode



ESP in Tunnel Mode



* Options for IPs in routing header

** Options for destination IP

Take the poll!

How is the **ICV** (**Integrity Check Value**) used in **IPsec** to provide integrity?

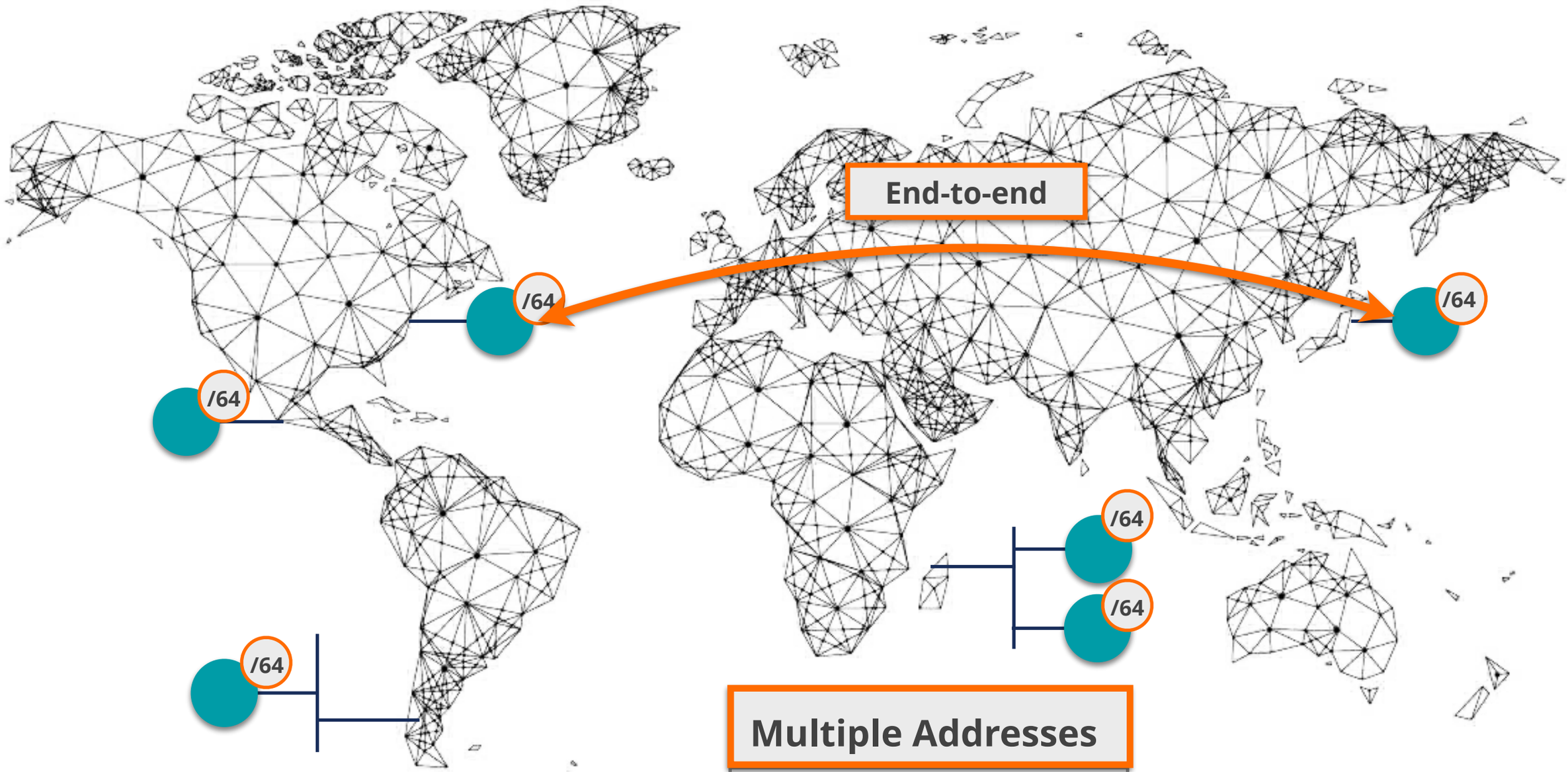
2 min.

Questions

IPv6 Addressing Architecture

Section 3

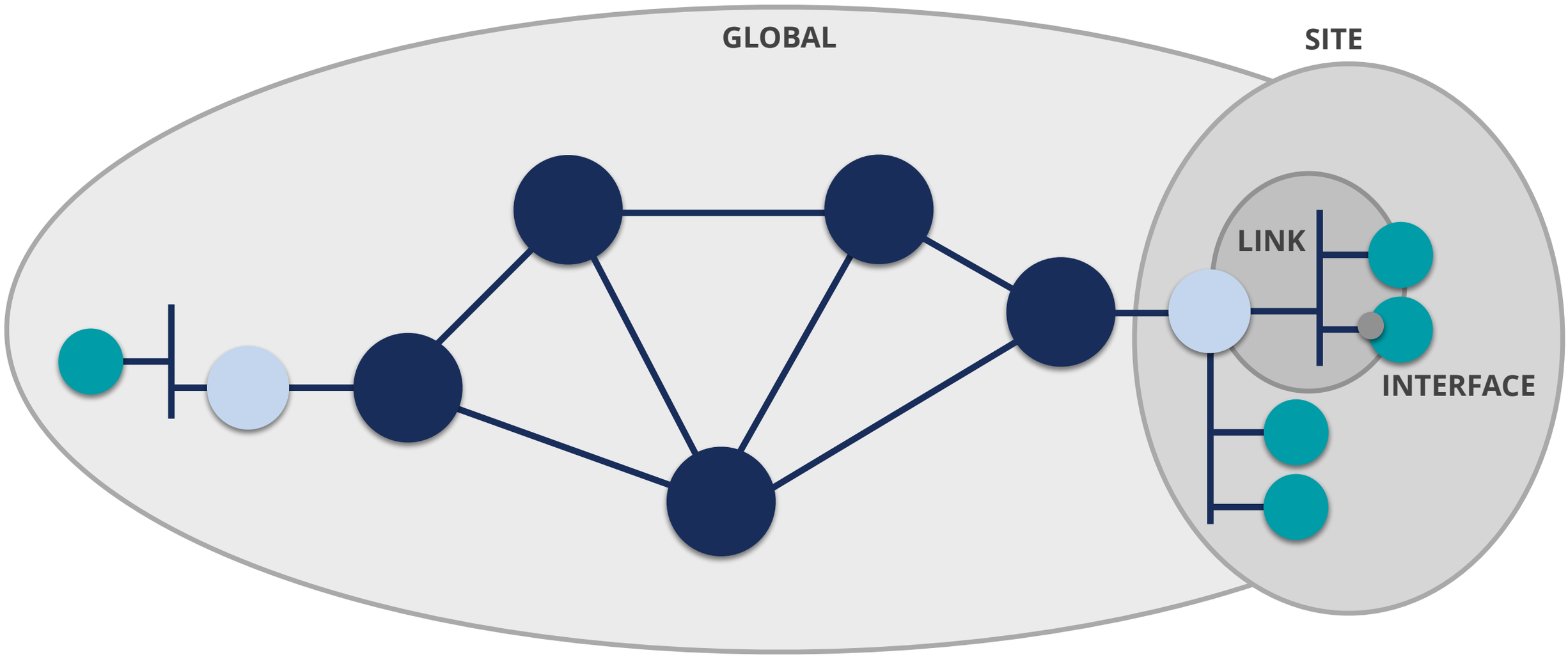
340,282,366,920,938,463,463,374,607,431,768,211,456



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

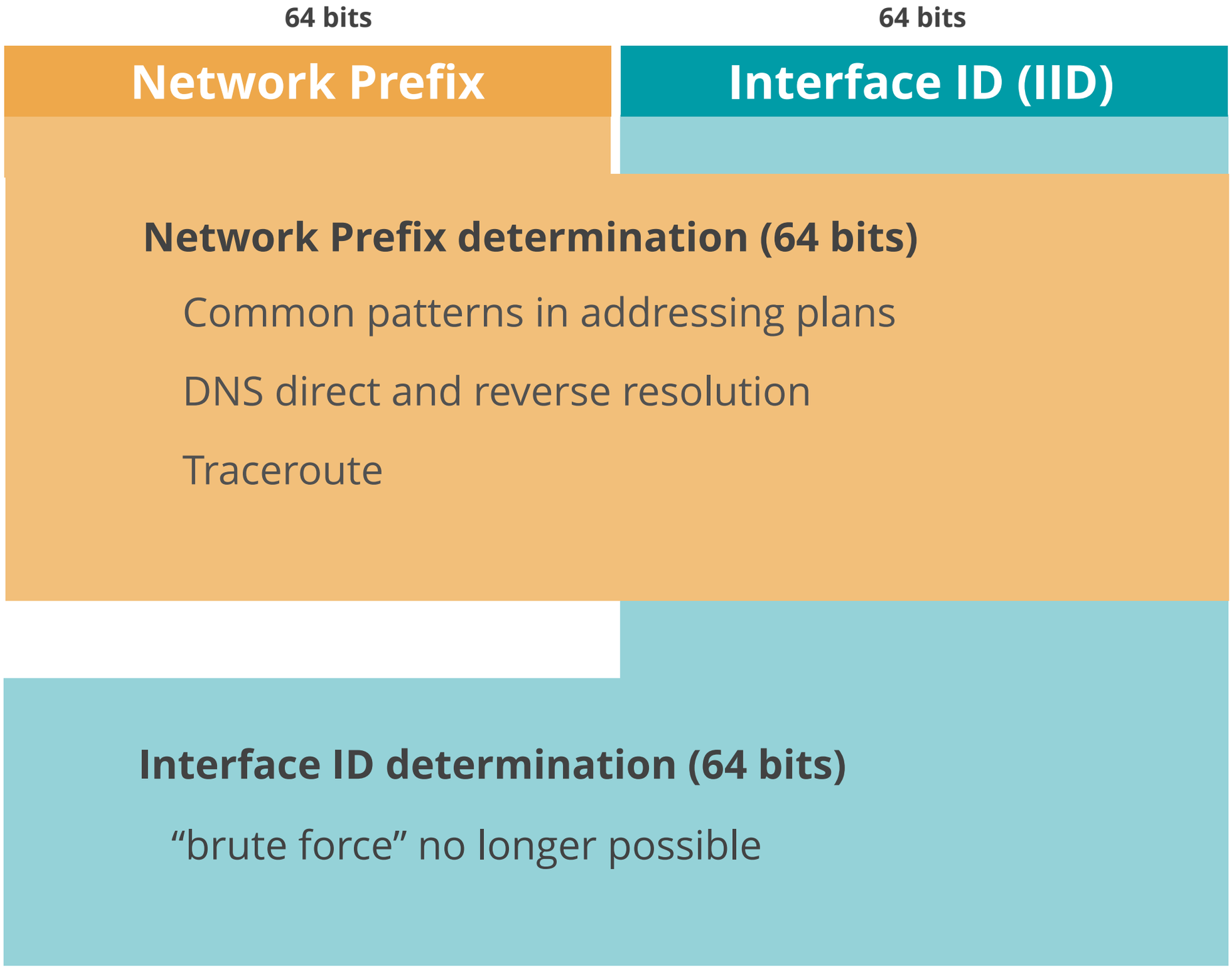
Take the poll!

What is the **scope** of the following IPv6 address?

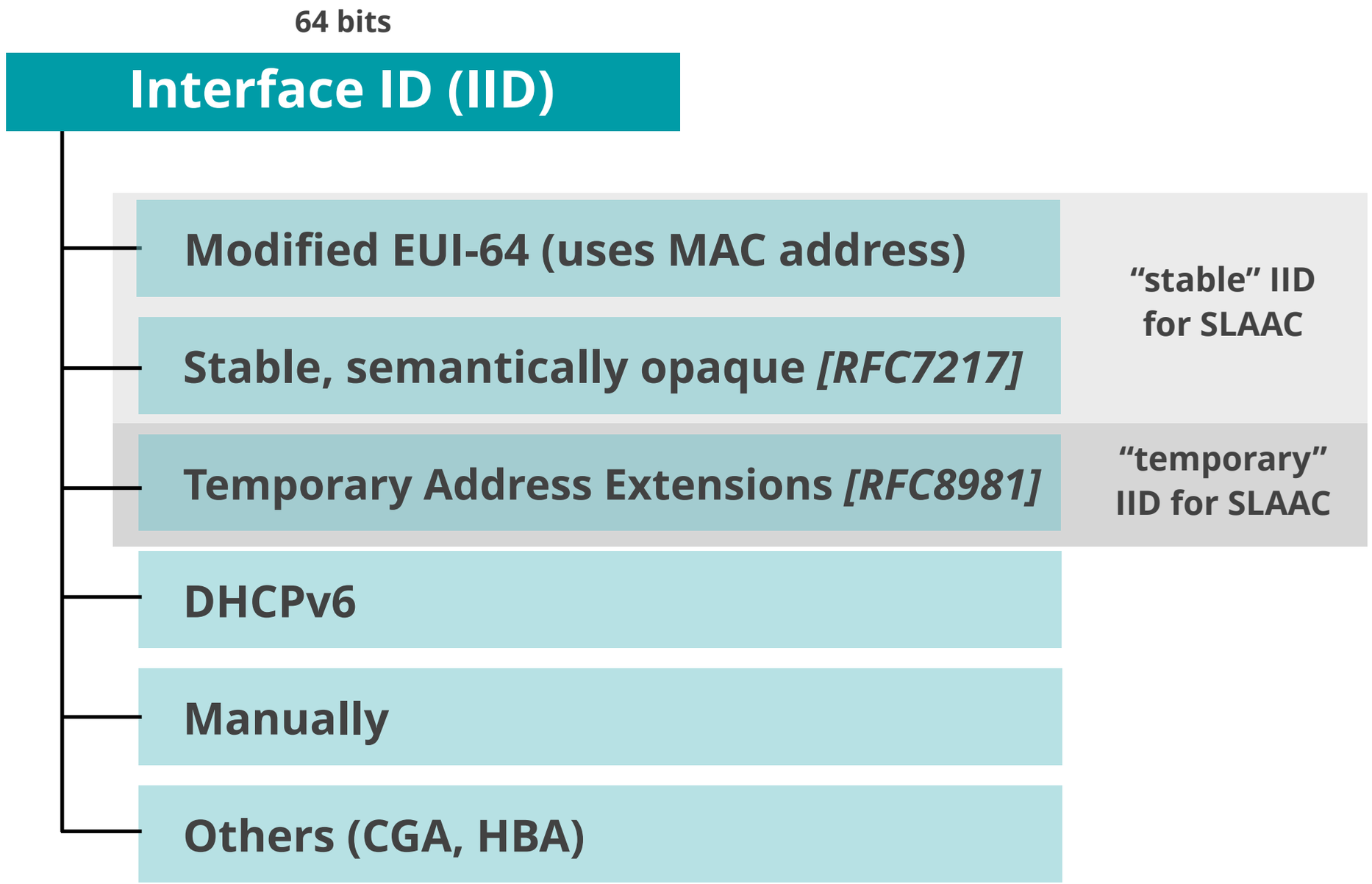
fe80::0123:aff:ad34

2 min.

IPv6 Network Scanning



IID Generation Options



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

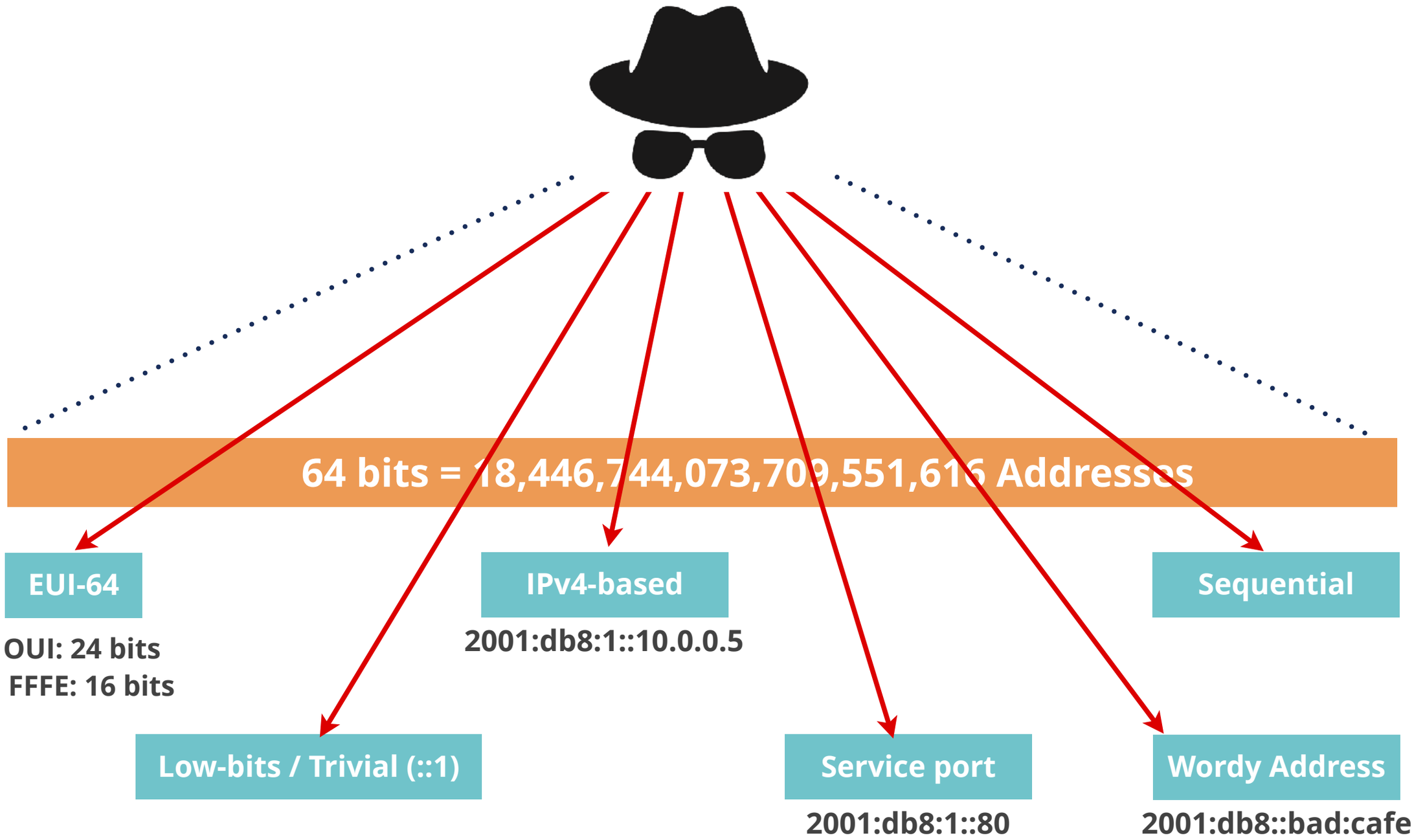
- **Widely used** and **standardised** for "stable" addresses *[RFC8064]*

Take the poll!

How can the **EUI-64** make it easier to guess an **IID**?

2 min.

Guessing IIDs

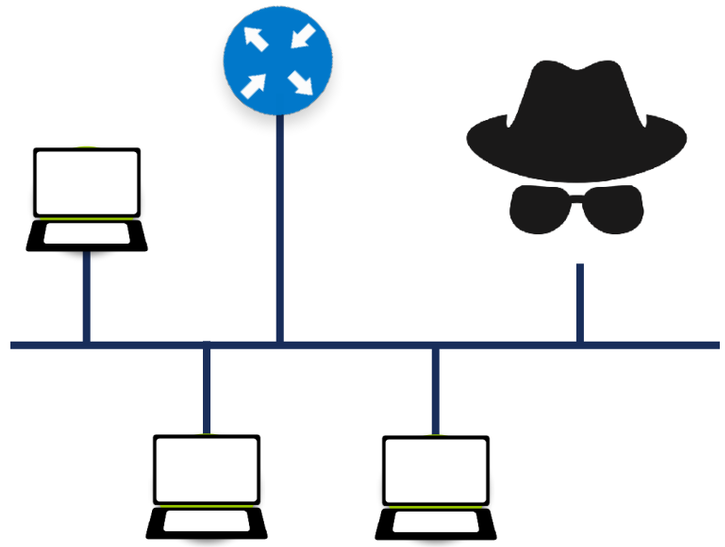


Take the poll!

Why is a **Dual-Stack network** easier to scan?

2 min.

Locally Scanning IPv6 Networks



- Traffic Snooping
- Dual-stack
- Routing Protocols
- Local Protocols
  - LLMNR [RFC4795]
  - Multicast DNS (mDNS) [RFC6762]
  - DNS Service Discovery (DNS-SD) [RFC6763]
- Local Scanning

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 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

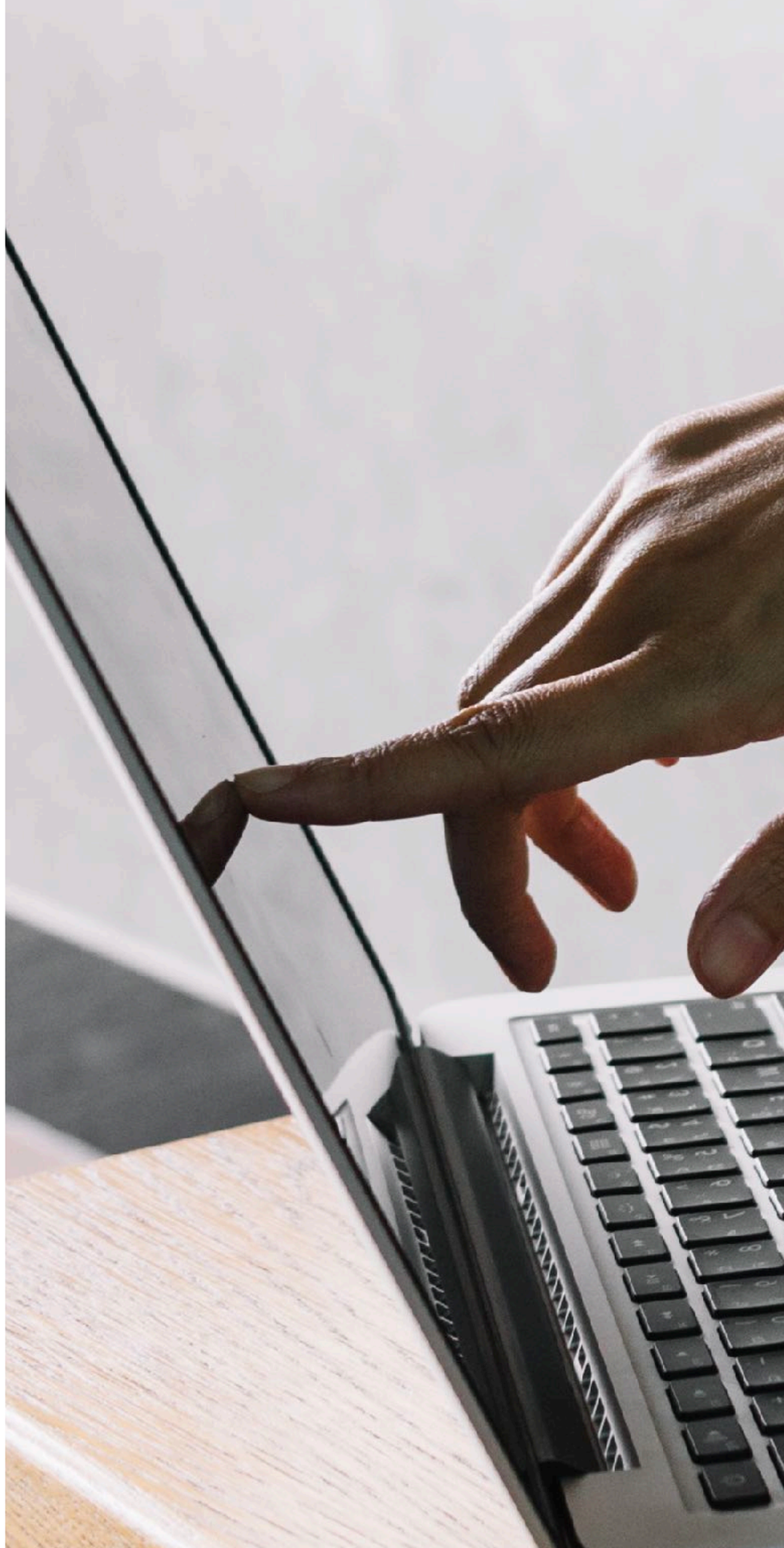
- Is it easy to **scan** an IPv6 network?

Demo 2

IPv6 Network Scanning

Demo time!

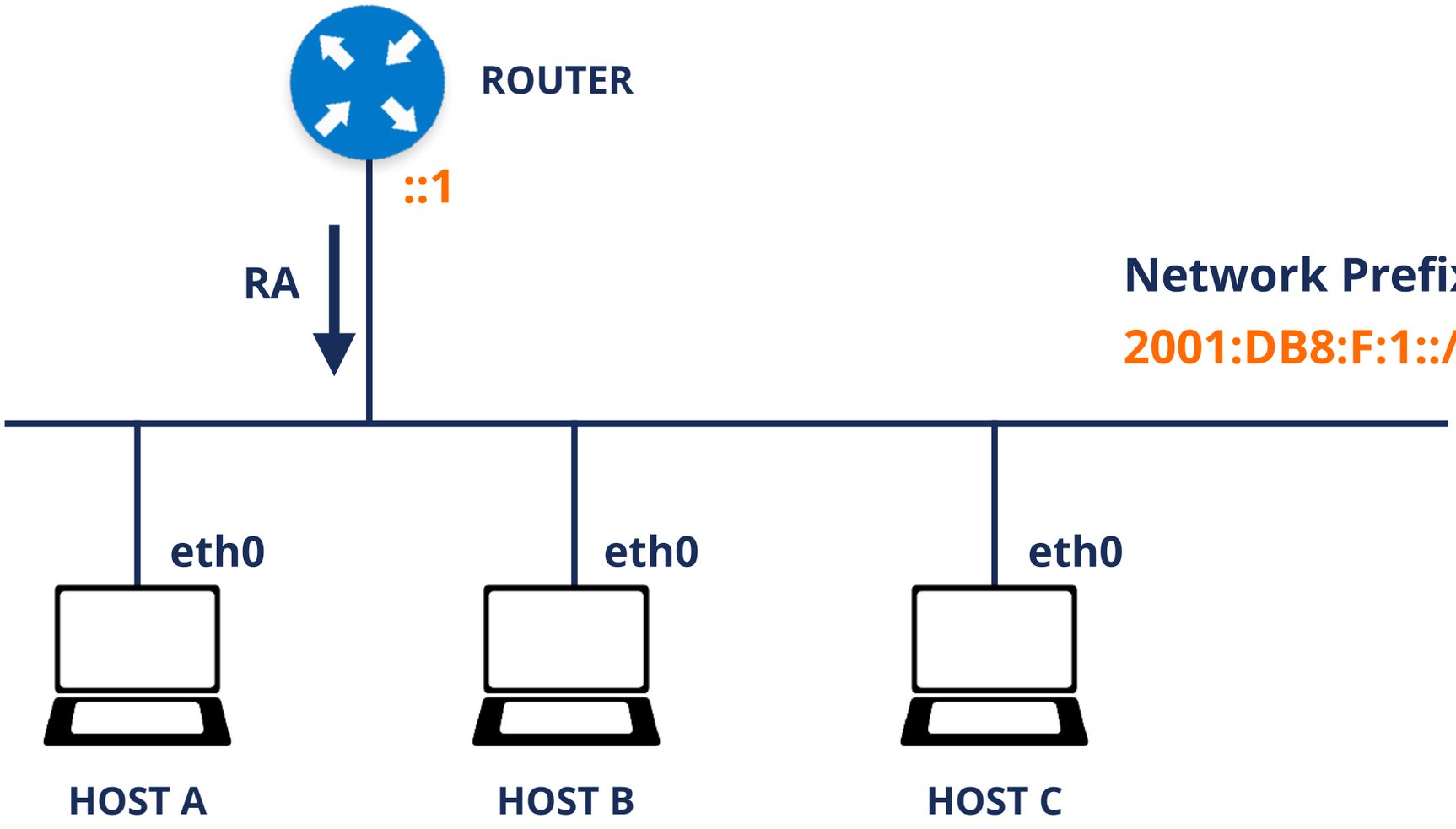
We will demo the activity on the screen.
Watch what we do.



Demo 2: IPv6 Network Scanning

- **Description**: Use available toolsets to scan a subnet
- **Goals**:
  - Know about two toolsets:
  - **THC-IPV6** (https://github.com/vanhauser-thc/thc-ipv6)
  - **The IPv6 Toolkit** (https://www.si6networks.com/tools/ipv6toolkit/)
  - Learn which tool they have to scan a link
- **Time**: 5-10 minutes
- **Demo**:
  - Use The IPv6 Toolkit to scan a subnet
  - Use THC-IPV6 to scan a subnet

Demo 2 Lab network



Network Prefix:

2001:DB8:F:1::/64

Demo 2: IPv6 Network Scanning

```
[root@host-c ~]# alive6 eth0
Alive: 2001:db8:f:1:5054:ff:fec1:4275 [ICMP echo-reply]
Alive: 2001:db8:f:1:5054:ff:fe9d:32ea [ICMP echo-reply]
Alive: 2001:db8:f:1::1 [ICMP echo-reply]

Scanned 1 address and found 3 systems alive
[root@host-c ~]#
```

Demo 2: IPv6 Network Scanning

```
[root@host-c ~]# scan6 -L -i eth0
[ 6797.089211] device eth0 entered promiscuous mode
fe80::5054:ff:fec1:4275
fe80::5054:ff:fe9d:32ea
fe80::5054:ff:fe99:5165
2001:db8:f:1:5054:ff:fec1:4275
2001:db8:f:1::1
2001:db8:f:1:5054:ff:fe9d:32ea
[ 6801.104679] device eth0 left promiscuous mode
```

Take the poll!

Why do you think **alive6** only finds **global** addresses and **scan6** also finds the **link-local** addresses?

2 min.

What Have We Seen?

Basics of IPv6 brings some security considerations

- **Same as in IPv4: IP spoofing, covert channel, or even IPsec**
- **New in IPv6: Extension headers, new addressing scheme, new scanning techniques**

There are tools that allow security assessment of IPv6 networks

- **Scapy**
- **THC-IPV6**
- **The IPv6 Toolkit**

Take the poll!

Think of what you learned in this webinar.

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

2 min.

What's Next in IPv6

Webinars

Attend another webinar live wherever you are.

- Introduction to IPv6 (2 hrs)
- 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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Son
დასასრული
הסוף
Кінець
Finis
Lõpp
Amaia
Tmiem
Liðugt
Kpaj
Sfârşit
Loppu
Slutt
Fund
Kraj
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