RIPE NCC

RIPE NETWORK COORDINATION CENTRE

# IPv6 Security

## RIPE NCC Days - Sofia

June 2023

# Overview

- IPv6 Security vs IPv4 Security
- Reachability of IPv6 Addresses
- Network Scanning in IPv6
- Attacks on IPv6
- IPv6 vs IPv4
- IPv6 Support
- IPv4-Only Networks
- IPv6 Security Resources

# 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.

# Reality

## A change of mindset is necessary

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

# For a Good Level of Security

| | |
|---|---|
| 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<br>IPv6 is also responsible for Internet growth |

# IPv6 Security Statements

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

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

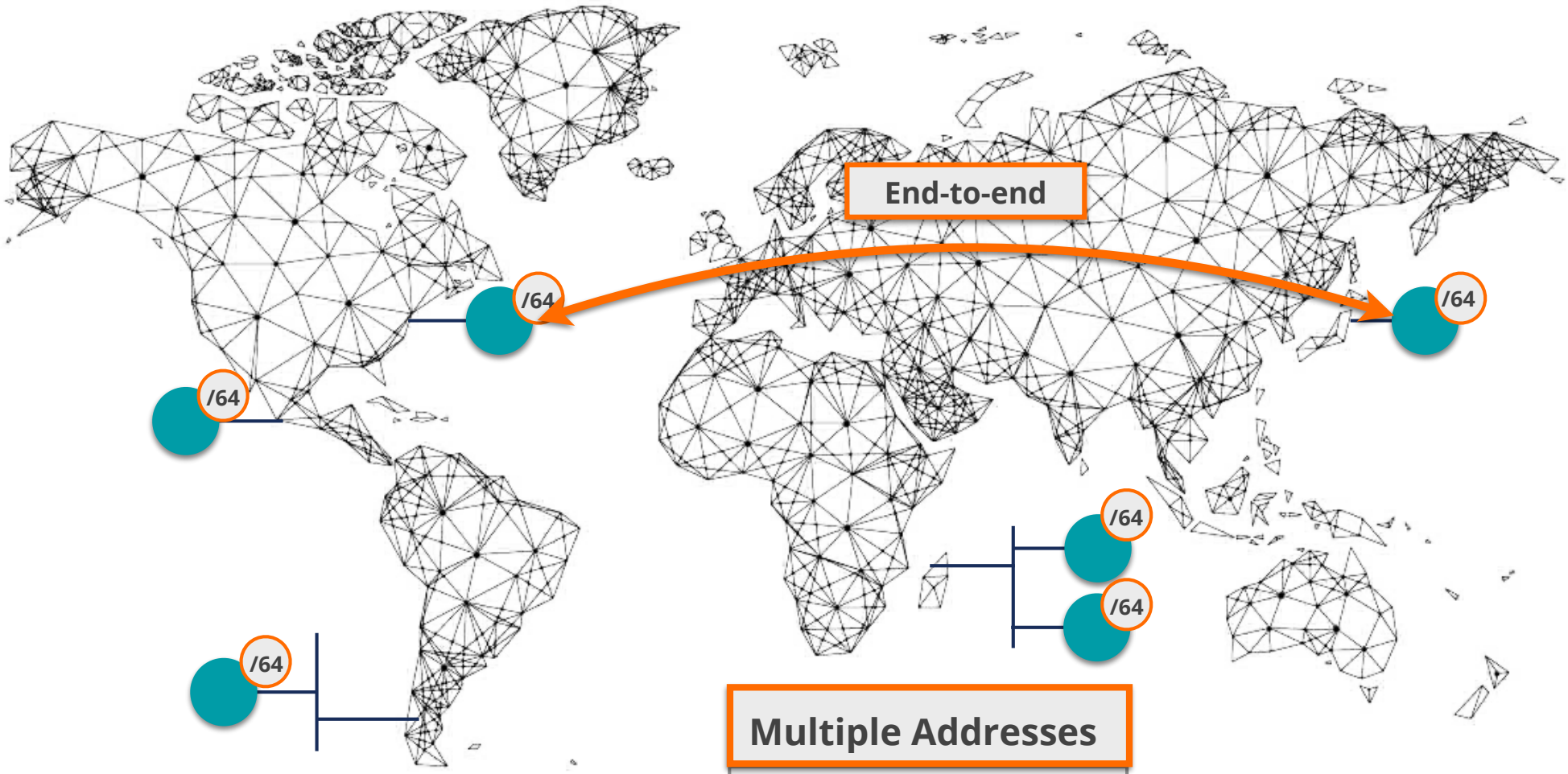
**Reason**:

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

**Reality**:

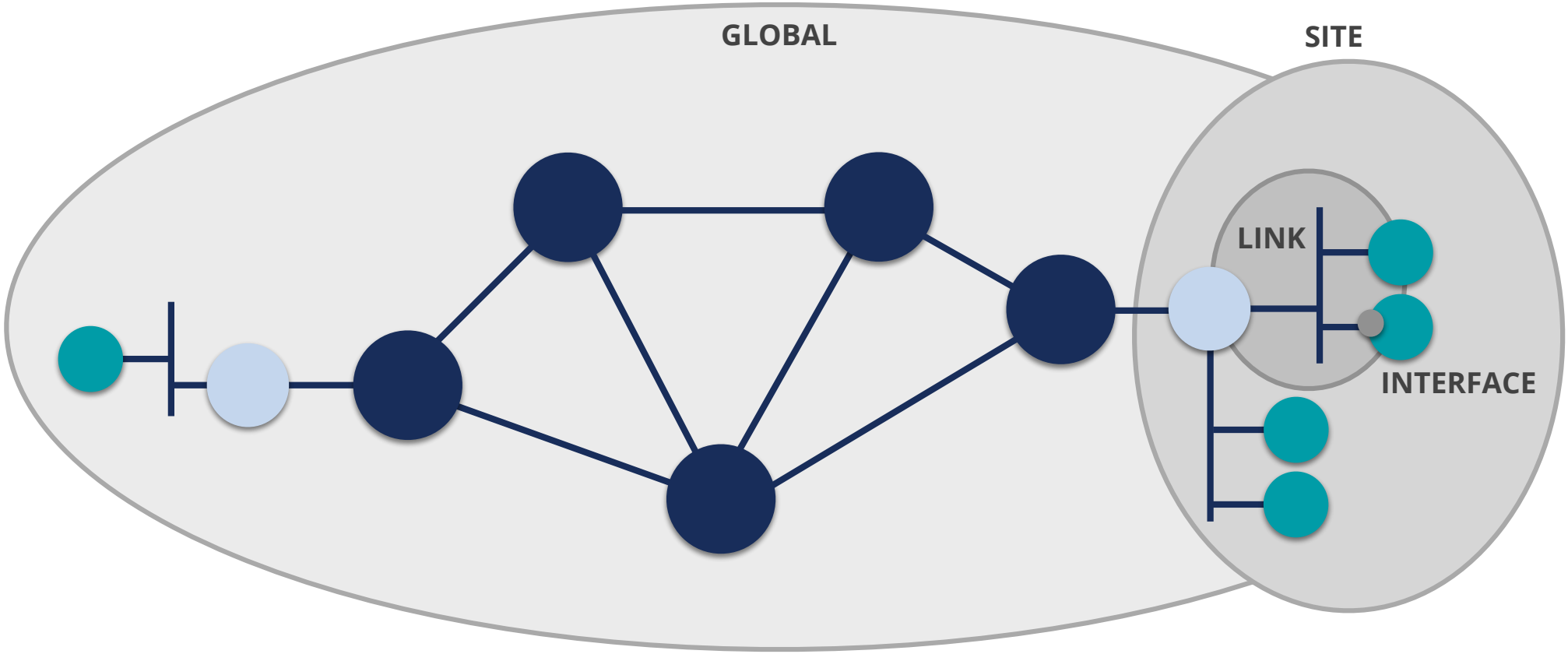
- Global addressing does not imply global reachability.
- You are responsible for reachability (filtering).

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

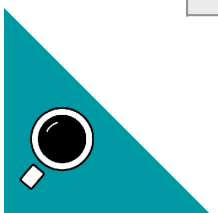
fd00:a:b::100

ff05::1:3

ff02::1

# 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 | RFC 3849 |
| **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 |

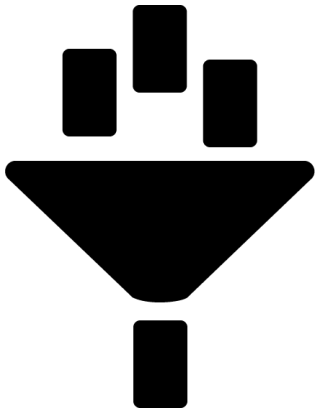


http://www.iana.org/assignments/iana-ipv6-special-registry/

# 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

# Filtering in IPv6 is very Important!

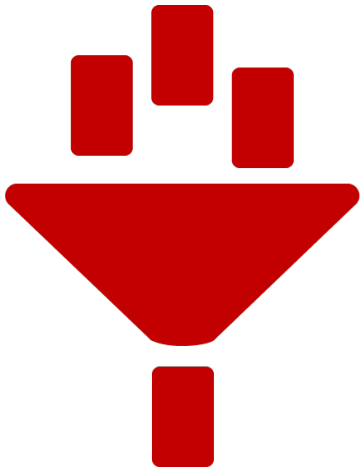


- Global Unicast Addresses
- A good **addressing plan**

**Easier** filtering!

# New Filters to Take Into Account

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



# FILTER ICMPv6 CAREFULLY!

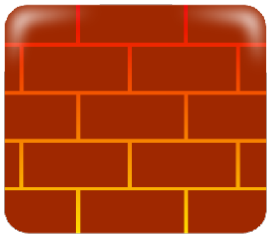
## Used in many IPv6 related protocols

# 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**

+

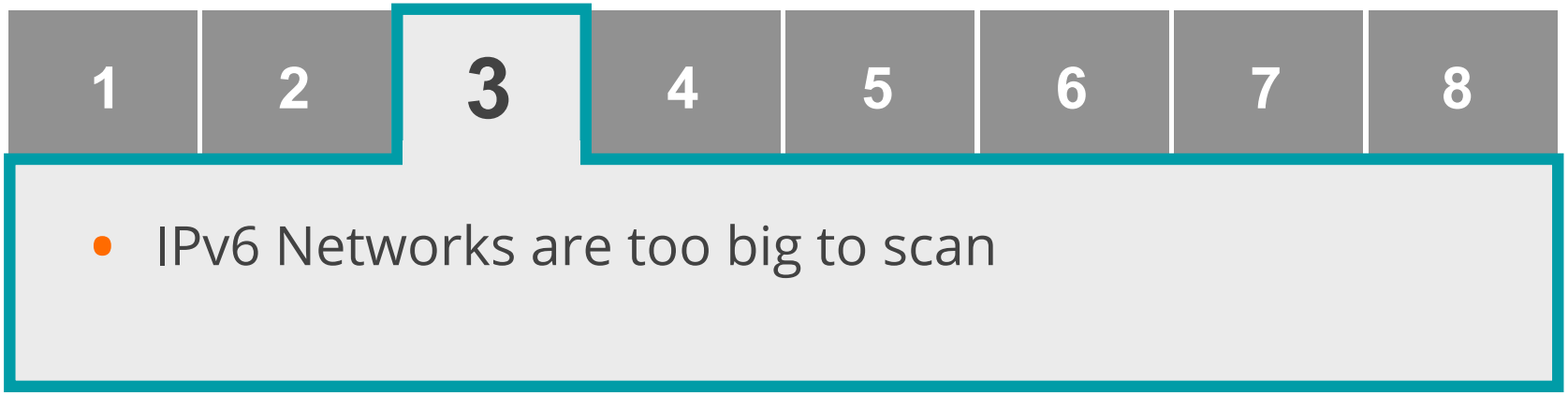
**Common IPv4 Practices**

+

**New IPv6 Considerations**

- End to End needs filtering
- ICMPv6 should be wisely filtered
- Filtering adapted to IPv6: EHs, TMs

# IPv6 Security Statements



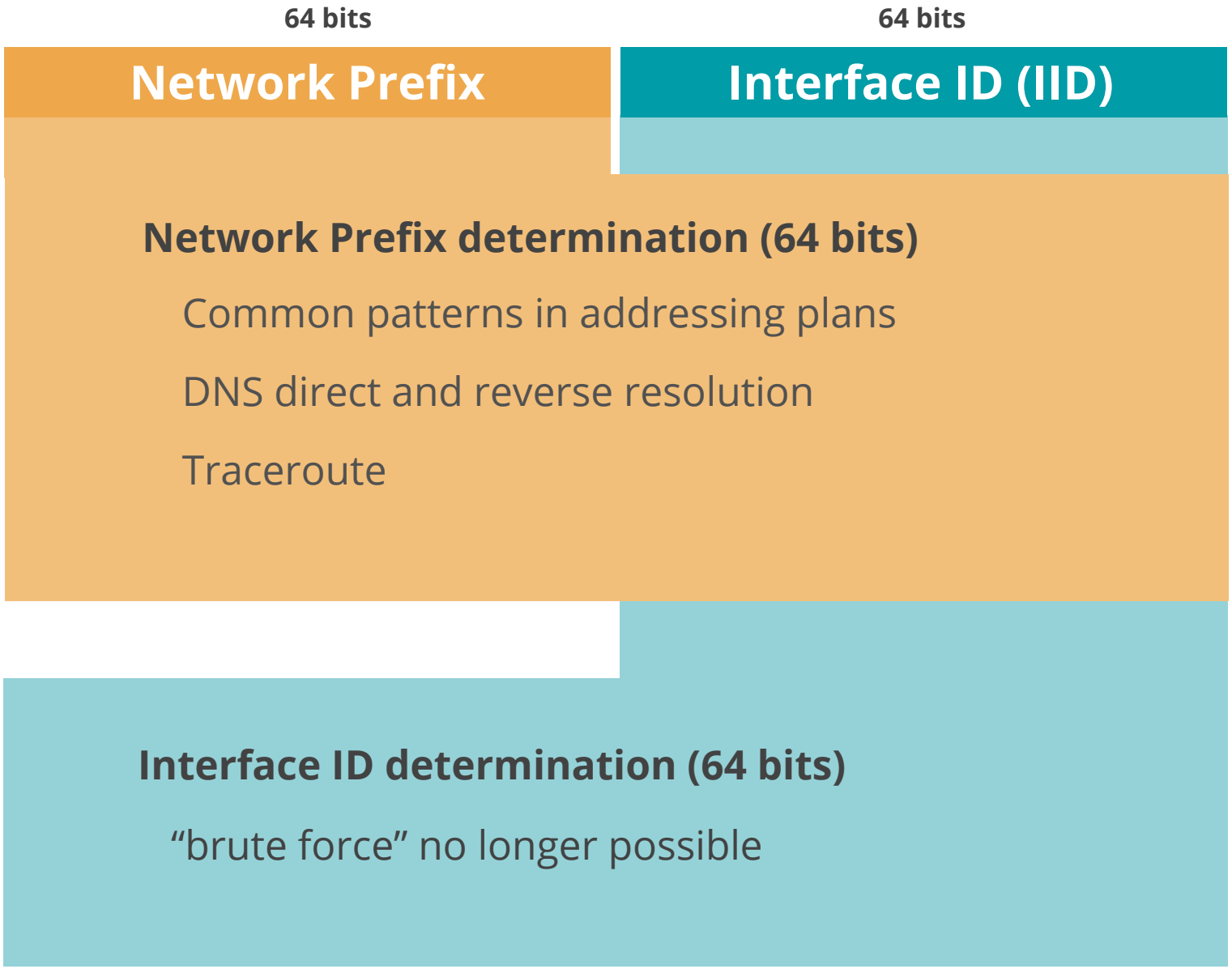

**Reason**:

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

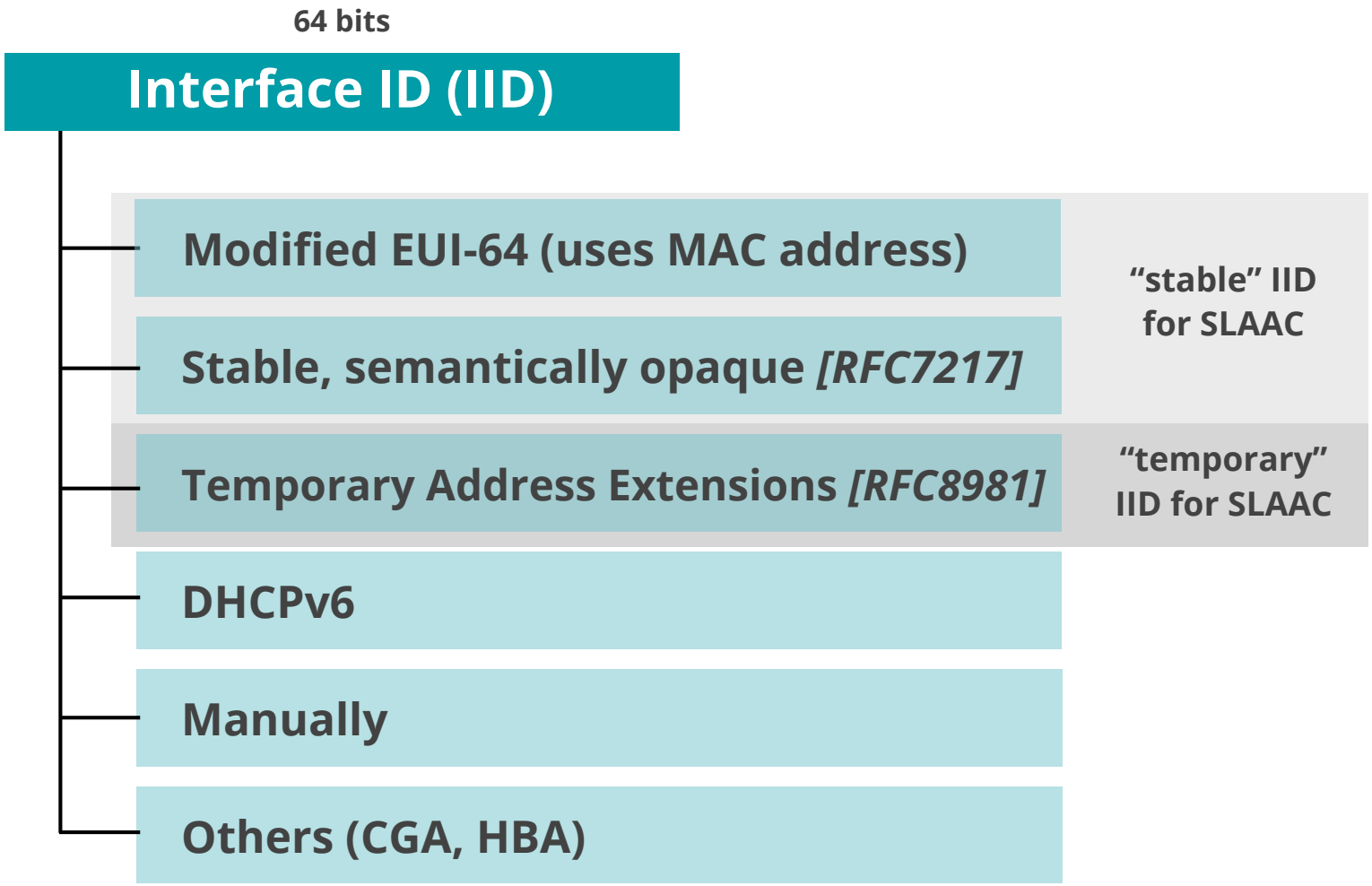
**Reality**:

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

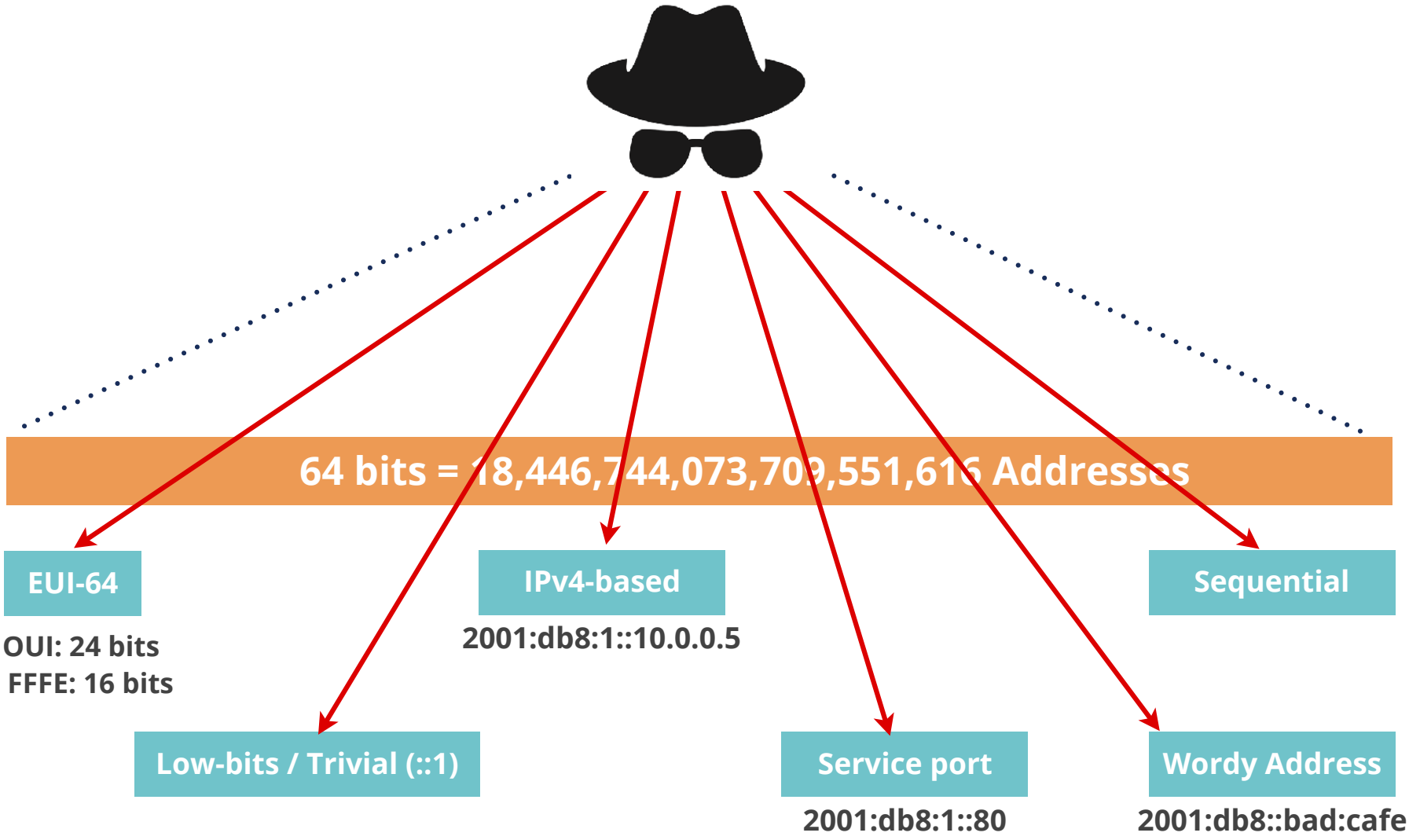
# IPv6 Network Scanning



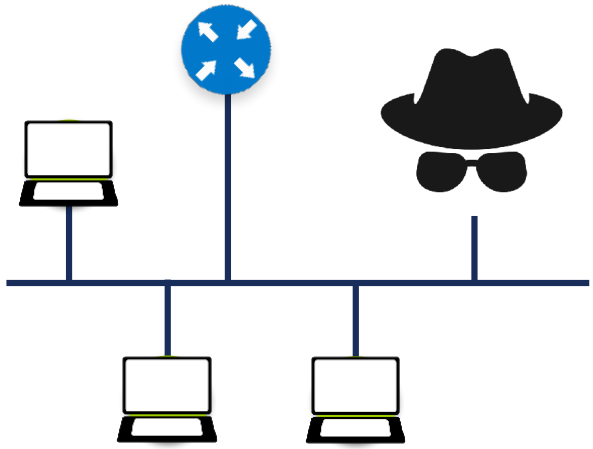
# IID Generation Options



# Guessing IIDs

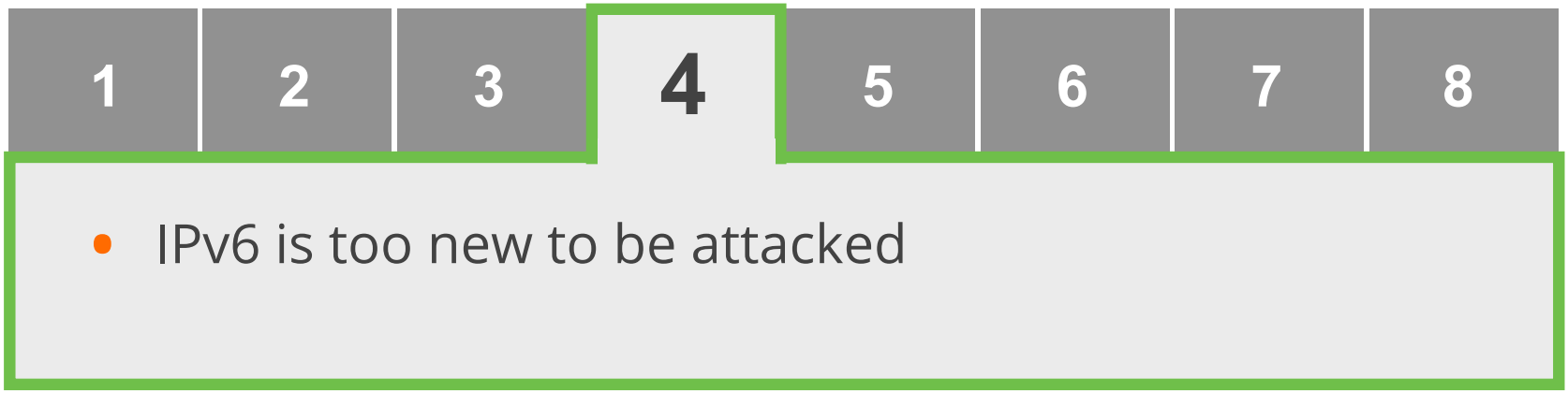


# Locally Scanning IPv6 Networks



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

# IPv6 Security Statements




**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

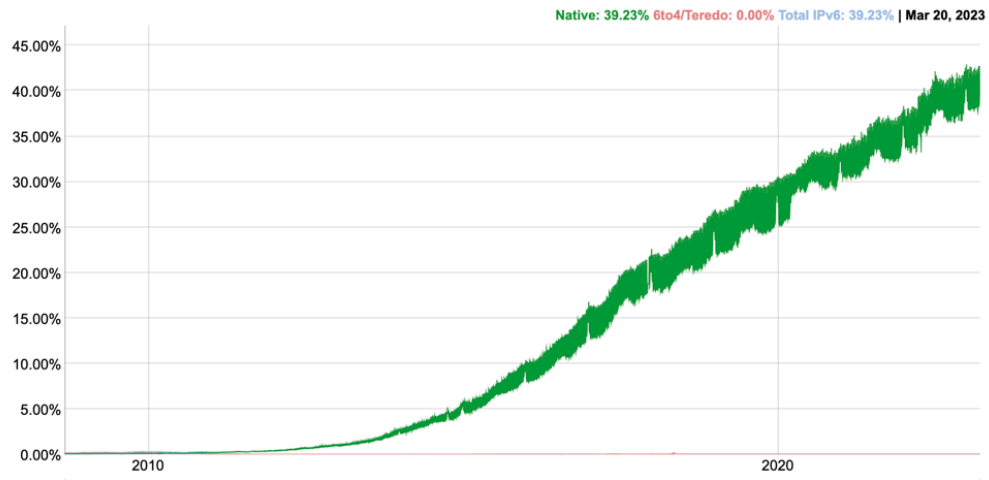
# IPv6 is happening…

| RANK | IPV6% | COUNTRY / REGION |
|---|---|---|
| 1 | 100% | Bahrain |
| 2 | 55.7% | Montserrat |
| 3 | 55.7% | Saudi Arabia |
| 4 | 54.9% | India |
| 5 | 53.9% | Uruguay |
| 6 | 53% | France |
| 7 | 53% | Malaysia |
| 8 | 52.1% | Germany |
| 9 | 50.7% | Greece |
| 10 | 50.4% | United States |
| 11 | 50.1% | Puerto Rico |
| 12 | 50% | Viet Nam |
| 13 | 48.6% | Belgium |
| 14 | 46.4% | Japan |

Show 10 entries Search:

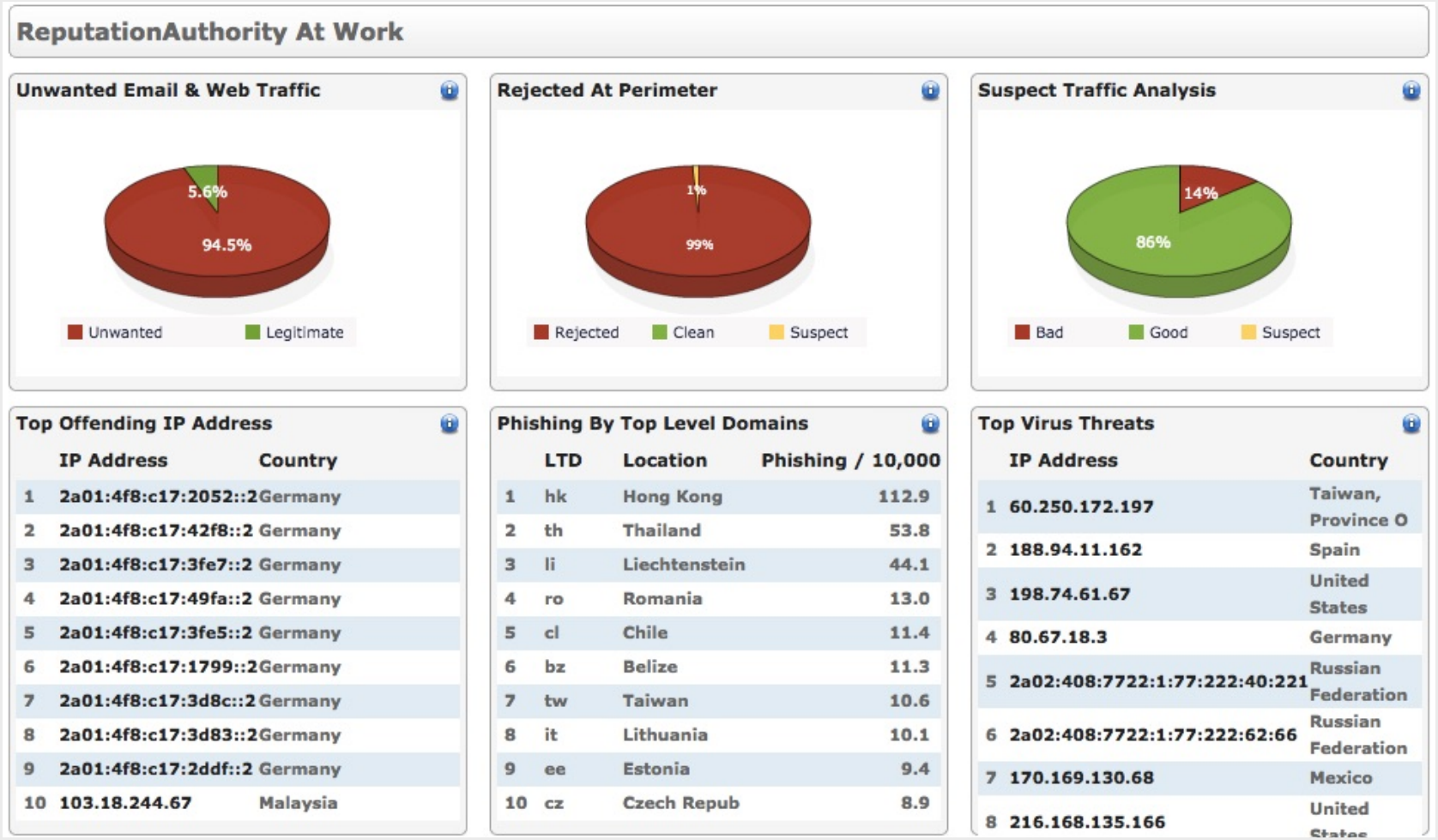
| Rank | Participating Network | ASN(s) | IPv6 deployment |
|---|---|---|---|
| 1 | RELIANCE JIO INFOCOMM LTD | 55836, 64049 | 92.58% |
| 2 | Comcast | 7015, 7016, 7725, 7922, 11025, 13367, 13385, 20214, 21508, 22258, 22909, 33287, 33489, 33490, 33491, 33650, 33651, 33652, 33653, 33654, 33655, 33656, 33657, 33659, 33660, 33661, 33662, 33664, 33665, 33666, 33667, 33668, 36732, 36733 | 73.62% |
| 3 | Combined US Mobile Carriers | 3651, 6167, 10507, 20057, 21928, 22394 | 87.74% |
| 4 | Charter Communications | 7843, 10796, 11351, 11426, 11427, 12271, 20001, 20115, 33363 | 56.41% |
| 5 | ATT | 6389, 7018, 7132 | 72.32% |
| 6 | T-Mobile USA | 21928 | 92.31% |
| 7 | Deutsche Telekom AG | 3320 | 74.48% |
| 8 | Orange Business Services | 3215 | 74.08% |
| 9 | Verizon Wireless | 6167, 22394 | 83.58% |
| 10 | Claro Brasil | 4230, 28573 | 74.53% |

Showing 1 to 10 of 345 entries First Previous 1 2 3 4 5 Next Last




Source: **http://worldipv6launch.org/measurements/ (22/3/2023)**

# … and so are IPv6 Security threats!



# IPv6 Security Statements

| 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**:

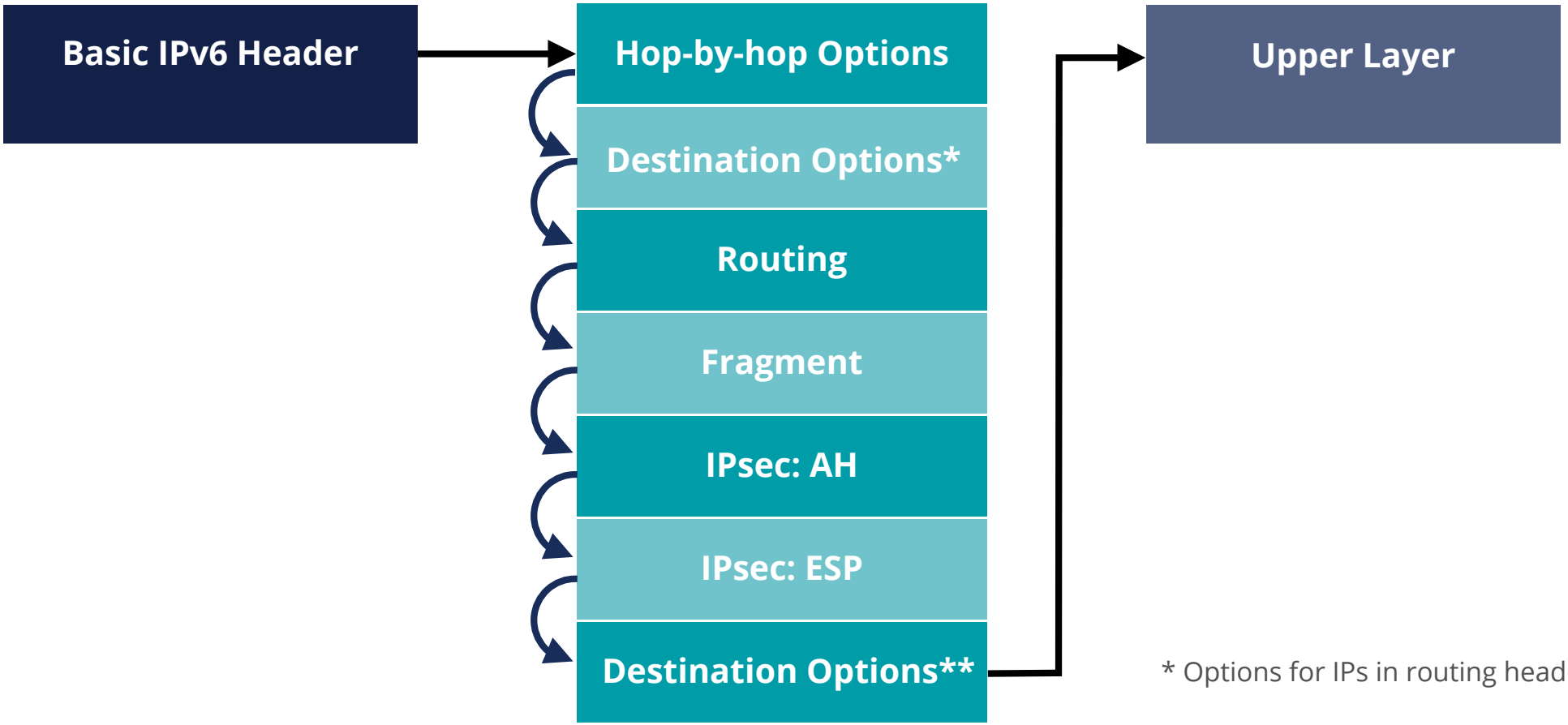
- Whole new addressing architecture
- Many associated new protocols

# IPv6 vs IPv4

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

**No changes with IPv6** | **Changes with IPv6** | **New IPv6 issues**

# IPv6 Extension Headers




* Options for IPs in routing header

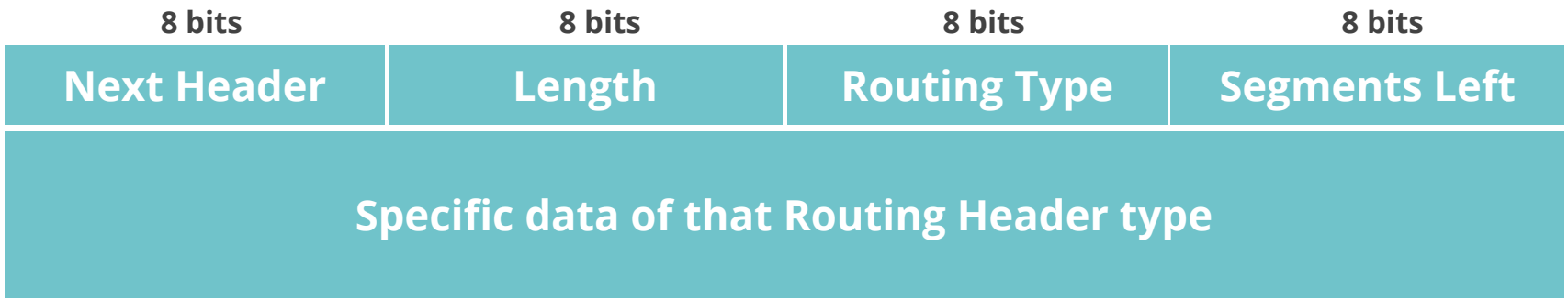
** Options for destination IP

- 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

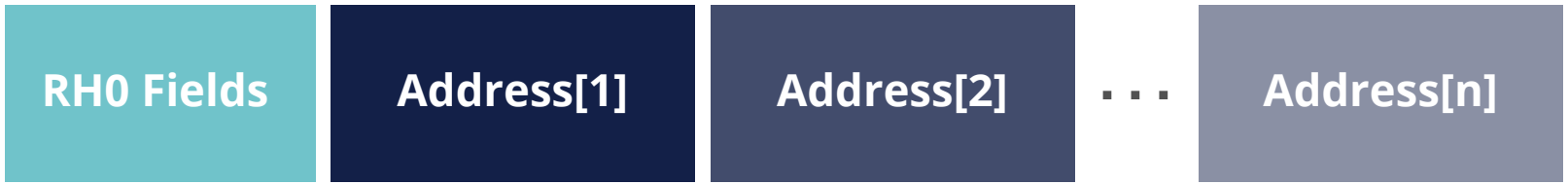
Includes one or more IPs that should be "*visited*" in the path

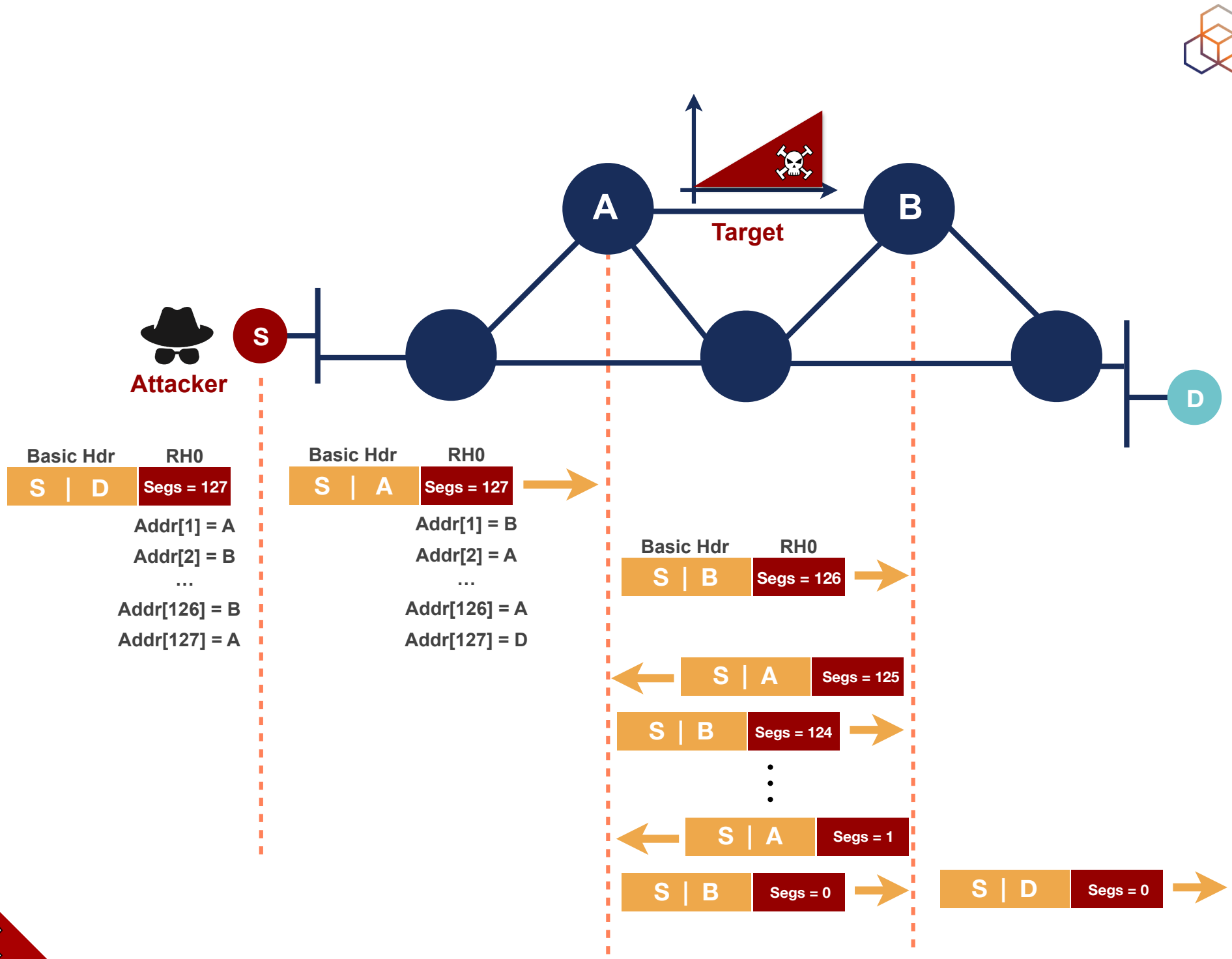
- Processed by the **visited routers**



# 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



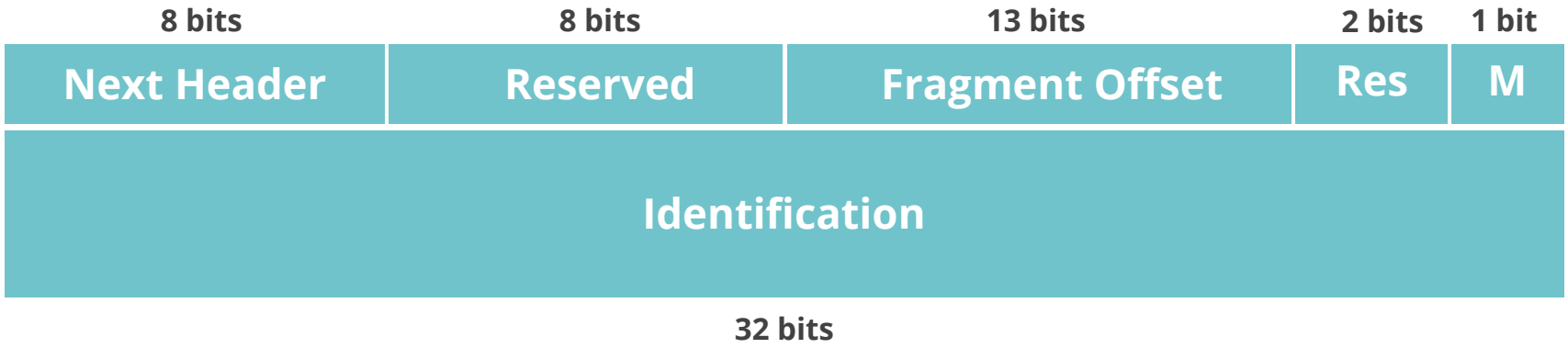

A
B
Target
S
Attacker
D
Basic Hdr
RH0
S | D
Segs = 127
Addr[1] = A
Addr[2] = B
…
Addr[126] = B
Addr[127] = A
Basic Hdr
RH0
S | A
Segs = 127
Addr[1] = B
Addr[2] = A
…
Addr[126] = A
Addr[127] = D
Basic Hdr
RH0
S | B
Segs = 126
S | A
Segs = 125
S | B
Segs = 124
S | A
Segs = 1
S | B
Segs = 0
S | D
Segs =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

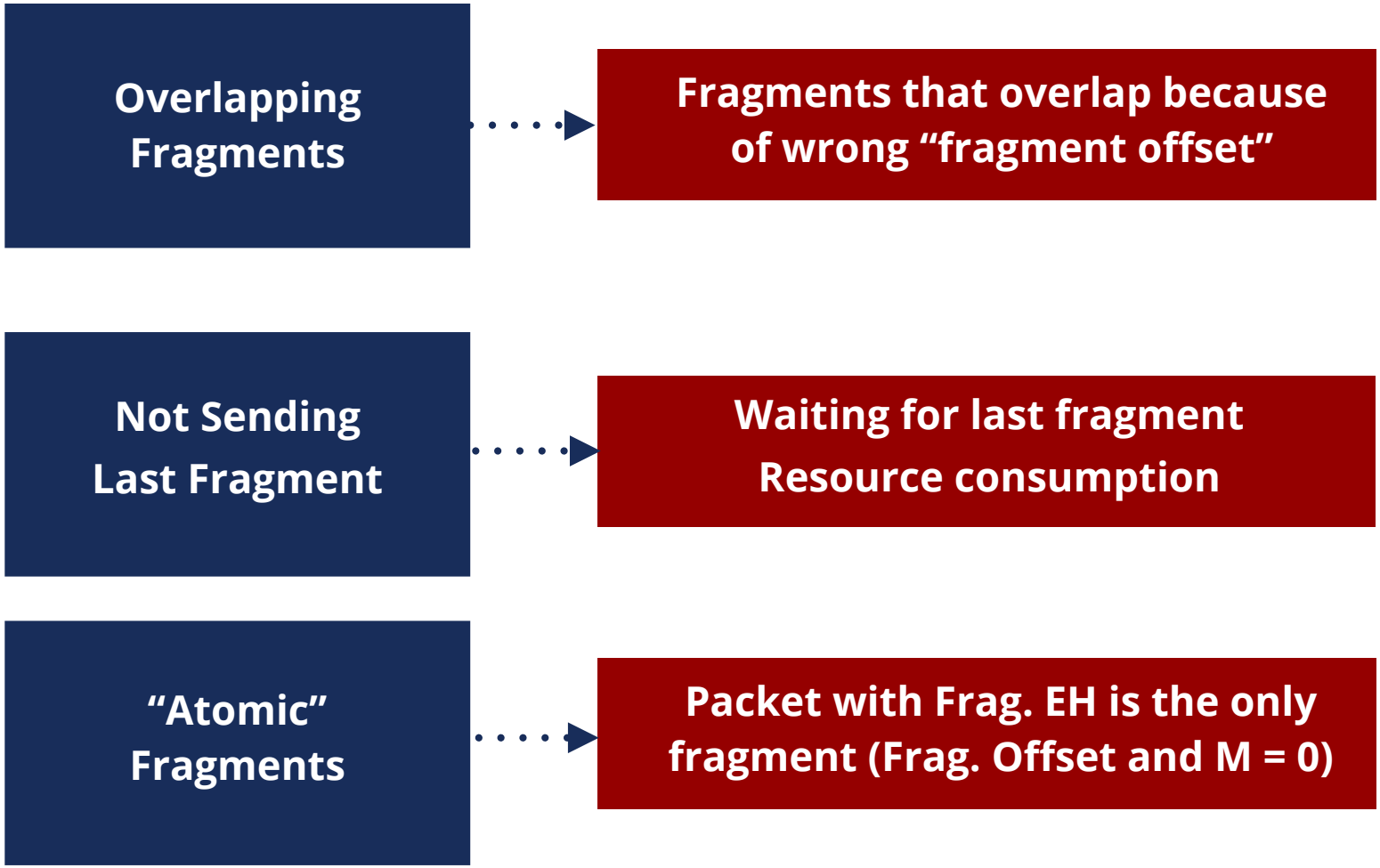



**M Flag**:

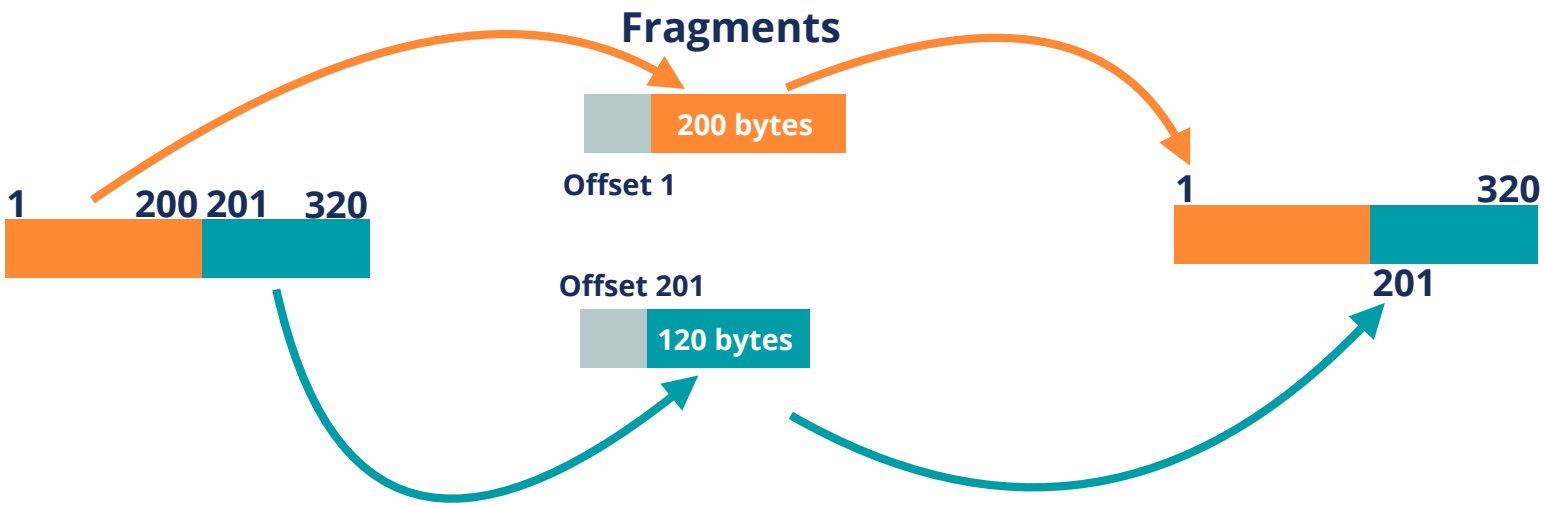
1 = more fragments to come;

0 = last fragment

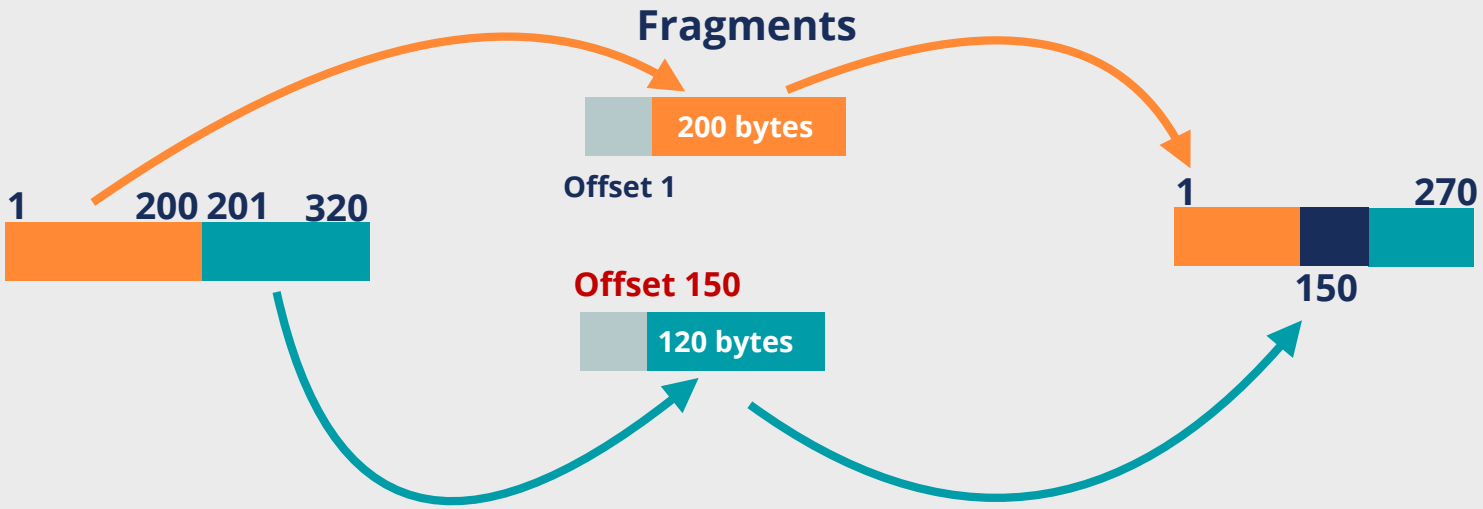
# EH Threats: Fragmentation




# Overlapping Fragments

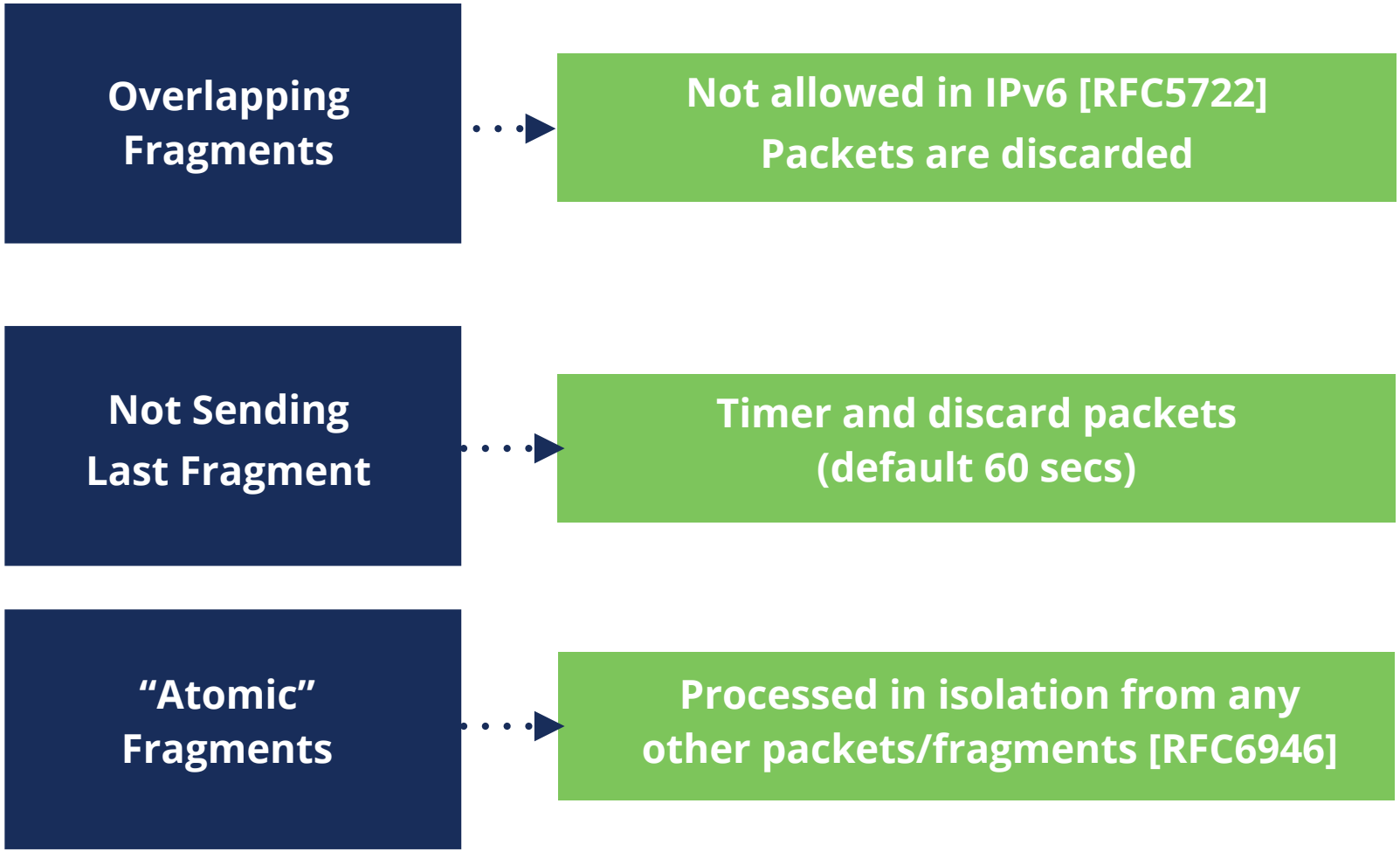



Normal fragments offset say where the data goes




Overlapping fragments have wrong offset values

# EH Solutions: Fragmentation




# 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

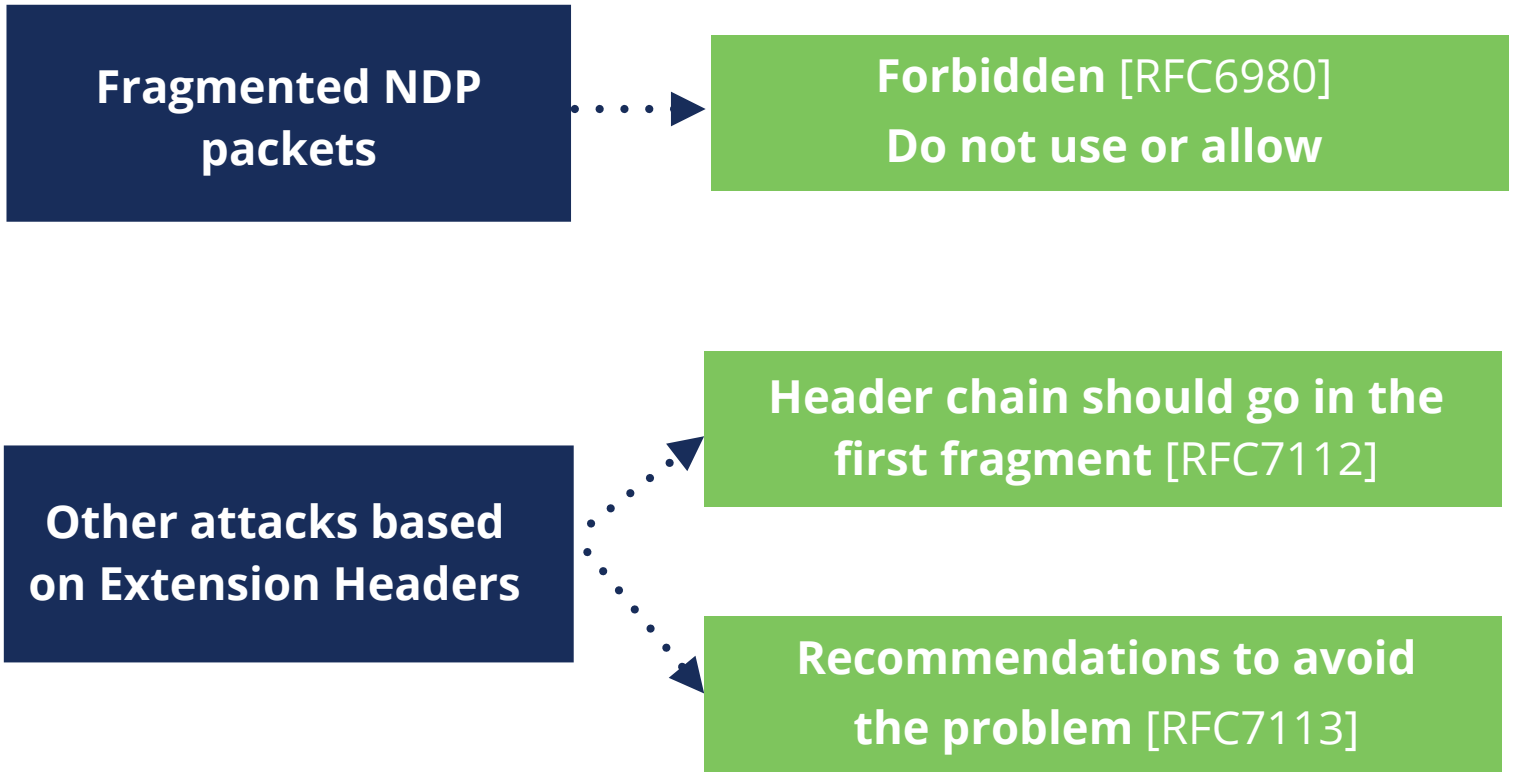
## Using **Fragment** Extension Header

| Basic IPv6 Header | Fragment | Destination Options |
|---|---|---|
| *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**

# Extension Headers Solutions




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

# NDP Features

**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

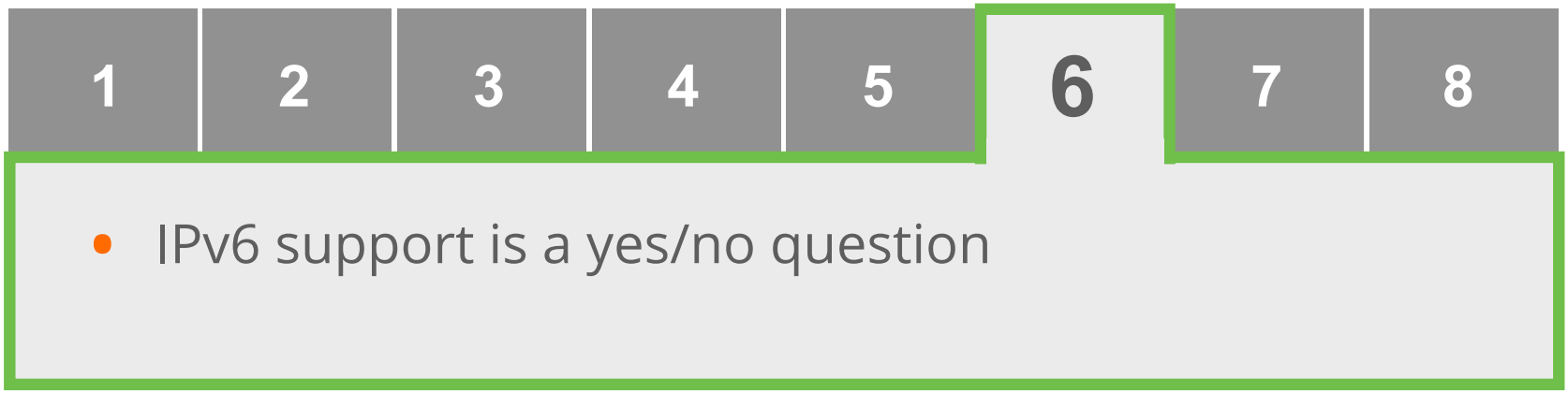
# NDP Threats

- **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 ?

# IPv6 Security Statements




## 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

# Devices Categories (RIPE-772)

## Host

- **IPSec** (if needed)
- **RH0** [RFC5095]
- **Overlapping Frags** [RFC5722]
- **Atomic Fragments** [RFC6946]
- **NDP Fragmentation** [RFC6980]
- **Header chain** [RFC7112]
- **Stable IIDs** [RFC8064][RFC7217] [RFC7136]
- **Temp. Address Extensions** [RFC8981]
- **Disable if not used:** LLMNR, mDNS, DNS-SD, 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]
  - **MD5 Signature Option** [RFC2385] *Obsoleted*
  - **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**

# 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

- 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 | Protect IPv6 at the same level as IPv4 |
| GUA Addresses | Filter end-to-end IPv6 properly |
| Use one IP version to attack the other | Don’t trust “IPv4-only” |

# 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

# IPv6 vs IPv4

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

**No changes with IPv6** | **Changes with IPv6** | **New IPv6 issues**

# 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 | |

# 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)

# 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

# Routing Protocols Authentication

| | Authentication Options | Comments |
|---|---|---|
| RIPng | - No authentication<br>- IPsec (general recommendation) | - RIPv2-like MD5 no longer available<br>- IPSec not available in practice |
| OSPFv3 | - IPsec [RFC4552]<br>- Authentication Trailer [RFC7166] | - ESP or AH. Manual keys<br>- Hash of OSPFv3 values. Shared key |
| IS-IS | - HMAC-MD5 [RFC5304]<br>- HMAC-SHA [RFC5310] | - MD5 not recommended<br>- Many SHA, or any other hash |
| MBGP | - TCP MD5 Signature Option [RFC2385]<br>- TCP-AO [RFC5925] | - Protects TCP. Available. Obsoleted<br>- 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

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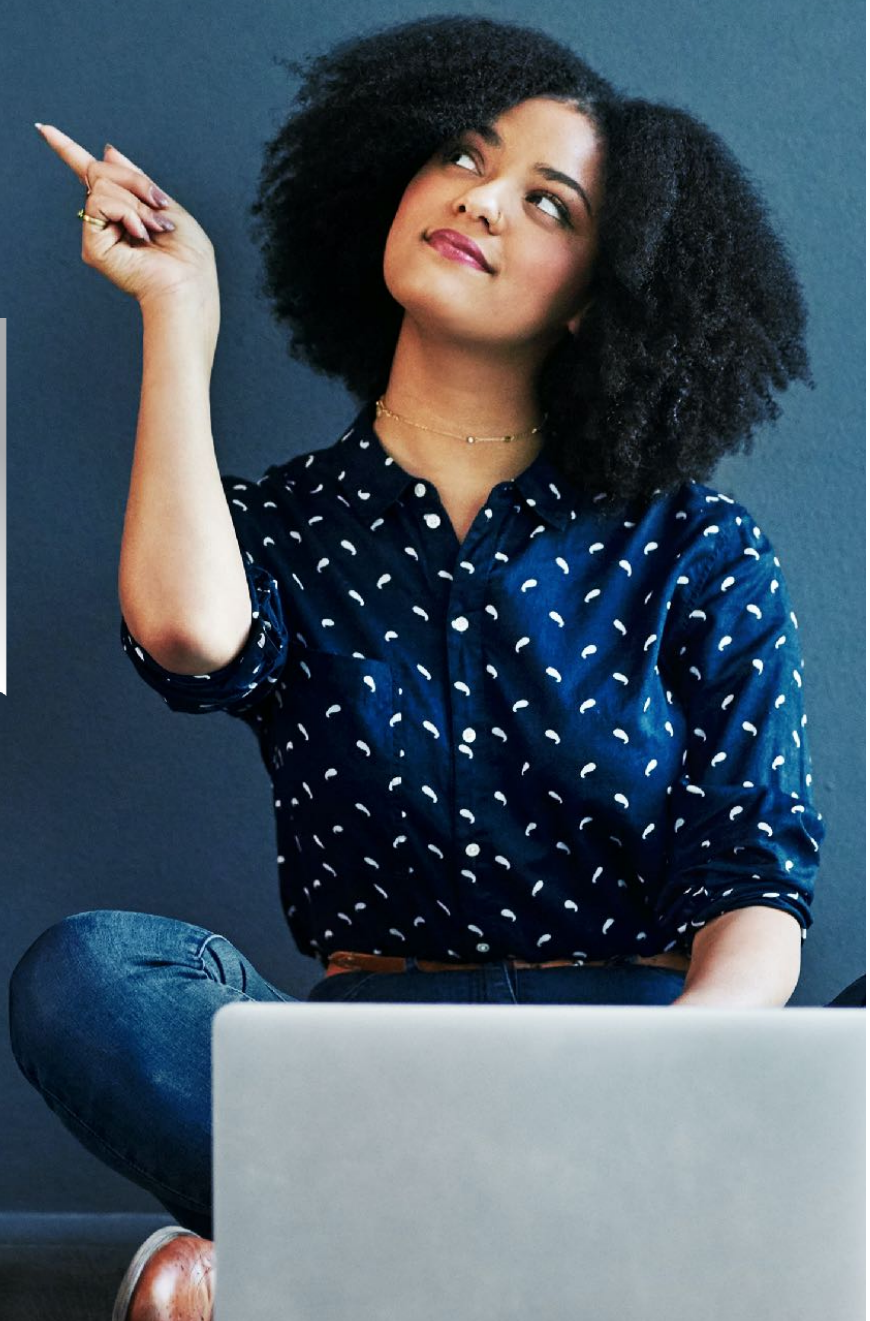


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