IPv6 Security Tools

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SI6 NETWORKS

UK IPv6 Council Security Workshop
London, UK. July 12, 2017

About...

- Security Researcher and Consultant at SI6 Networks
- Published 30 IETF RFCs (15+ on IPv6)
- Contributor to TechTarget.com on IPv6
  - http://www.techtarget.com/contributor/Fernando-Gont
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IPv6 tools

THC-IPv6 Toolkit: Introduction

- First and only IPv6 attack toolkit for many years
- Easy to use
  - Only minimal IPv6 knowledge required
- Features:
  - Only runs on Linux with Ethernet
  - Free software
- Available at: http://www.thc.org/thc-ipv6

SI6 Networks' IPv6 Toolkit

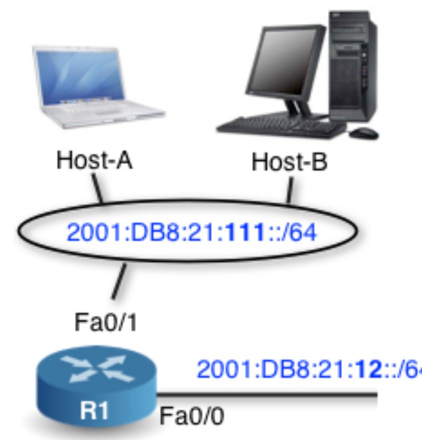
- Brief history:
  - Originally produced as part of a governmental project on IPv6 security
  - Maintenance and extension taken over by SI6 Networks
- Goals:
  - Security assessment and trouble-shooting of IPv6 networks and implementations
  - Clean, portable, and secure code
  - Good documentation

SI6 Networks' IPv6 Toolkit (II)

- Supported OSes:
  - Linux, FreeBSD, NetBSD, OpenBSD, OpenSolaris, and Mac OS
- License:
  - GPL (free software)
- Home:
  - https://www.si6networks.com/tools/ipv6toolkit
- Collaborative development:
  - https://www.github.com/fgont/ipv6toolkit.git

SI6 Networks' IPv6 Toolkit: Philosophy

IPV6 TOOLKIT



IDEAS → TOOLS → IPV6 NETWORK

"an interface between your ideas and an IPv6 network"

IPv6 Addressing

Address Scanning

Introduction

- Address scanning in IPv4 is typically “brute force”
  - search space is so small we can get away with such a loosy job!
- Bruteforce approach simply unfeasible for IPv6
  - search space would be too big (2^{64} addresses)

Approaching IPv6 address scanning

- Two (totally-different) problem areas:
  - Local-network scans
  - Remote-network scans
- Local-network scans rather easy
- Remote-network scans more challenging
- It is key to understant the IPv6 Addressing Architeture

IPv6 addressing

Implications on address scanning of local networks

Overview

- Leverage IPv6 all-nodes link-local multicast address
- Employ multiple probe types:
  - Normal multicasted ICMPv6 echo requests (don't work for Windows)
  - Unrecognized options of type 10xxxxxx
- Combine learned IIDs with known prefixes to learn all addresses
- Example:

```
# scan6 -i eth0 -L
```

IPv6 Addressing

Implications on address scanning of remote networks

IPv6 host scanning attacks

"Thanks to the increased IPv6 address space, IPv6 host scanning attacks are unfeasible. Scanning a /64 would take 500.000.000 years"

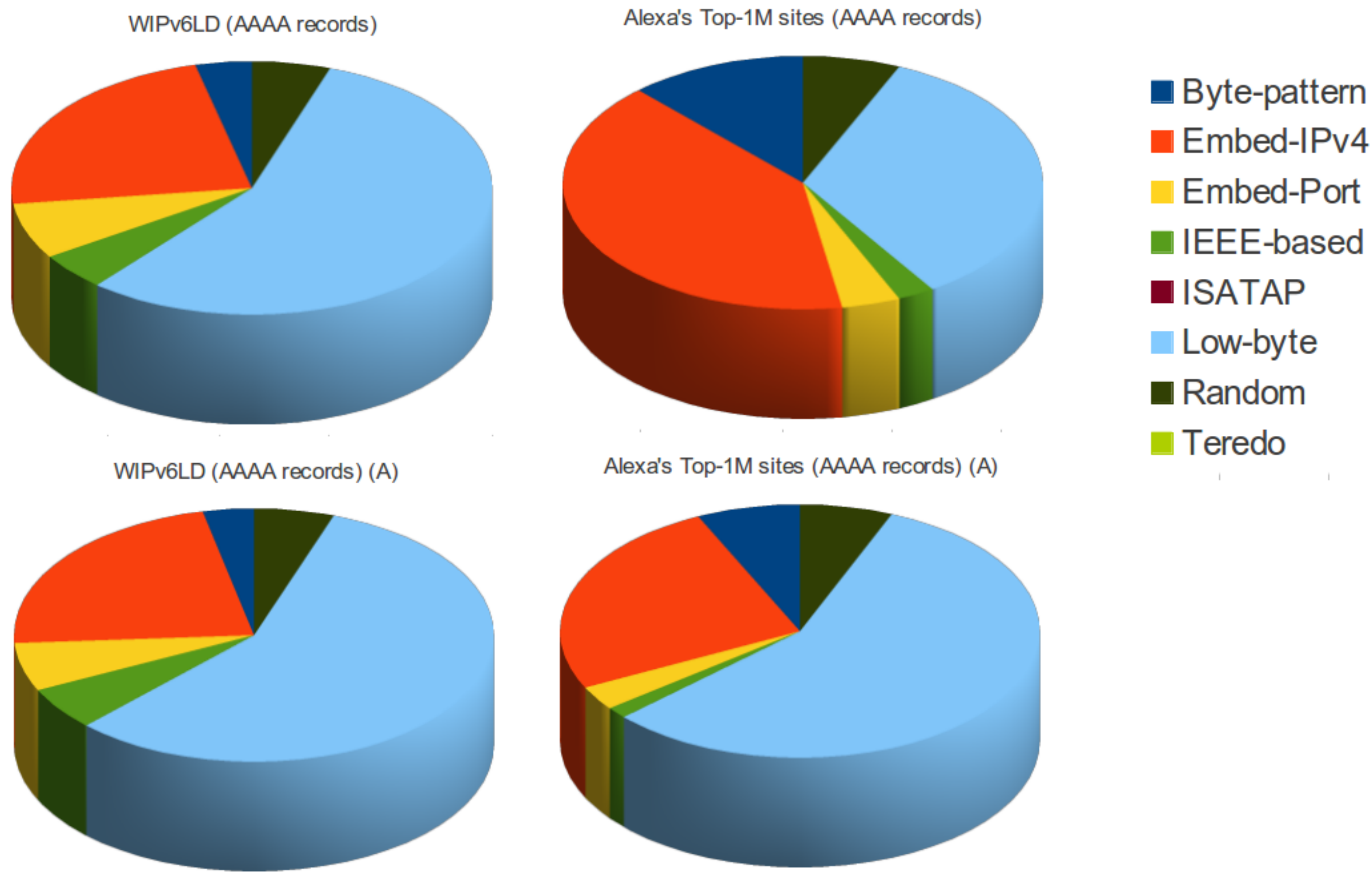
– Urban legend

Is the search space for a /64 really 2^{64} addresses?

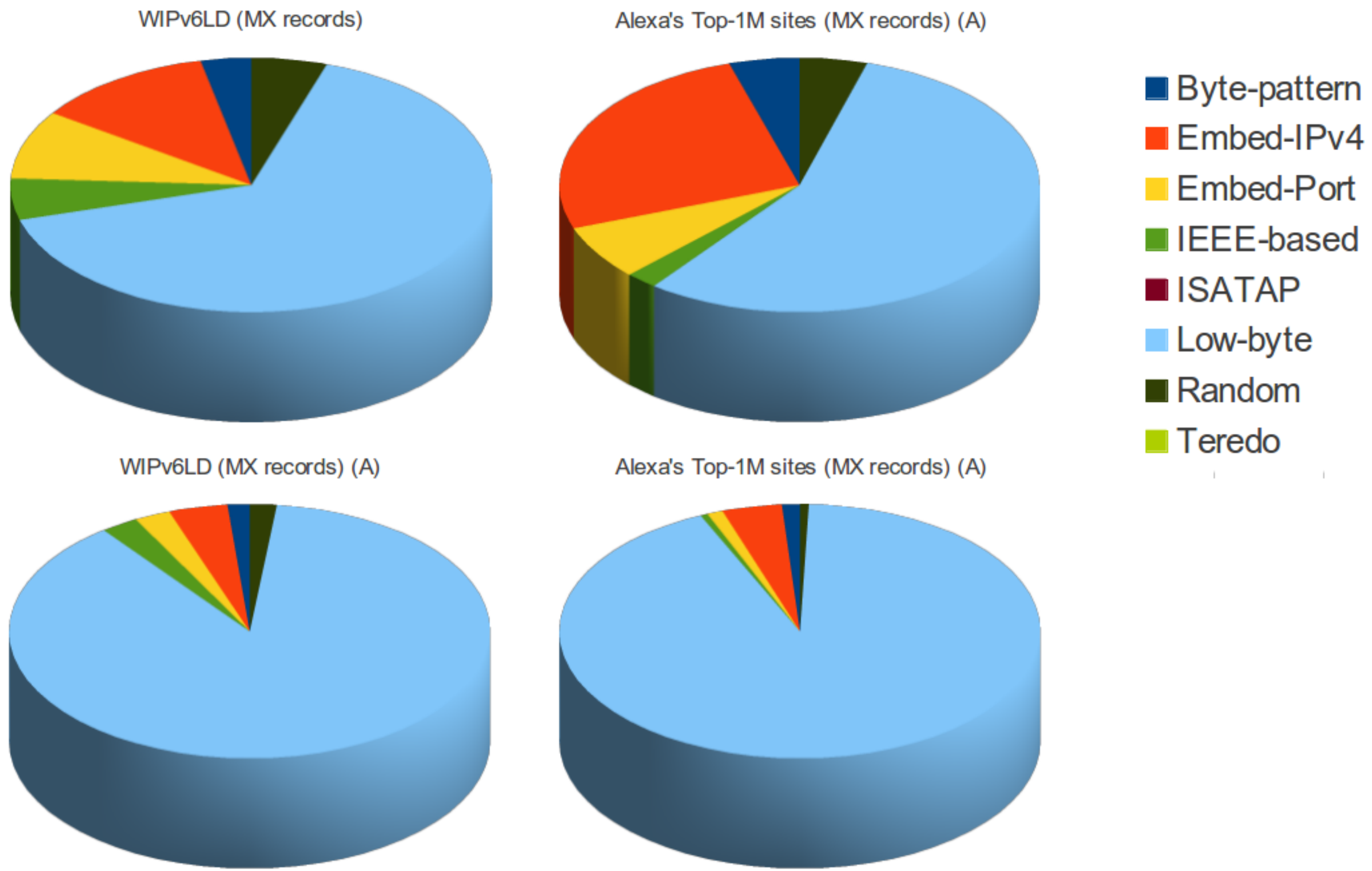
Our experiment

- Find “a considerable number of IPv6 nodes” for address analysis:
  - Alexa Top-1M sites + perl script + dig
  - World IPv6 Launch Day site + perl script + dig
- For each domain:
  - AAAA records
  - NS records -> AAAA records
  - MX records -> AAAA records
- What did we find?

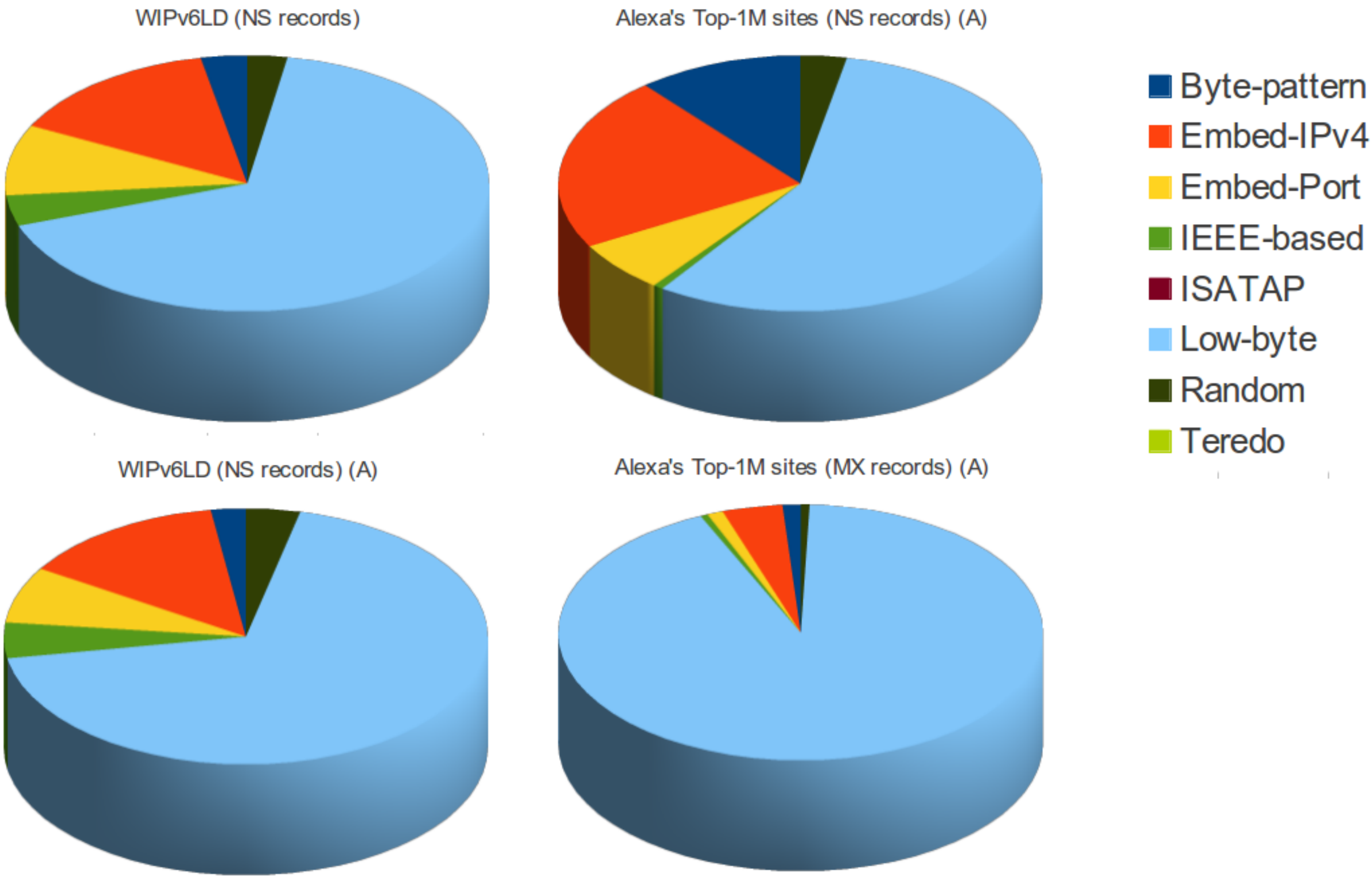
IPv6 address distribution for the web



IPv6 address distribution for mail servers



IPv6 address distribution for the DNS



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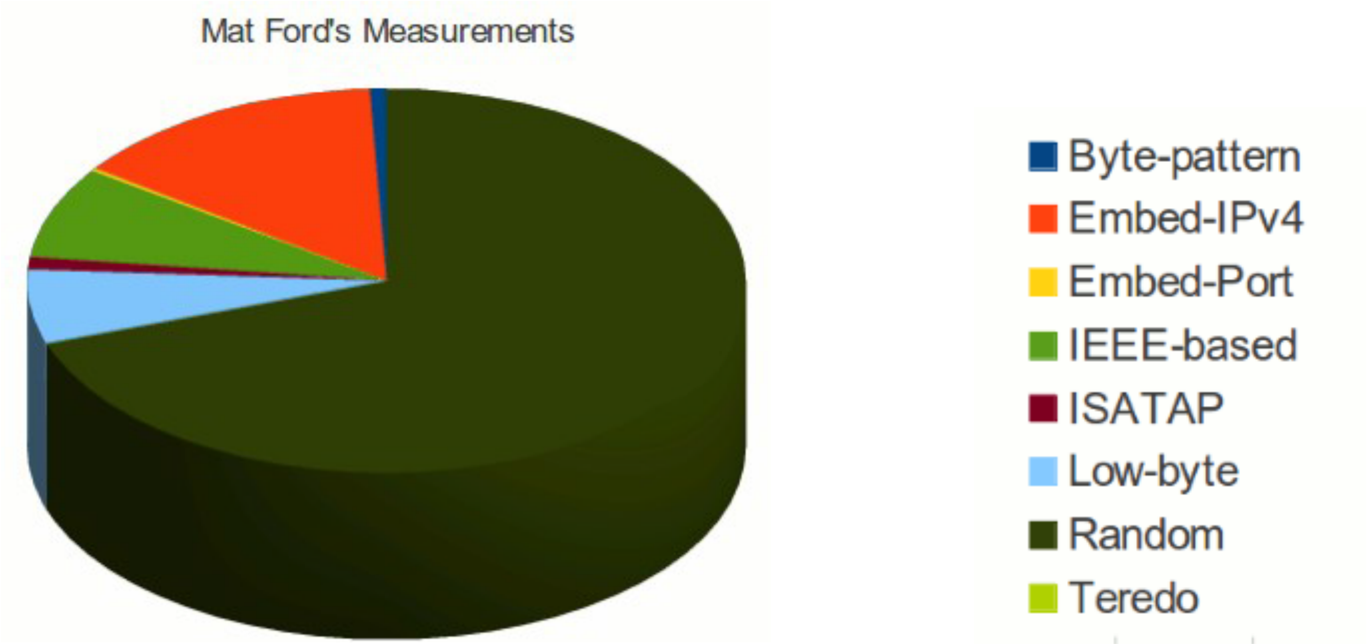
Client addresses



- Caveats:
  - Graphic illustrates IID types used for outgoing connections.
  - No data about IID types used for stable addresses when RFC4941 is employed.

Source: <http://www.internetsociety.org/blog/2013/05/ipv6-address-analysis-privacy-transition-out>

IPv6 address patterns

- MAC-address based
  - e.g.: 2001:db8::**fad1**:**22**ff:fe**c0**:**fb44**
- Embed-IPv4:
  - 2000:db8::**192.168.0.1** <- Embedded in 32 bits
  - 2000:db8::**192**:**168**:**0**:**1** <- Embedded in 64 bits
- Embed-port:
  - 2001:db8::**1**:**80** <- n:port
  - 2001:db8::**80**:**1** <- port:n
- Low-byte addresses:
  - 2001:db8::**n1**:**n2** <- where n1 is typically greater than n2

Some take-aways from our study

- Server addresses clearly do follow patterns
  - The majority of addresses follow patterns with a small search space
- Passive measurements on client addresses are of little use
  - Due to IPv6 temporary addresses (RFC4941)

IPv6 address scanning

- scan6 can target specific address patterns
- “What if I'm lazy enough to 'set' an appropriate address pattern?”
  - scan6 infers the address pattern for you!
- Example:

```
# scan6 -d DOMAIN/64 -v
```

Conclusions about scanning attacks

- IPv6 address scanning attacks are **feasible**, but typically harder than in IPv4
- They require more “intelligence” on the side of the attacker
- It is **possible** to make them infeasible
  - Just do not employ addresses that follow patterns
  - RFC7217 and RFC8064 fix that for SLAAC
- It is likely that many other scanning strategies/techniques will be explored (more on this later)

IPv6 Extension Headers
Reconnaissance and Troubleshooting

path6: An EH-enabled traceroute

- How far do your IPv6 EH-enabled packets get?
- No existing traceroute tool supported IPv6 extension headers
- Hence we produced our path6 tool
  - Supports IPv6 Extension Headers
  - Can employ TCP, UDP, or ICMPv6 probes
  - It's faster ;-)
- Example:

```
# path6 -u 100 -d fc00:1::1
```

Dst Opt Hdr

path6: An EH-enabled traceroute (II)

- Example of traceroute with 8-byte DOH:

```
# path6 -d DEST -u 8 -p icmp
```

- Example of traceroute with fragmentation:

```
# path6 -d DEST -p icmp -P 500 -y 256
```

- Example of traceroute with TCP payload:

```
# path6 -d DEST -p tcp -a 80
```

blackhole6: Finding IPv6 blackholes

- How it works?
  - path6 without EHs + path6 with EHs + a little bit of magic

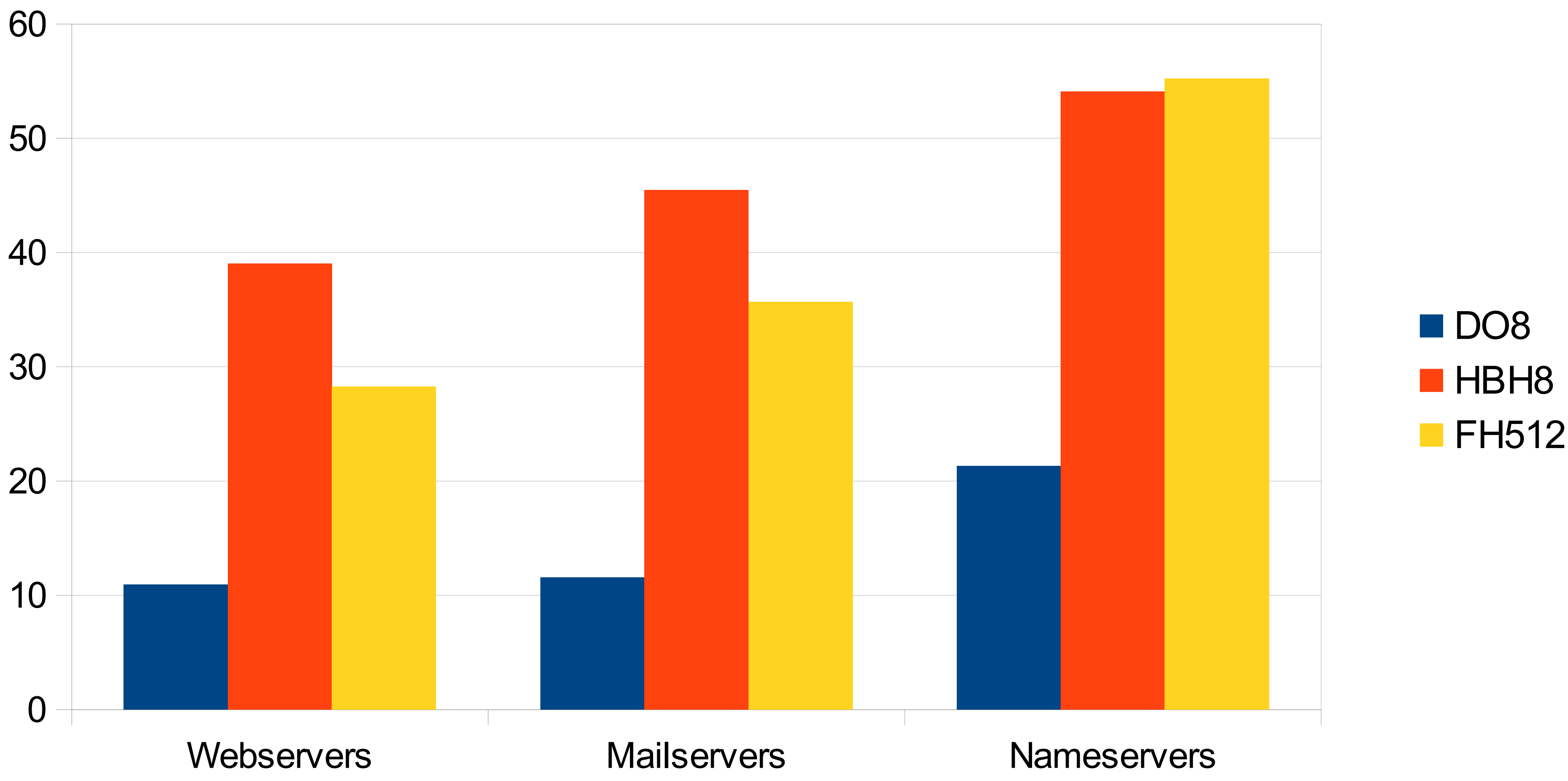
```
fgont@satellite:~$ sudo blackhole6 www.google.com do8
SI6 Networks IPv6 Toolkit v2.0
blackhole6: A tool to find IPv6 blackholes
Tracing www.google.com (2607:f8b0:400b:807::1012)...

Dst. IPv6 address: 2607:f8b0:400b:807::1012 (AS15169 - GOOGLE - Google
Inc.,US)
Last node (no EHs): 2607:f8b0:400b:807::1012 (AS15169 - GOOGLE - Google
Inc.,US) (13 hop(s))
Last node (DO 8): 2001:5a0:12:100::72 (AS6453 - AS6453 - TATA
COMMUNICATIONS (AMERICA) INC,US) (7 hop(s))
Dropping node: 2001:4860:1:1:0:1935:0:75 (AS15169 - GOOGLE - Google
Inc.,US || AS15169 - GOOGLE - Google Inc.,US)
```

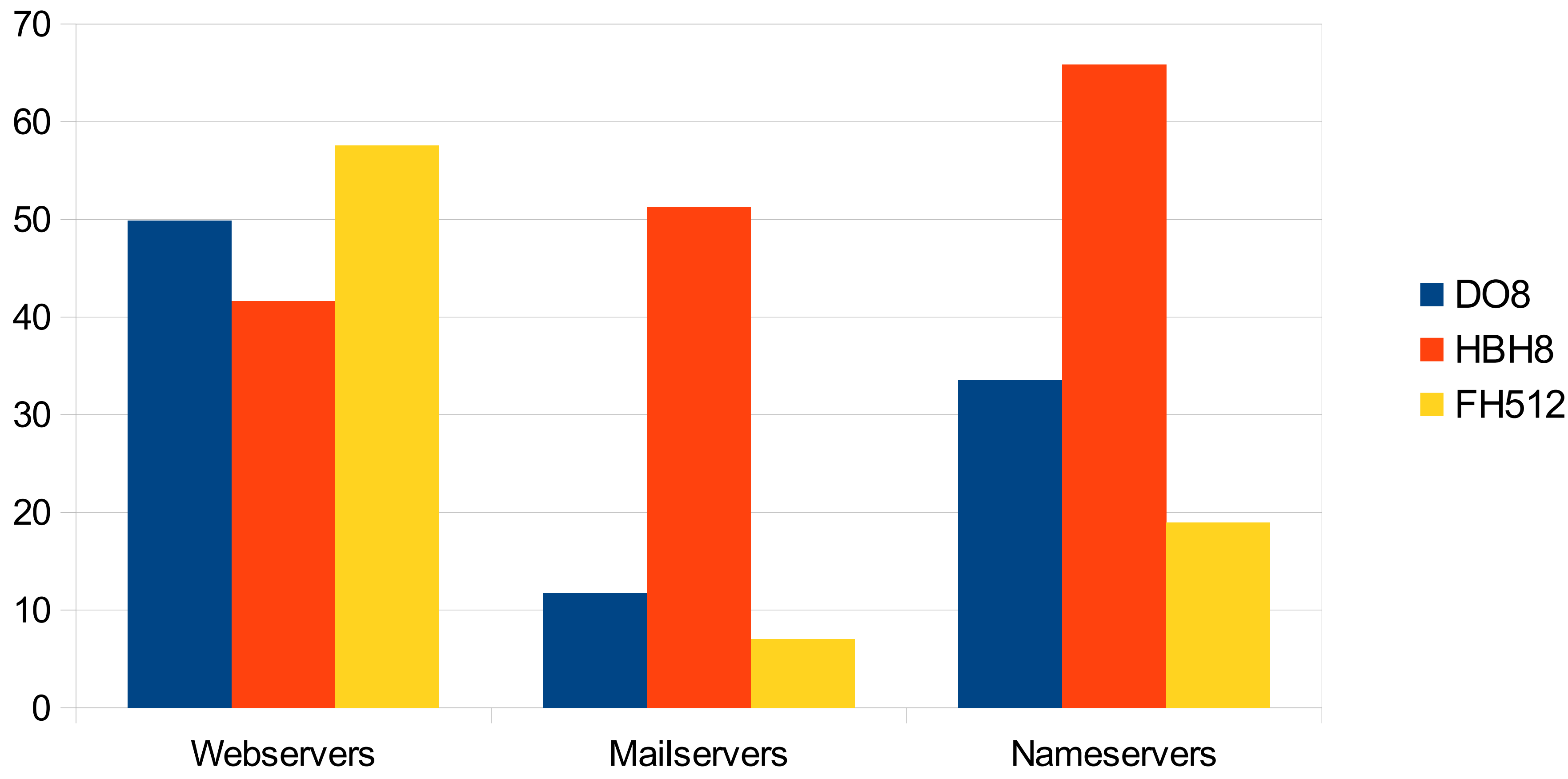
IPv6 Extension Headers

In The Real World

Packet Drop rate for Alexa's Top 1M sites



Drops by diff AS for Alexa's Top 1M sites



So... what does this all mean?

- Good luck with getting IPv6 EHs working in the Internet!
  - They are widely dropped
- IPv6 EHs “not that cool” for evasion, either
  - Chances are that you will not even hit your target

Neighbor Discovery for IPv6

Neighbor Discovery for IPv6

Address Resolution

Address Resolution in IPv6

- Employs ICMPv6 Neighbor Solicitation and Neighbor Advertisement
- It (roughly) works as follows:
  - Host A sends a NS: Who has IPv6 address fc01::1?
  - Host B responds with a NA: I have IPv6 address, and the corresponding MAC address is 06:09:12:cf:db:55.
  - Host A caches the received information in a “Neighbor Cache” for some period of time (this is similar to IPv4’s ARP cache)
  - Host A can now send packets to Host B

Neighbor Discovery for IPv6

Address Resolution Attacks

“Man in the Middle” or Denial of Service

- They are the IPv6 version of IPv4’s ARP cache poisoning
- Without proper authentication mechanisms in place, its trivial for an attacker to forge Neighbor Discovery messages
- Attack:
  - Send forged Neighbor Advertisement, with a forged target link-layer address option
- If the “Target Link-layer address” corresponds to a non-existing node, traffic is dropped, resulting in a DoS.
- If the “Target Link-layer address” is that of the attacker, he can perform a “man in the middle” attack.

Performing the attack with the na6 tool

- Run the tool as:

```
# na6 -i IFACE -t VICTIMADDR -E MACADDR -o -c -L
```

Neighbor Discovery for IPv6
Address Resolution Attacks – Countermeasures

Possible mitigations for ND attacks

- Do you mitigate similar vulnerabilities for IPv4?
- Possible mitigations for IPv6:
  - SAVI / ND snooping
  - Monitor Neighbor Discovery traffic (e.g., with NDPMon)
  - Restrict access to the local network
  - Use static entries in the Neighbor Cache
  - Deploy SEND (SEcure Neighbor Discovery)

Neighbor Discovery for IPv6
Stateless Address Auto-configuration (SLAAC)

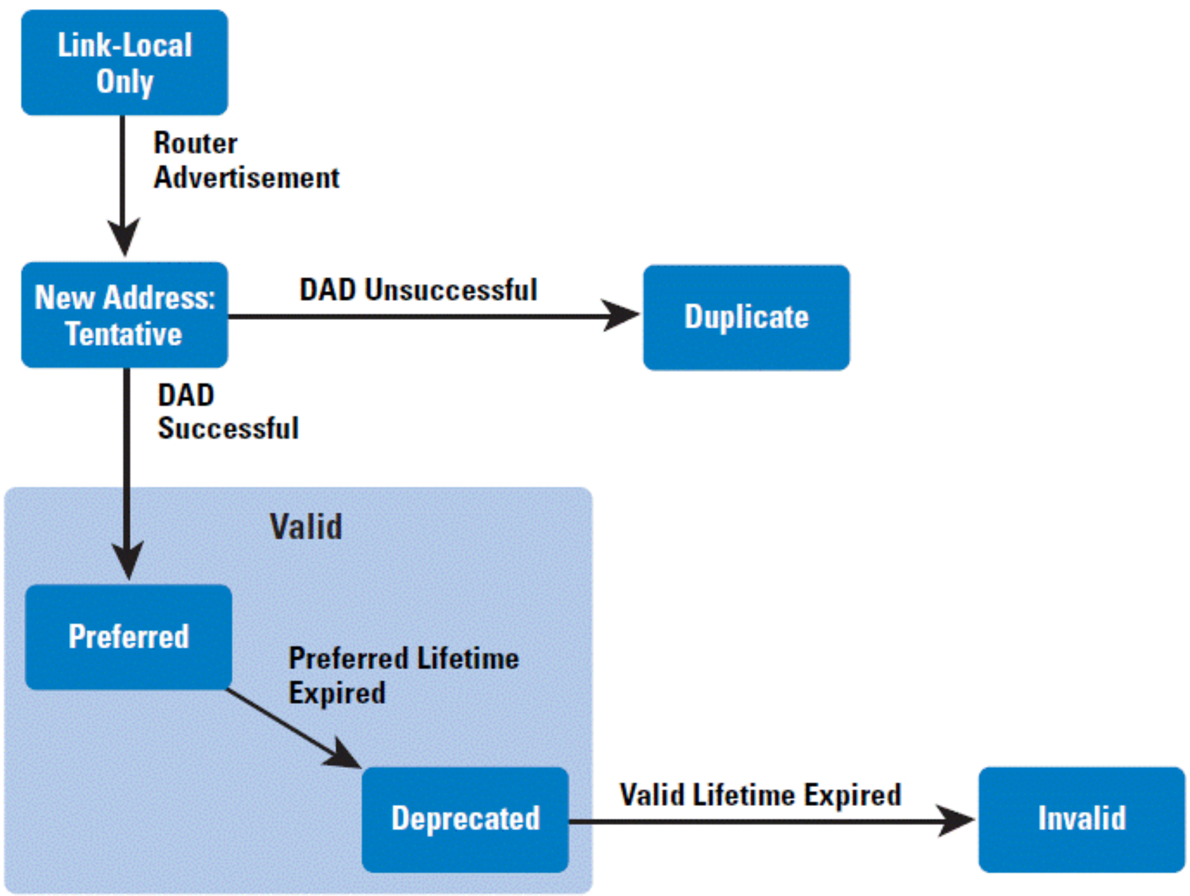
Brief overview

- Two auto-configuration mechanisms in IPv6:
  - Stateless Address Auto-Configuration (SLAAC)
    - Based on ICMPv6 messages
  - DHCPv6
    - Based on UDP packets
- SLAAC is mandatory, while DHCPv6 is optional
- Basic operation of SLAAC:
  - Host solicit configuration information by sending Router Solicitation messages
  - Routers convey that information in Router Advertisement messages:
    - Auto-configuration prefixes
    - Routes
    - Network parameters
    - etc.

SLAAC: Step by step

- It works (roughly) as follows:
  1. The host configures a link-local address
  2. It checks that the address is unique – i.e., it performs Duplicate Address Detection (DAD) for that address
     - Sends a NS, and waits for any answers
  3. The host sends a Router Solicitation message
  4. When a Router Advertisement is received, it configures a “tentative” IPv6 address
  5. It checks that the address is unique – i.e., it performs Duplicate Address Detection (DAD) for that address
     - Sends a NS, and waits for any answers
  6. If the address is unique, it typically becomes a “preferred” address

Address Autoconfiguration flowchart



Neighbor Discovery for IPv6

SLAAC attacks

Exploit DAD for DoS attacks

- Listen to NS messages with the Source Address set to the IPv6 “unspecified” address (::)
- Respond to such messages with a Neighbor Advertisement message
- As a result, the address will be considered non-unique, and DAD will fail
- The host will not be able to use that “tentative” address
- Perform this attack with the na6 tool as follows:

```
# na6 -i IFACE -b ::/128 -L -vv
```

Or possibly:

```
# na6 -i em0 -b ::/128 -B VICTIMMAC -L -vv
```

Disable an Existing Router

- Forge a Router Advertisement message that impersonates the local router
- Set the "Router Lifetime" to 0 (or some other small value)
- As a result, the victim host will remove the router from the "default routers list"
- Perform this attack with the ra6 tool:

```
# ra6 -i IFACE -s ROUTERADDR -d TARGETADDR -t 0 -l 1 -v
```

Possible mitigations for SLAAC attacks

- Do you mitigate similar attacks for the IPv4 case?
- Possible mitigations:
  - Deploy Router Advertisement Guard (RA-Guard) -- **beware of RFC7113 attacks!**
  - Monitor Neighbor Discovery traffic (e.g., with NDPMon)
  - Restrict access to the local network
  - Deploy SEND (SEcure Neighbor Discovery)

Upper-layer attacks

Brief Overview

- IPv6 is just a network-layer protocol
- Everything above the network layer is essentially the same
  - Transport-layer attacks
  - Application layer attacks
  - etc,

tcp6: TCP-based attacks

- The tcp6 tool can send arbitrary TCP/IPv6 packets
- It can also trigger virtually any TCP state at a target system
- Example: SYN-flood attack

```
# tcp6 -s SRCPRF -d TARGET -a DSTPORT -X S -F
100 -l -z 1 -v
```

Mitigations for upper-layer attacks

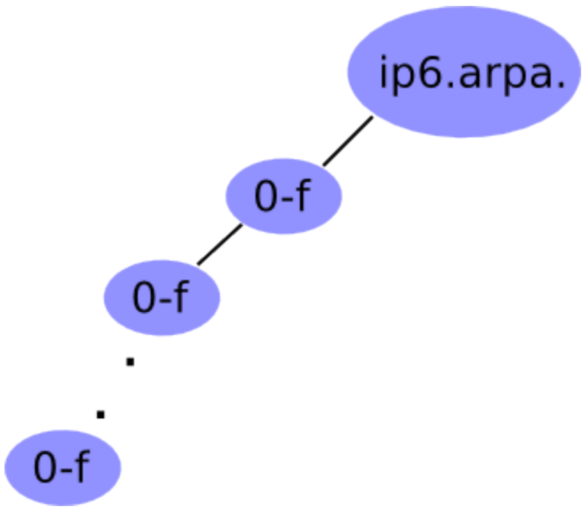
- Usually the same as in the IPv4 case
- Caveat: Mitigations on a per-IPv6-prefix basis (rather than (per-address)

DNS support for IPv6

DNS for Network Reconnaissance

- Most of this ground is well-known from the IPv4-world:
  - DNS zone transfers
  - DNS bruteforcing
  - etc.
- DNS reverse-mappings particularly useful for “address scanning”

IPv6 DNS reverse mappings



- Technique:
  - Given a zone X.ip6.arpa., try the labels [0-f].X.ip6.arpa.
  - If an NXDOMAIN is received, that part of the "tree" should be ignored
  - Otherwise, if NOERROR is received, "walk" that part of the tree
- Example (using dnsrevenum6 from THC-IPv6):

```
$ dnsrevenum6 DNSSERVER IPV6PREFIX
```

Mitigating DNS reverse mappings scans

- Reverse mappings only actually required for mail servers
- For the general case:
  - Do not configure reverse mappings, or,
  - Wildcard reverse mappings

Some conclusions

- Many IPv4 vulnerabilities have been re-implemented in IPv6
  - We just didn't learn the lesson from IPv4, or,
  - Different people working on IPv6 than working on IPv4, or,
  - The specs could make implementation more straightforward, or,
  - **All of the above?** :-)
- Still quite some work to be done in IPv6 security
  - There is always room for improvements
  - **We need IPv6, and should work to improve it**
- **There's no question that you should deploy IPv6**

Questions?

Thank you's

- Veronika McKillop
- Tim Chown
- Andy Butcher
- UK IPv6 Council
- Axians

Thanks!

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IPv6 Hackers mailing-list

http://www.si6networks.com/community/

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