Fast IPv6 Network Periphery Discovery and Security Implication

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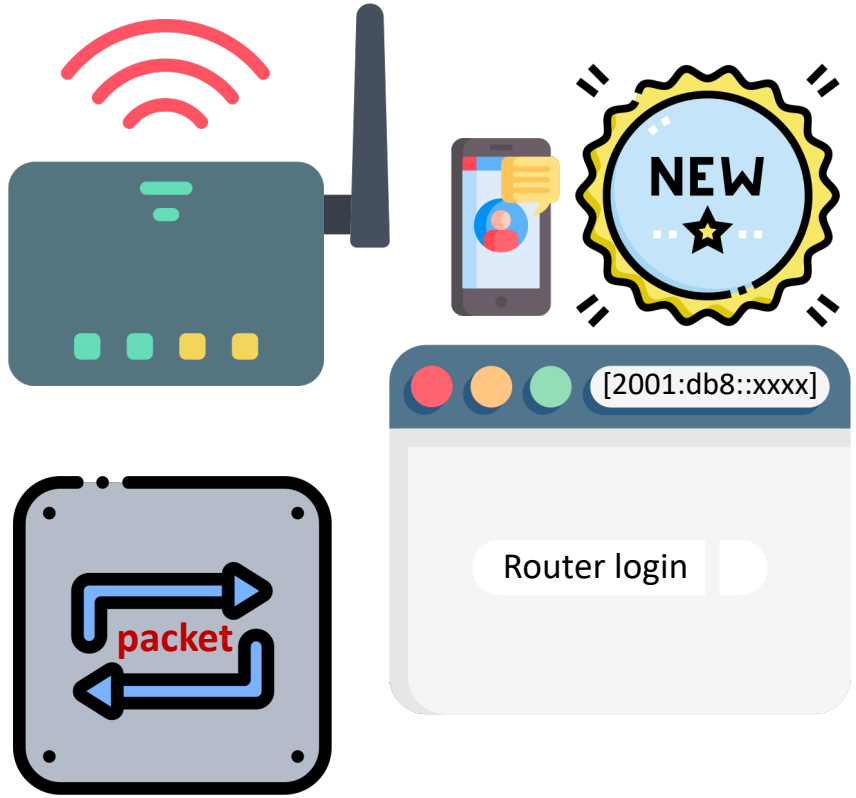
What did we do?

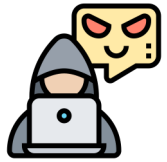
- New Approach
  - IPv6 network periphery discovery

- New Findings
  - 52M IPv6 peripheries
  - Unintended exposed services
  - Routing loop attack, **20** vendors, **4** OSes



What did we find?

131 CVE/CNVD



ASUS

LINKSYS

NETGEAR®

D-Link®

tp-link

MERCURY

HUAWEI

MikroTik

ZTE

Tenda

Skyworth

中国移动 China Mobile

H3C

TOTOLINK The Smartest Network Device

FiberHome

FAST

Hisense

友华通信 YOUHUA TECHNOLOGY

iKuai

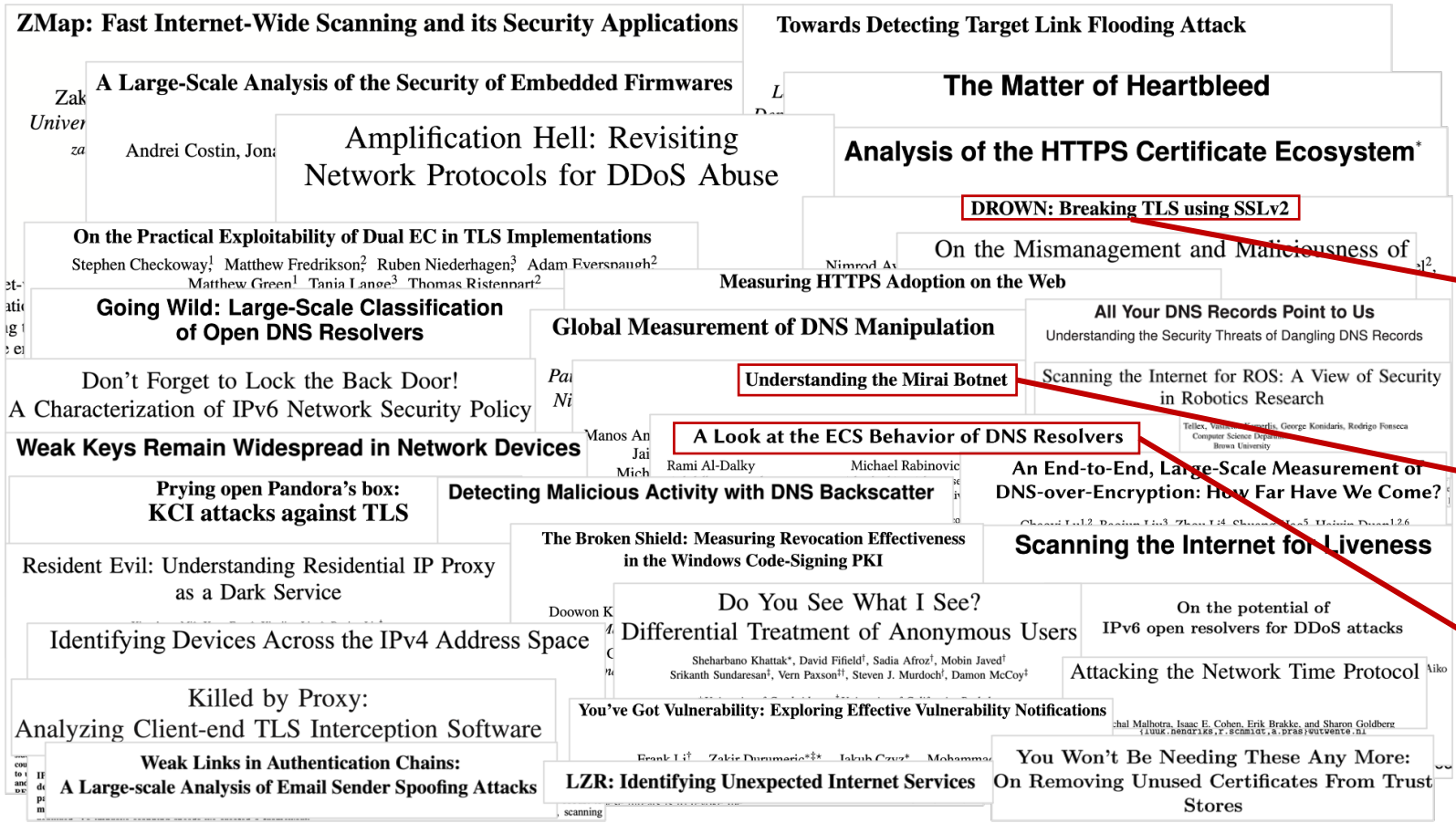
OpenWrt WIRELESS FREEDOM

Gargoyle Router Management Utility

DD-WRT

How to find devices in IPv4?

- Network Scanning



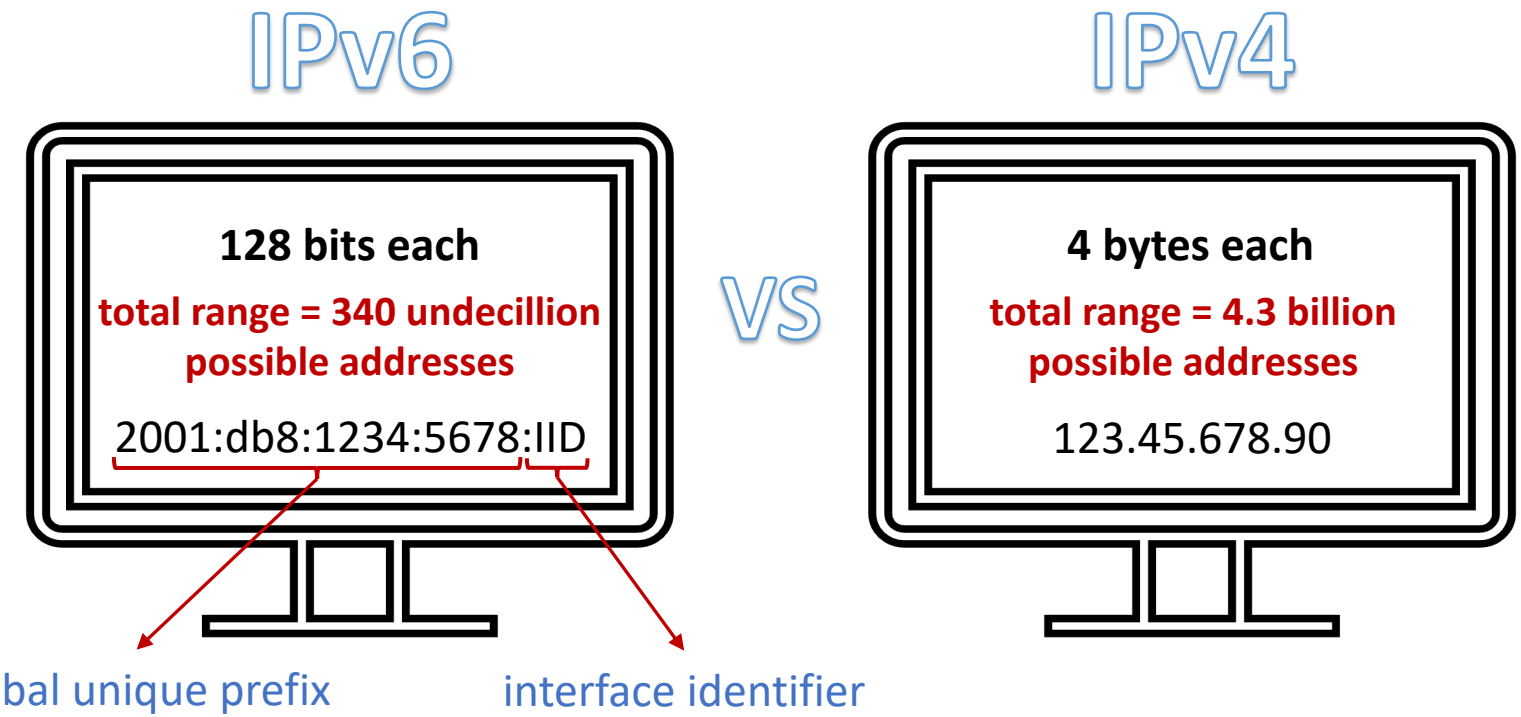
Uncover vulnerabilities
→ USENIX Security '16
→ CCS '17

Track botnets' behaviors
→ USENIX Security '17

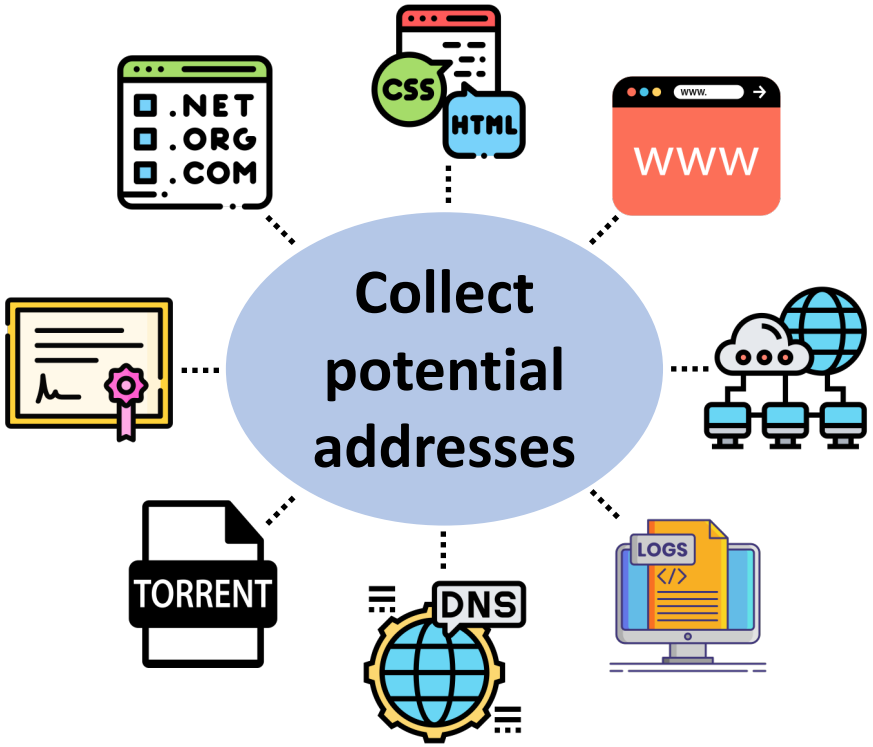
Measure protocol adoption
→ IMC '19

IPv6 Address Space

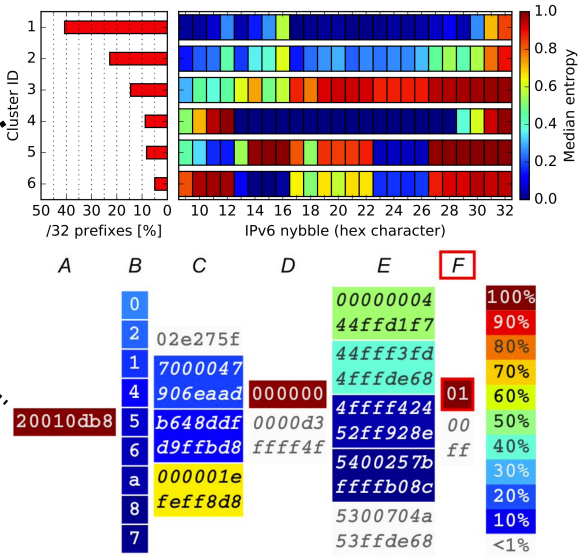
- A lot lot lot of addresses
  - 340 trillion trillion trillion addresses
- IPv4-style brute force won't work



Active IPv6 Host Discovery

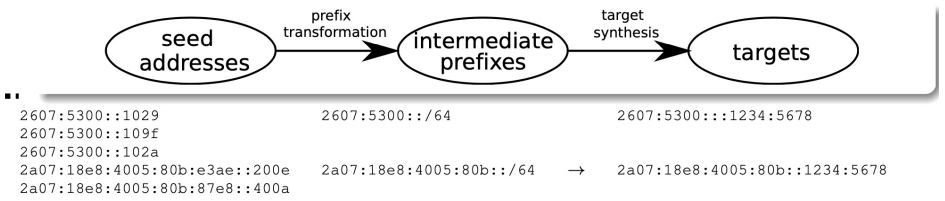


Identify address patterns



Pawel Foremski, David Plonka, and Arthur Berger. Entropy/IP: Uncovering Structure in IPv6 Addresses. (IMC '16)

Generate candidate addresses



Robert Beverly, Ramakrishnan Durairajan, David Plonka, and Justin P. Rohrer. In the IP of the Beholder: Strategies for Active IPv6 Topology Discovery. (IMC '18)

Active IPv6 Host Discovery

Collect potential addresses

Identify address patterns

Pawel Foremski, David Plonka, and Arthur Berger. Entropy/IP: Uncovering Structure in IPv6 Addresses. (IMC '16)

Not real-time

Not large-scale

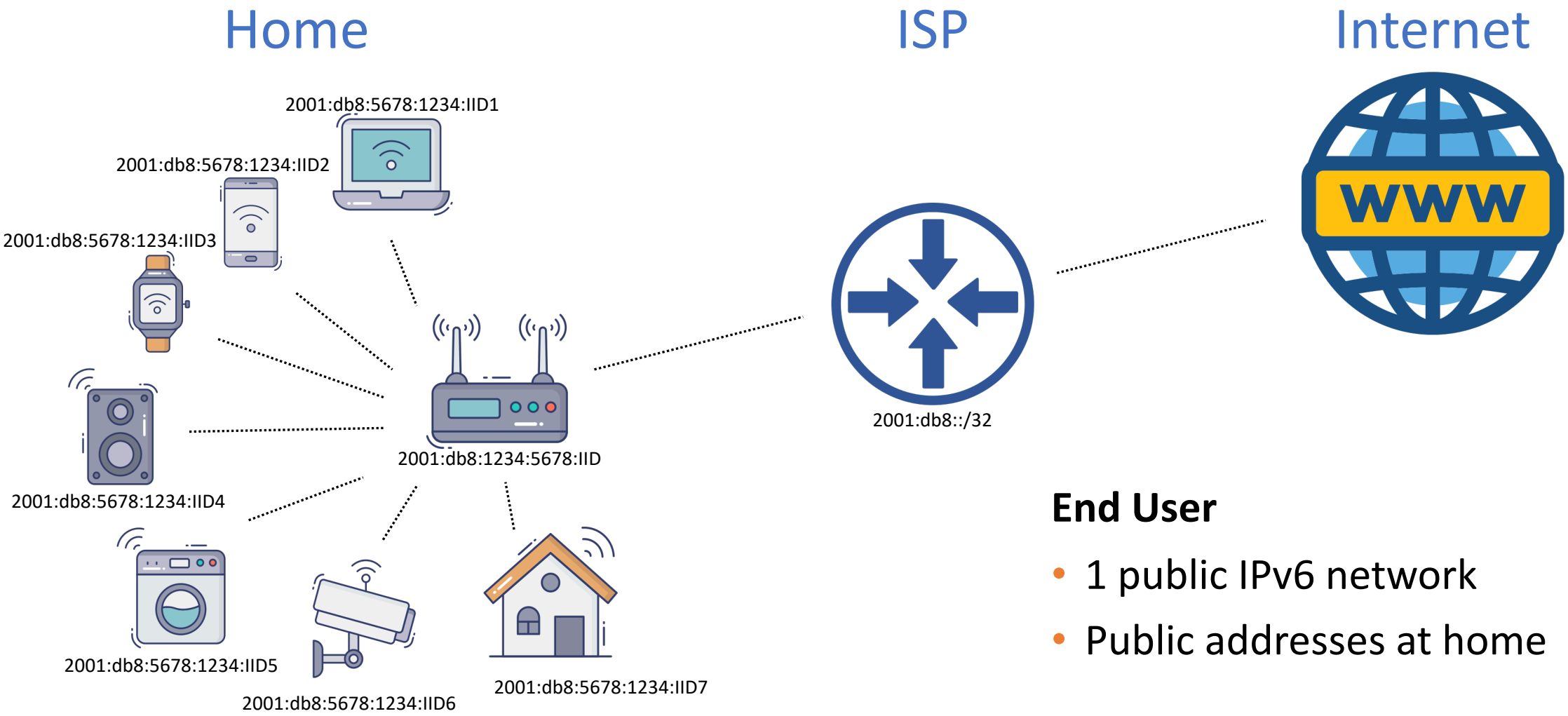
Generate candidate addresses

Robert Beverly, Ramakrishnan Durairajan, David Plonka, and Justin P. Rohrer. In the IP of the Beholder: Strategies for Active IPv6 Topology Discovery. (IMC '18)

Our Scanning Perspective

To find the IPv6 network periphery

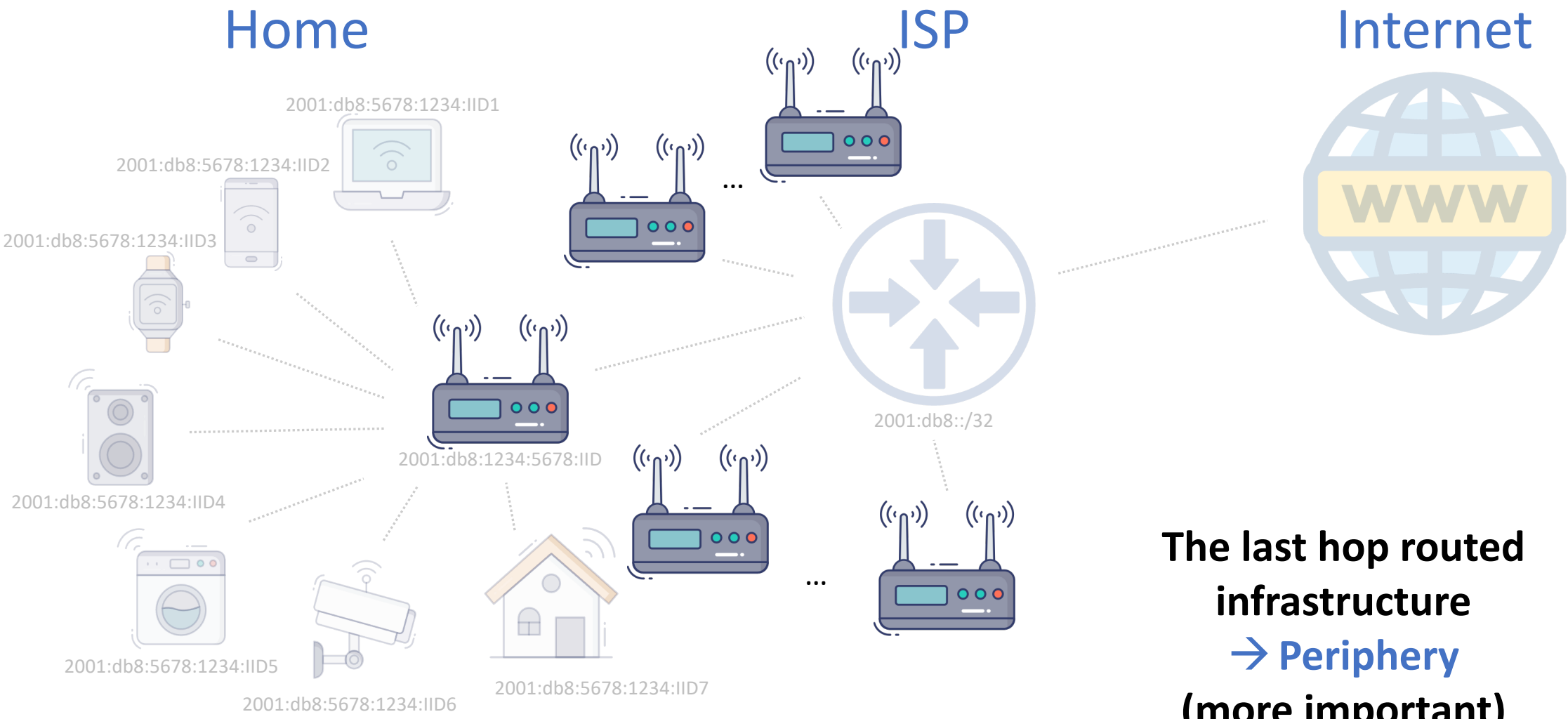
IPv6 Internet



End User

- 1 public IPv6 network
- Public addresses at home

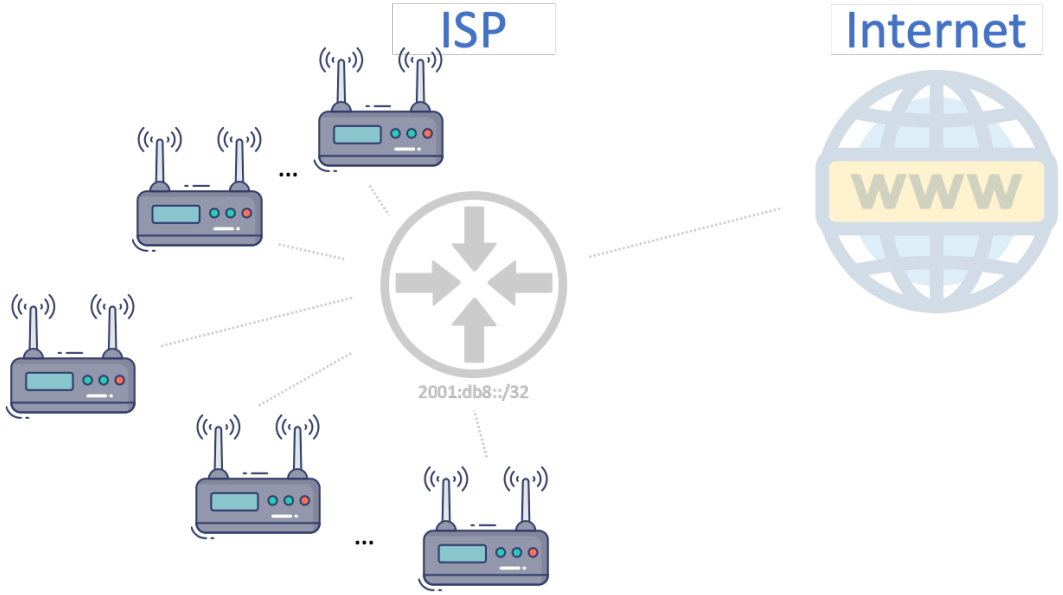
What's IPv6 Network Periphery



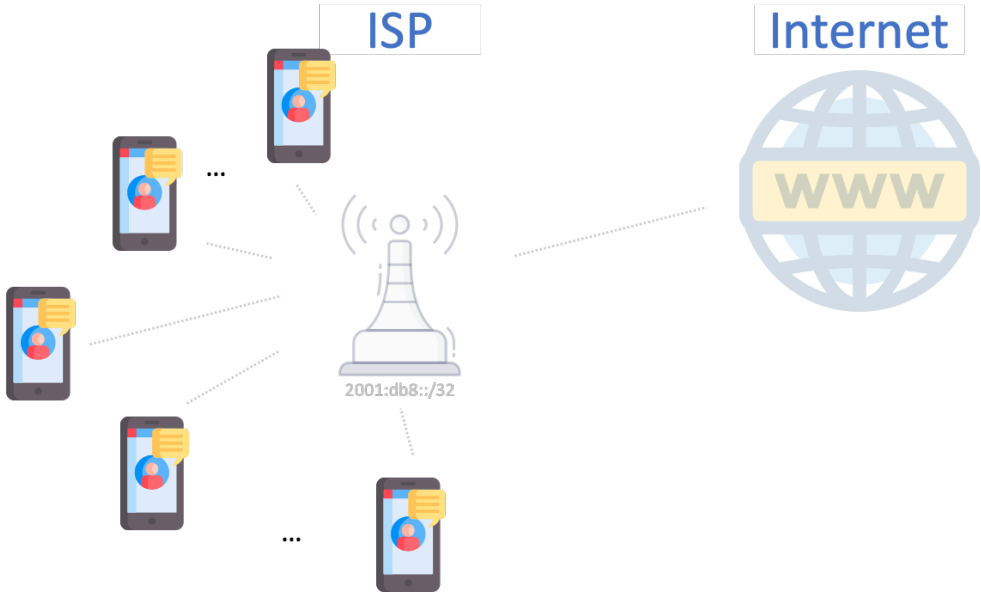
The last hop routed infrastructure
→ Periphery
(more important)

What’s IPv6 Network Periphery

Broadband Network



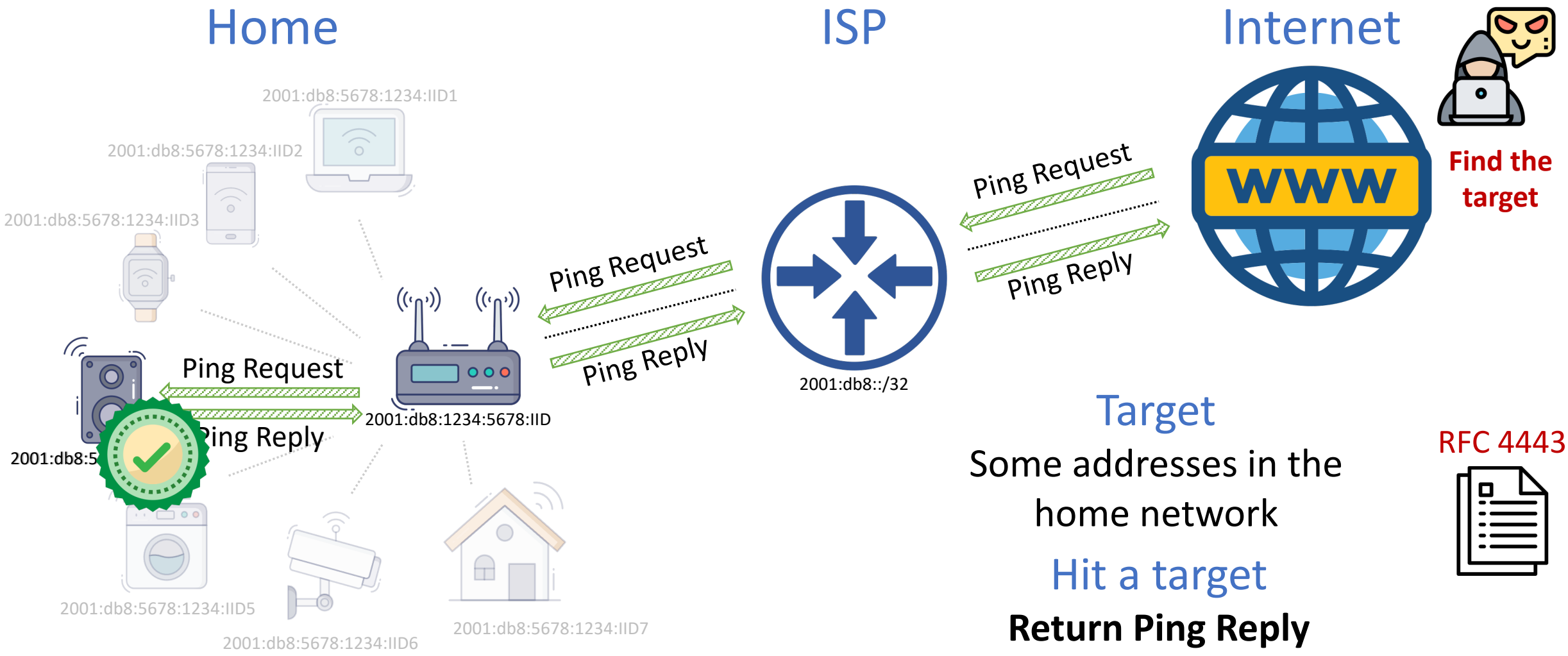
Mobile Network



The last hop routed infrastructure

→ Periphery

How to find?



Target

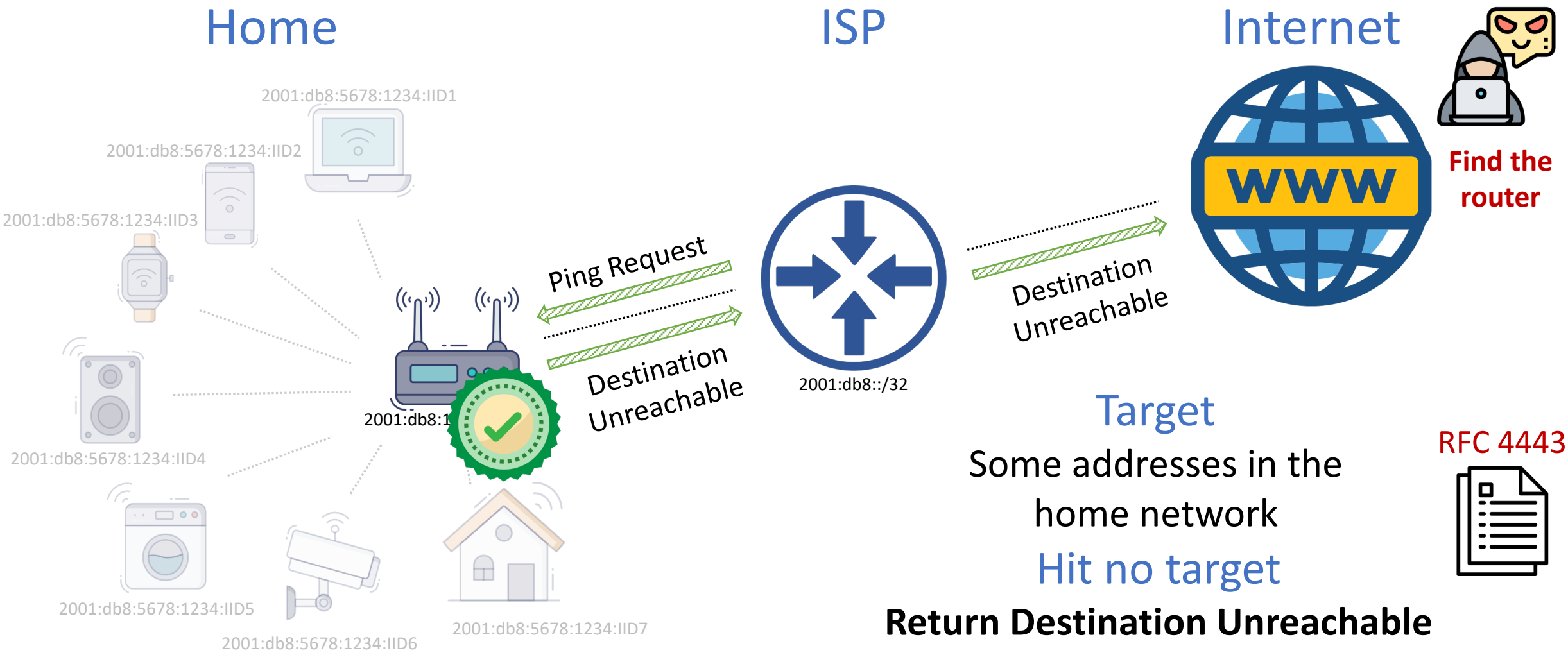
Some addresses in the home network

Hit a target

Return Ping Reply

RFC 4443

How to find?



Target

Some addresses in the home network

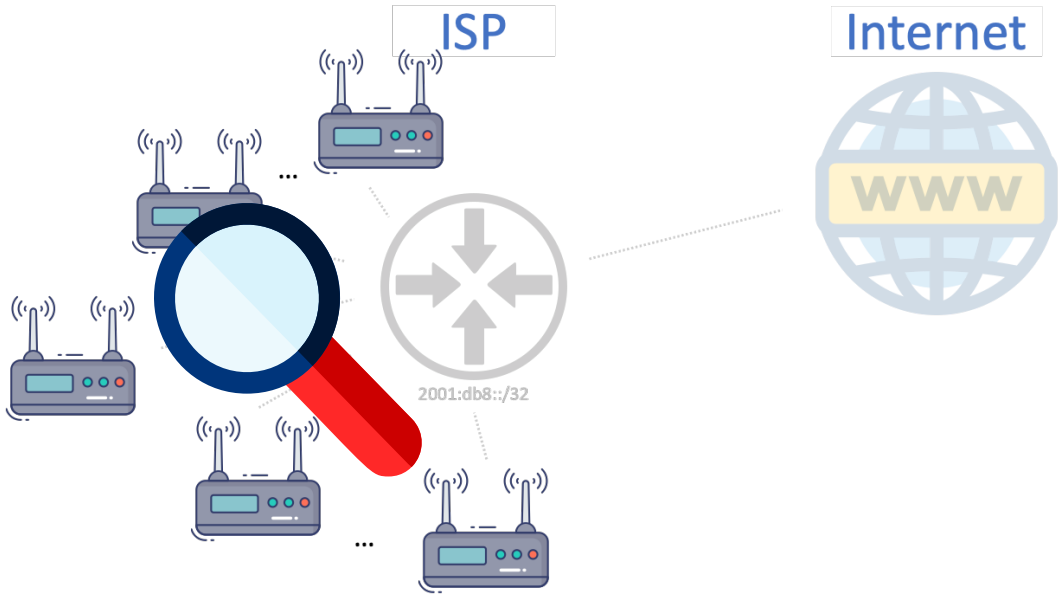
Hit no target

Return Destination Unreachable

RFC 4443

How to find?

Broadband Network



Mobile Network

Scan the IPv6 prefix space

Probe each sub-prefix once for any address under it

How many devices did we find?

- Scanning targets
  - 12 ISPs' 15 IPv6 blocks, sample 32-bit prefix space
  - <15Mbps, 48h for each sample, 52M devices

Country	Network	ISP	# Periphery
Total	**3**	**12**	**52,478,703**
IN	Broadband	Reliance Jio	3,365,175
	Mobile	Bharti Airtel	22,542,690
US	**Broadband**	AT&T	740,141
	Mobile	AT&T	1,734,506
	Enterprise	Mediacom	38,399
...	...	...	...
CN	Broadband	Telecom	2,122,292
		Mobile	7,316,861
	Mobile	Unicom	3,696,275

Security Implications

- Q1: IPv6 Address Privacy
- Q2: IPv6 Application Services
- Q3: Routing Loop Attack

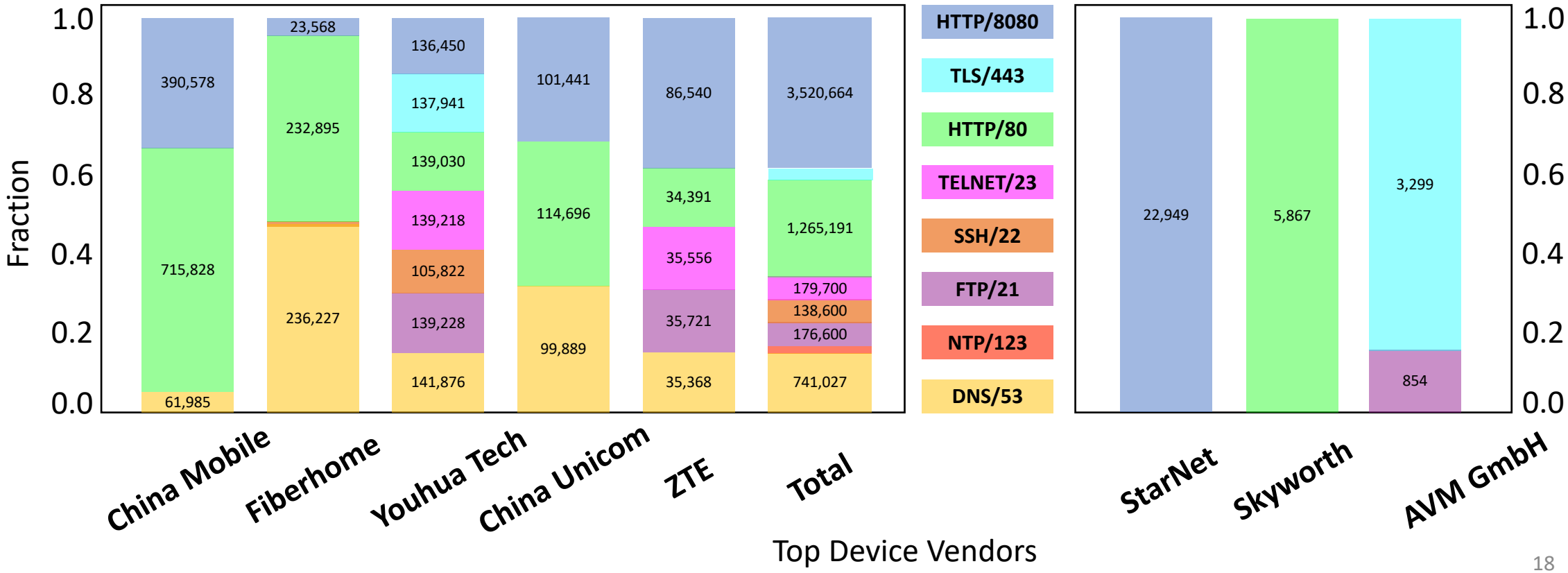
IPv6 Address Privacy

- EUI-64 format IPv6 address
  - Device MAC addresses are embedded into IPv6 addresses
- Still, lots of EUI-64 format addresses
  - Customer premise edge devices, e.g., home routers
  - User equipment devices, e.g., smartphones
  - >62 vendors

Pattern	# device
EUI-64	**3.97M**
Randomized	39.60M
Low-byte	511.18k
Byte-pattern	5.46M
Embed-IPv4	2.91M
Total	**52.48M**

IPv6 Application Services: Devices

- Invisible services through IPv4
- Exposed to the Internet via IPv6
  - 4.7M, e.g., DNS, NTP, FTP, SSH, TELNET, HTTP, TLS



IPv6 Application Services: Software

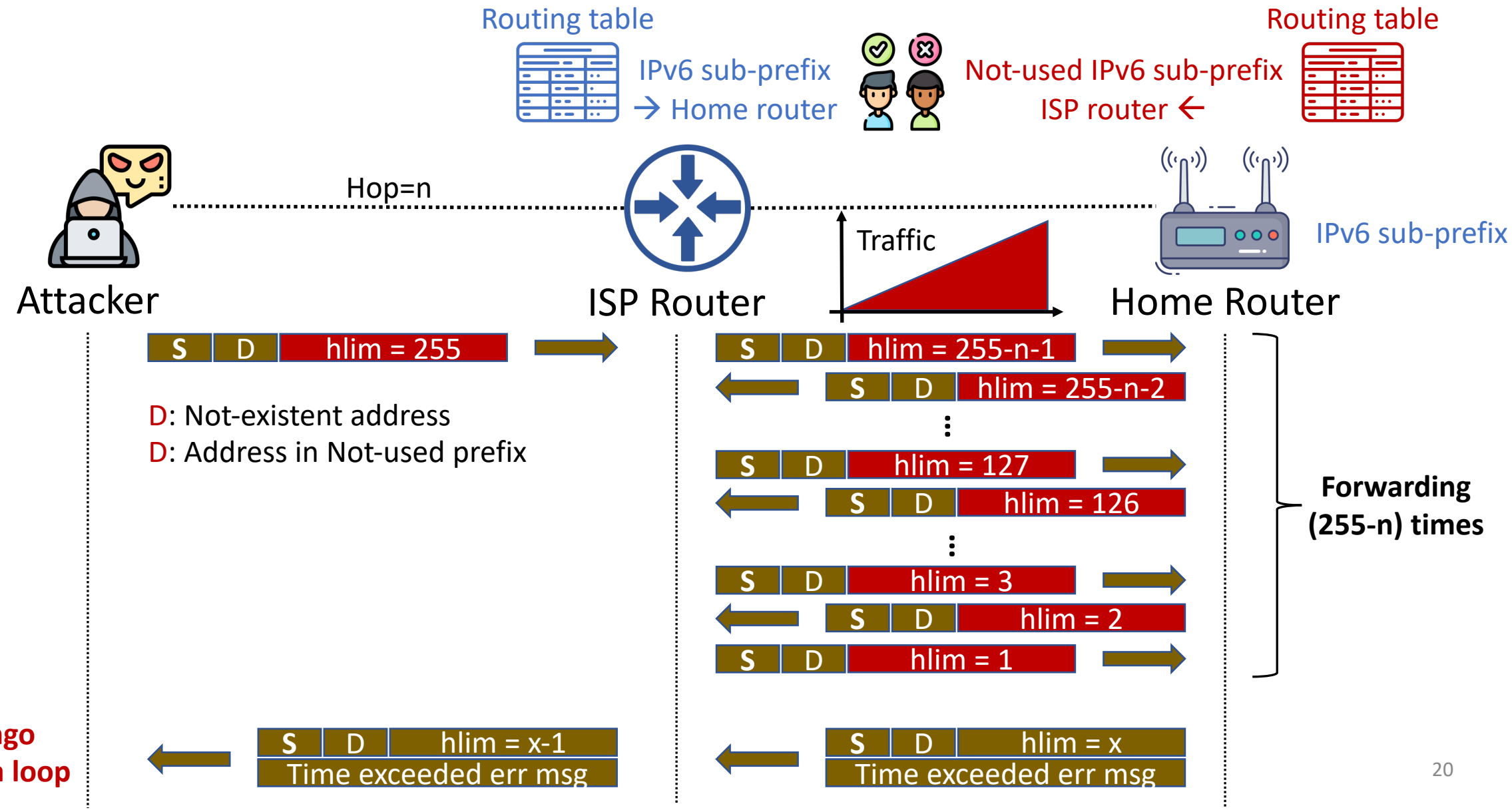
- Most software is released 8-10 years ago
  - e.g., DNS and SSH
- Affected by many CVEs

Released ~8 years ago

Service	Top Software & Version (# device)	# CVE
DNS	dnsmasq 2.4x (142k), dnsmasq 2.5x (3.6k) dnsmasq 2.6x (2.4k), dnsmasq 2.7x (52k)	16
SSH	dropbear 0.46 (6k), 0.48 (106k), 0.5x (937) 2012.55 (20k), 2017.75 (3k), 2011-2019.x (233)	10
	openssh 3.5 (469), 5.x (27) 6.x (144), 7.x (118), 8.x (35)	74

Released before 2006

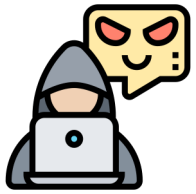
Routing Loop Attack: Threat Model



Routing Loop Attack: Measurement

- How wide is the vulnerability
  - IPv6 BGP prefix probing
- How many devices are under the attack
  - 12 ISPs' 15 IPv6 blocks probing
- Method
  - Use the Time-exceeded msg
- Results
  - 5.8M vulnerable devices
  - 3,877 ASes, 132 countries

Routing Loop Attack: Vulnerable Routers



- **20** router vendors (**95** devices), **4** OSes
- **All vendors confirm and are fixing**

131 CVE/CNVD

ASUS LINKSYS NETGEAR

D-Link tp-link MERCURY HUAWEI

MikroTik ZTE Tenda Skyworth

中国移动 China Mobile H3C TOTOLINK The Smartest Network Device FiberHome

FAST Hisense 友华通信 YOUHUA TECHNOLOGY iKuai

OpenWrt WIRELESS FREEDOM Gargoyle Router Management Utility DD-WRT

Community Contribution: XMap

- **Open source tool**
  - Rewritten thoroughly from ZMap
  - **Support IPv6 & IPv4**
  - Fast periphery discovery
  - Discovering routing loop vulnerability
  - Multiple ports probing
  - …
  - https://github.com/idealeer/xmap
  - Everyone can join!!! Maybe star it

Discussion

- **Mitigation**
  - Avoid/Block ICMPv6 ‘reply’ msgs
  - Strengthen access control policies
  - Add unreachable routes for not-used prefixes
- **IPv6 Network Security**
  - IPv6 network peripheries should be focused
  - IPv6 strategies need to be revisited

Questions?

Thank you

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