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Deploying IPv6-mostly access networks

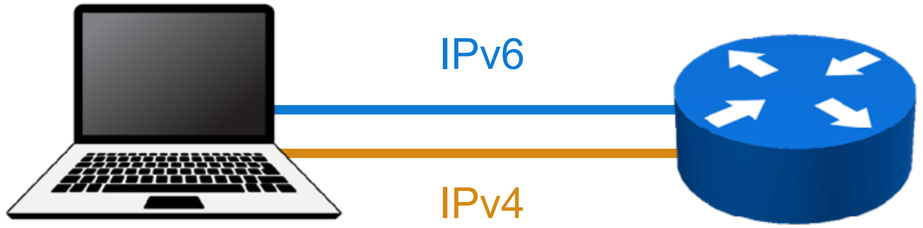
IPv6-only and dual stack in one network

Ondřej Caletka | 24 April 2023 | UK IPv6 Council

The best transition mechanism

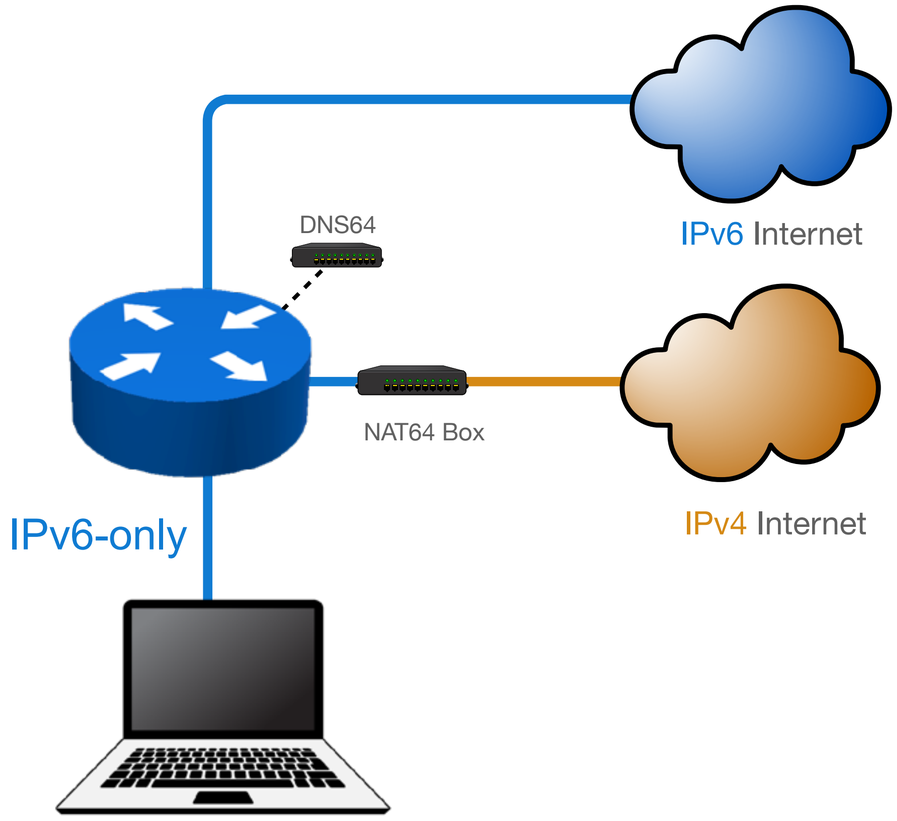
- IPv4-only and IPv6-only resources **directly accessible**
- IPv6 preferred for dual-stack resources
- Problems with IPv6 **masked** by Happy Eyeballs algorithm
- But it **does not address IPv4 scarcity**

Dual Stack



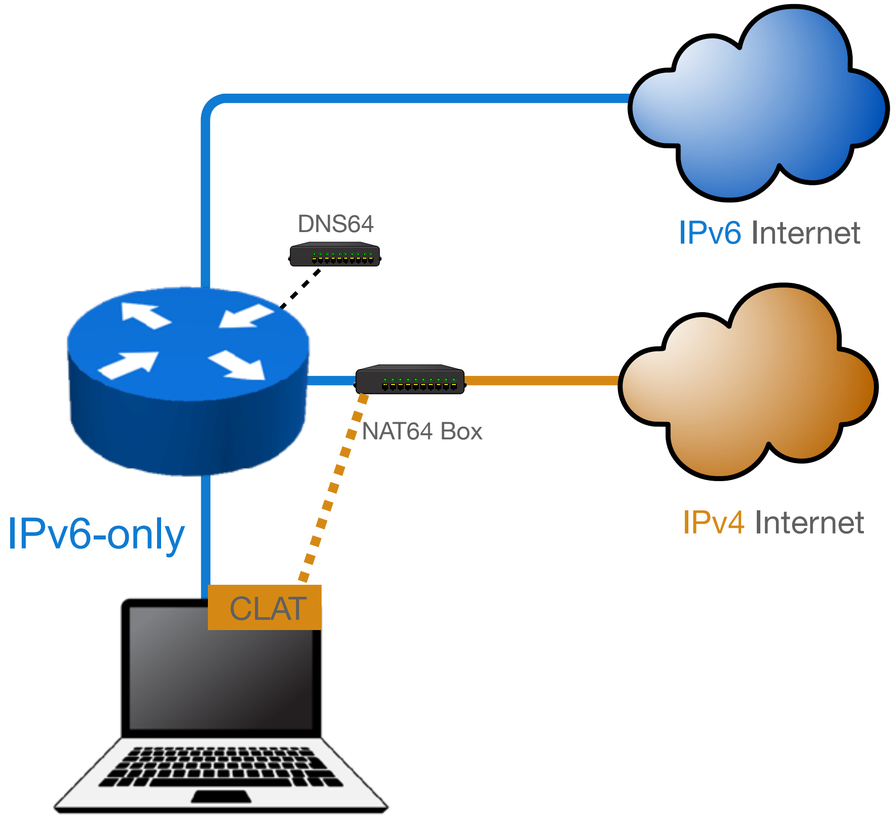
NAT64 allows IPv6-only networks

- IPv6 accessible natively
- IPv4 is translated into part of IPv6 address space
- Together with **DNS64**, everything seems to be **accessible over IPv6**
- **But sometimes you run into…**
  - IPv4 literals
  - Legacy software opening IPv4-only sockets
  - Dual-stack servers with broken IPv6



Mobiles are ready

- Apple forces all iOS apps to work well on IPv6-only networks with NAT64
- There is **Happy Eyeballs 2.0** for IPv4 literals or broken IPv6 on dual stack servers
- Finally **CLAT** is used for tethering to a computer
- Android uses just CLAT (464XLAT)
  - so IPv4 is accessible via two translations



Desktops suffer on IPv6-only

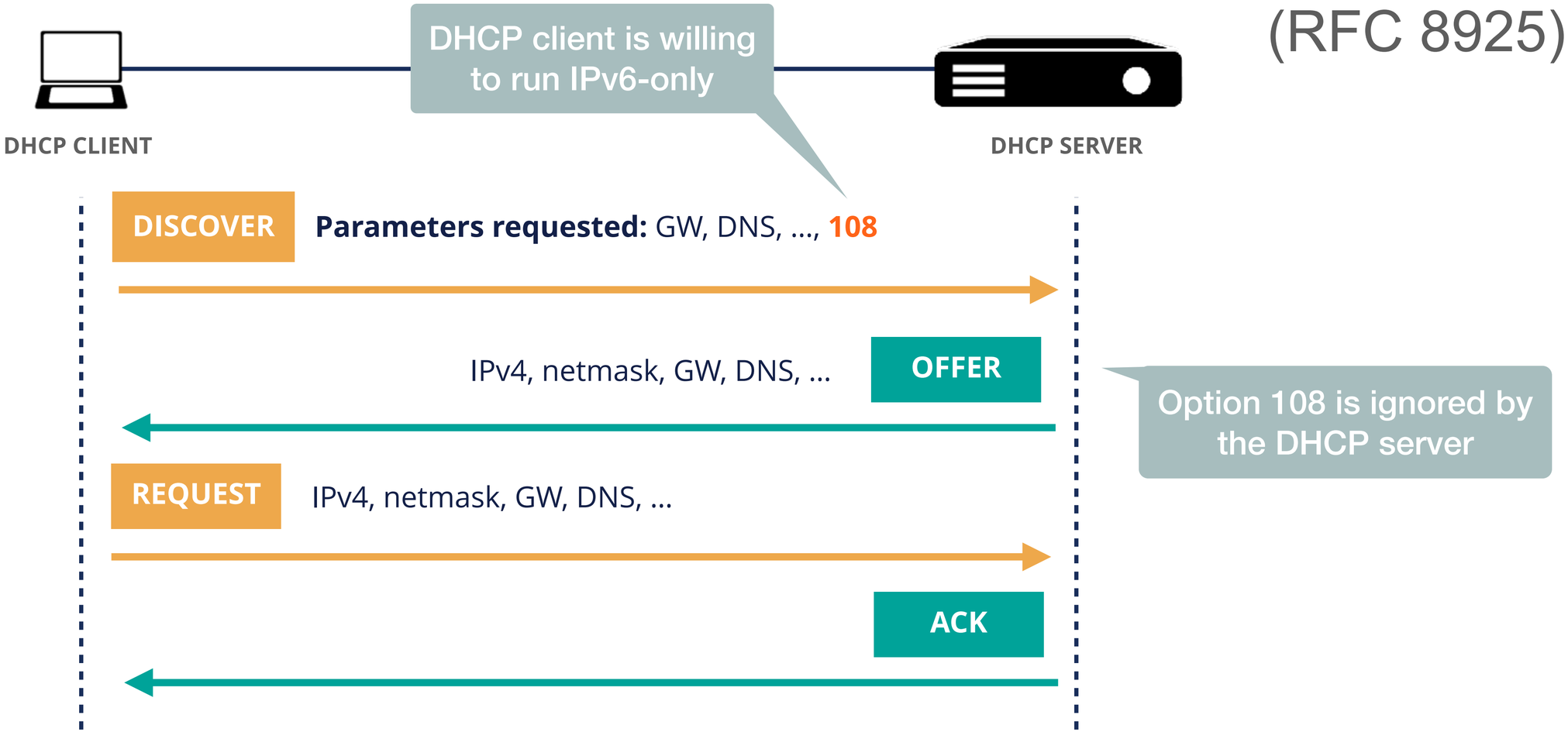
- No Happy Eyeballs 2.0 implementation outside Apple
  - and even on Apple, only high-level APIs support it *(eg. Safari, not Firefox)*
  - Chrome got recently “Use NAT64 translation for IPv4 literals” feature
- **No CLAT** in Windows, Linux or ChromeOS
- Well known small problems:
  - Legacy applications using IPv4-only sockets
  - IPv4 literals do not work *(except Chrome)*
  - Dual-stack servers where IPv6 is broken do not work
  - Legacy Happy Eyeballs **doesn’t help** since there's no IPv4 to fall back to
  - Most corporate VPNs do not work (often *just* a configuration issue)

Can we do IPv6-only?

At least for some devices…

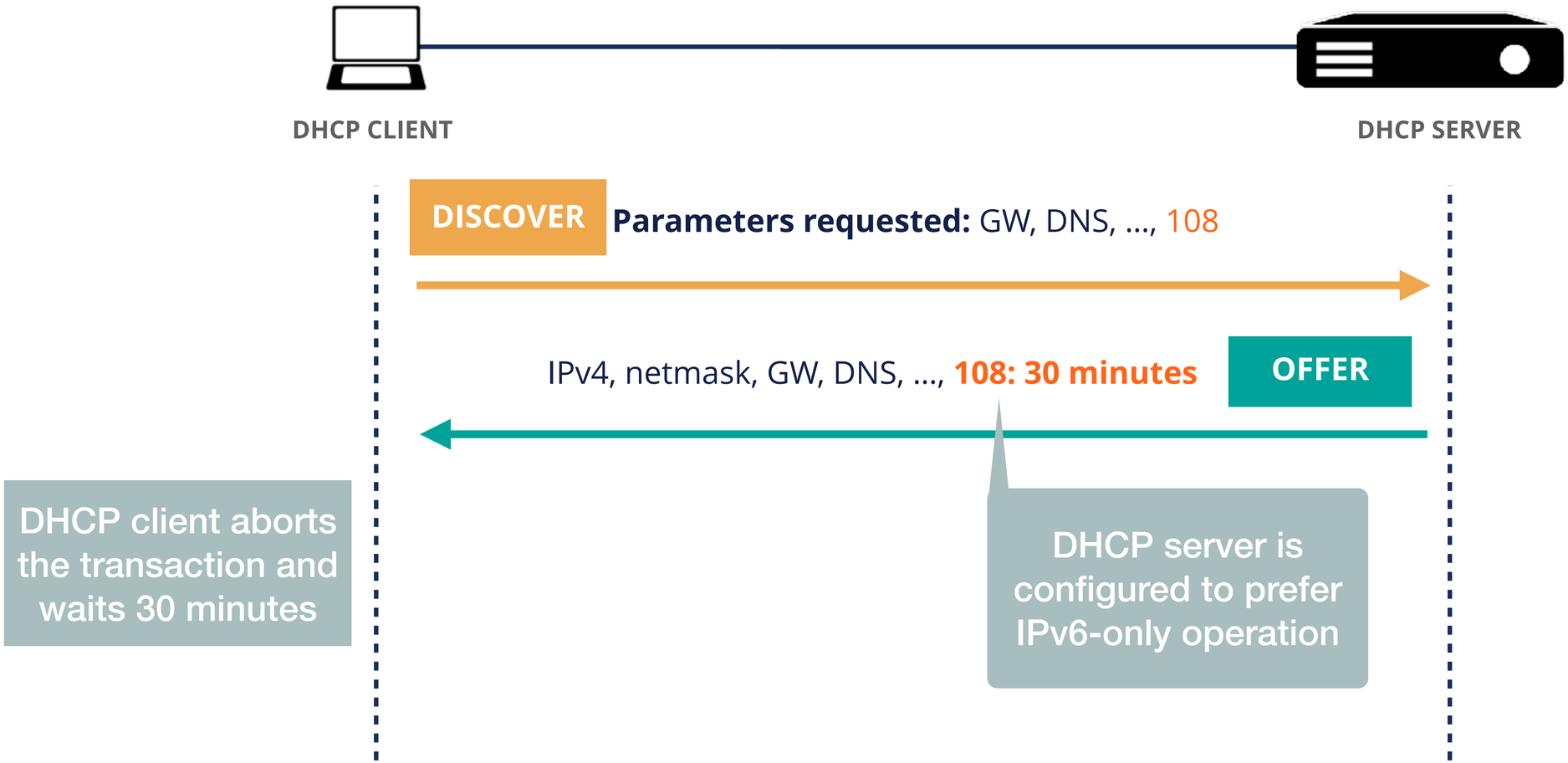
IPv6-only Preferred option of DHCP

(RFC 8925)



Using DHCP to turn IPv4 off

(RFC 8925)



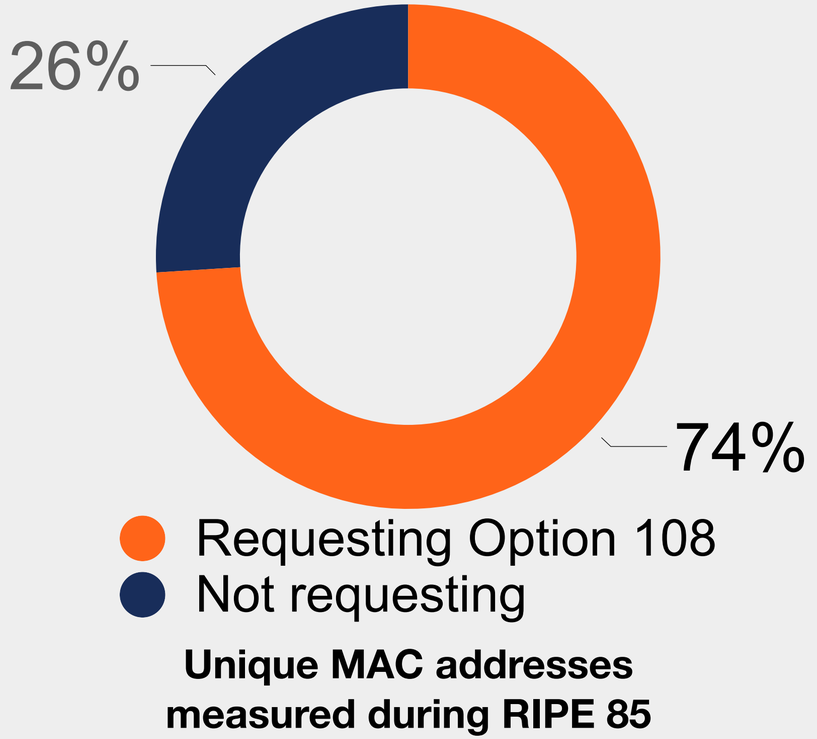
Is DHCP option 108 already deployed?

You bet! Option 108 is requested by recent:

Android

iOS

macOS



Devices are ready, networks are lagging behind.

But what about macOS?

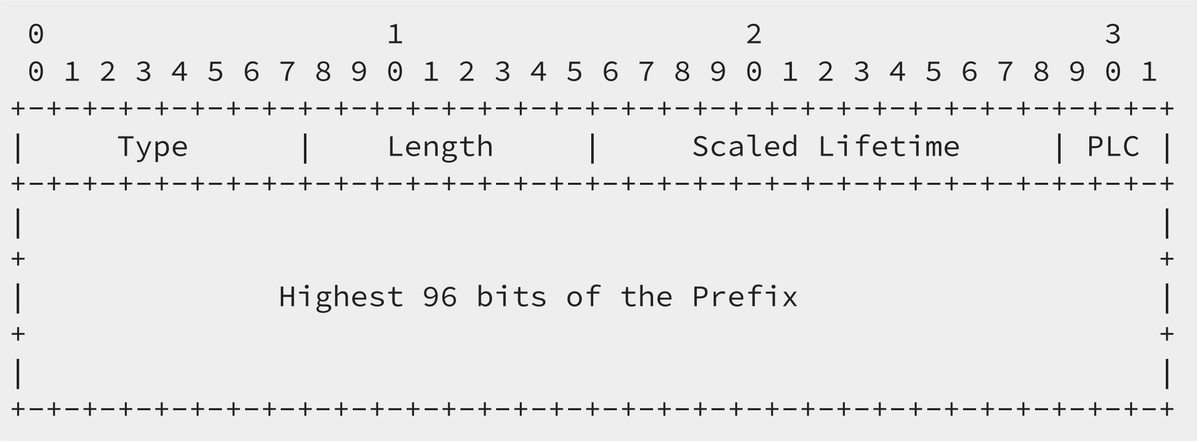
- It allows you to run *any* software including those using legacy IPv4-only APIs
- It turned out **there is CLAT in macOS** too!
  - On macOS 12, it gets activated by DHCP Option 108 **together with RA Option PREF64**
  - Since macOS 13, it gets **activated without any special requirements**
  - At the same time, **pure IPv6-only networks** (without NAT64) are not supported anymore

```
➜  ~ ifconfig en0
en0: flags=8963<UP,BROADCAST,SMART,RUNNING,PROMISC,SIMPLEX,MULTICAST> mtu 1500
        options=6463<RXCSUM,TXCSUM,TSO4,TSO6,CHANNEL_IO,PARTIAL_CSUM,ZEROINVERT_CSUM>
        ether f0:18:98:31:36:c6
        inet6 fe80::1477:9fe8:a21d:56a6%en0 prefixlen 64 secured scopeid 0x6
        inet6 2a02:          :80:c48:6e99:5e6c:e453 prefixlen 64 autoconf secured
        inet6 2a02:          :80:392d:6ea9:e5fd:ddd1 prefixlen 64 autoconf temporary
        inet6 fdba:91fa:4142:80:813:d49b:cca9:9b87 prefixlen 64 autoconf secured
        inet 192.0.0.1 netmask 0xffffffff broadcast 192.0.0.1
        inet6 fdba:91fa:4142:80:fa:bf88:9a02:cbb1 prefixlen 64 clat46
        nat64 prefix 64:ff9b:: prefixlen 96
        nd6 options=201<PERFORMNUD,DAD>
        media: autoselect
        status: active
➜  ~ ping -c 5 1.1.1.1
PING 1.1.1.1 (1.1.1.1): 56 data bytes
64 bytes from 1.1.1.1: icmp_seq=0 ttl=56 time=5.045 ms
64 bytes from 1.1.1.1: icmp_seq=1 ttl=56 time=10.375 ms
64 bytes from 1.1.1.1: icmp_seq=2 ttl=56 time=11.156 ms
64 bytes from 1.1.1.1: icmp_seq=3 ttl=56 time=10.977 ms
64 bytes from 1.1.1.1: icmp_seq=4 ttl=56 time=10.280 ms

--- 1.1.1.1 ping statistics ---
5 packets transmitted, 5 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 5.045/9.567/11.156/2.286 ms
➜  ~
```

PREF64 RA Option

- A Router Advertisement option **carrying NAT64 prefix**
- Needed for **CLAT configuration**, local DNS64 or Happy Eyeballs 2.0 *(dealing with IPv4 literals)*
- **Shares fate** with other configuration parameters
  - can be trusted **a bit more** than DNS64
- Supported by recent Android, iOS and macOS



Running IPv6-mostly

DHCP option 108 is easy

- **Native support** in the latest Kea
- Most DHCP servers support defining **custom options**
  - for instance: `dnsmasq -O 108,0:0:1:2c`
  - the option value represents duration for which the IPv4 stack should be disabled
- **No special processing** on the DHCP server side is *required*
- But there **have to be free addresses** in the IPv4 address pool
  - Otherwise the DHCP server will not respond

PREF64 RA option is harder

- No **custom RA option** support in routers
  - We already **had this issue** with Recursive DNS Server option, now we **have it again**
  - Router vendors should really implement **custom options** similar to DHCP
- Adoption is *slowly* increasing:
  - `radvd` (merged but unreleased)
  - `FRR` (pull request pending)
  - `odhcpd` (pull request pending)
  - rad (part of OpenBSD)
  - MikroTik RouterOS v7.8 beta2

Surprises on macOS

If there are multiple network prefixes, CLAT picks up a single address from a **random one**, without considering ULA or deprecated prefixes

```
➜  ~ ifconfig en0
en0: flags=8963<UP,BROADCAST,SMART,RUNNING,PROMISC,SIMPLEX,MULTICAST> mtu 1500
        options=6463<RXCSUM,TXCSUM,TSO4,TSO6,CHANNEL_IO,PARTIAL_CSUM,ZEROINVERT_CSUM>
        ether f0:18:98:31:36:c6
        inet6 fe80::1477:9fe8:a21d:56a6%en0 prefixlen 64 secured scopeid 0x6
        inet6 2a02:          :80:c48:6e99:5e6c:e453 prefixlen 64 autoconf secured
        inet6 2a02:          :80:392d:6ea9:e5fd:ddd1 prefixlen 64 autoconf temporary
        inet6 fdba:91fa:4142:80:813:d49b:cca9:9b87 prefixlen 64 autoconf secured
        inet 192.0.0.1 netmask 0xffffffff broadcast 192.0.0.1
        inet6 fdba:91fa:4142:80:fa:bf88:9a02:cbb1 prefixlen 64 clat46
        nat64 prefix 64:ff9b:: prefixlen 96
        nd6 options=201<PERFORMNUD,DAD>
        media: autoselect
        status: active
```

Surprises on macOS

If user sets up a **custom IPv4 DNS server address**, DNS will not work, despite commands like `host` working normally

```
➜  ~ scutil --dns | head
DNS configuration

resolver #1
  search domain[0] : mtg.ripe.net
  nameserver[0] : 1.1.1.1
  flags    : Request A records, Request AAAA records
  reach    : 0x00000002 (Reachable)

resolver #2
  domain   : local
➜  ~ host google.com
google.com has address 172.217.168.238
google.com has IPv6 address 2a00:1450:400e:811::200e
google.com mail is handled by 10 smtp.google.com.
➜  ~ ping google.com
ping: cannot resolve google.com: Unknown host
➜  ~
```

Summary

Pros

- **Only one network** to join
- **No waste of IPv4** addresses for every single device
  - Cool if you **don't use NAT**
- Even for dual-stack clients, the usage of IPv4 is **minimal**
  - DNS64 will **force** all IPv6-capable applications **to use NAT64** instead of native IPv4

Cons

- **Most complex** network setup
- IPv4 still **has to be deployed**
- NAT64 is **needed**
- **Problematic** interoperability between dual-stack and IPv6-only hosts within the network
  - Setting up a Chromecast from an Android phone is *impossible*

When to consider IPv6-mostly

- You **don't use NAT** and your DHCP pool is filling up
- You do use NAT but are **running out** of private addresses
- There are mostly **mobile** or **Apple devices** in your network
- You **already have NAT64** in place and want to gradually undeploy IPv4

RIPE 85 Meeting network experience

- Three networks deployed on the venue:
  - Main: **IPv6-mostly**
  - NAT64: **IPv6-only**
  - Legacy: **dual-stack**
- **74 %** of devices in the main network were **running IPv6-only**
- Biggest issue: **custom DNS servers** or **disabled IPv6** on a Mac
- Some Apple users rather connected to the legacy network
- Only observed issues with Cisco AnyConnect / OpenConnect VPN
- Networked printer (Lexmark CS510de) **printed without issues**

Questions

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