internet2.edu

Testing IPv6 Only Networks

James Harr, DevOps NetEng, Internet2

ABOUT INTERNET2


NETWORK

High-Speed National Research & Education Network (NREN)

- US Optical and Packet backbone
- 46 POPs around the US
- 100GE / 400GE connections to connectors/members
- International peerings to other NRENs
- I2PX - Internet2 Peering Exchange - cloud/commercial peerings
- L2VPN & L3VPN solutions


CLOUD


SECURITY

InCommon / Trust & Identity

- Federated single sign on across members
- eduroam - authenticated roaming between campuses


COMMUNITY

Community

- Member-run non-profit organization

AGENDA

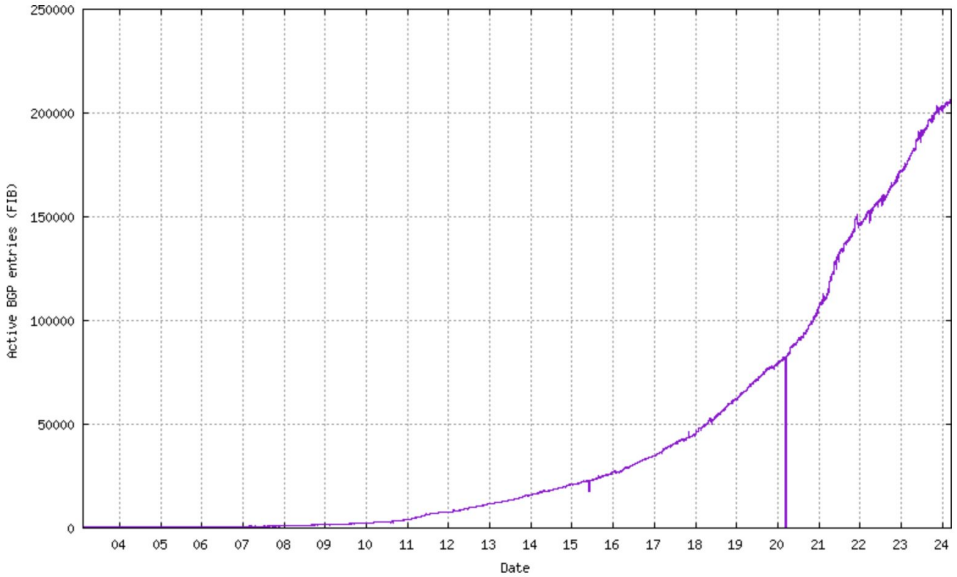
- Events in IPv6
- Measuring IPv6 adoption
- IPv6-only Networks and Transition Technologies
- The IPv6 Test Pod Project
- Current Project Status

Events in IPv6

- 1998 December - IPv6 Draft Standard Released
- 2011 June - World IPv6 Test Day
- 2012 June - World IPv6 Launch
- 2015 September - ARIN Free IPv4 pool depleted
- 2017 July - IPv6 Standard Ratified
- 2020 December - US Gov IPv6-Only Mandate
- 2024 March - draft-link-v6ops-6mops-00
- 2024 March - Microsoft plans to expand CLAT support

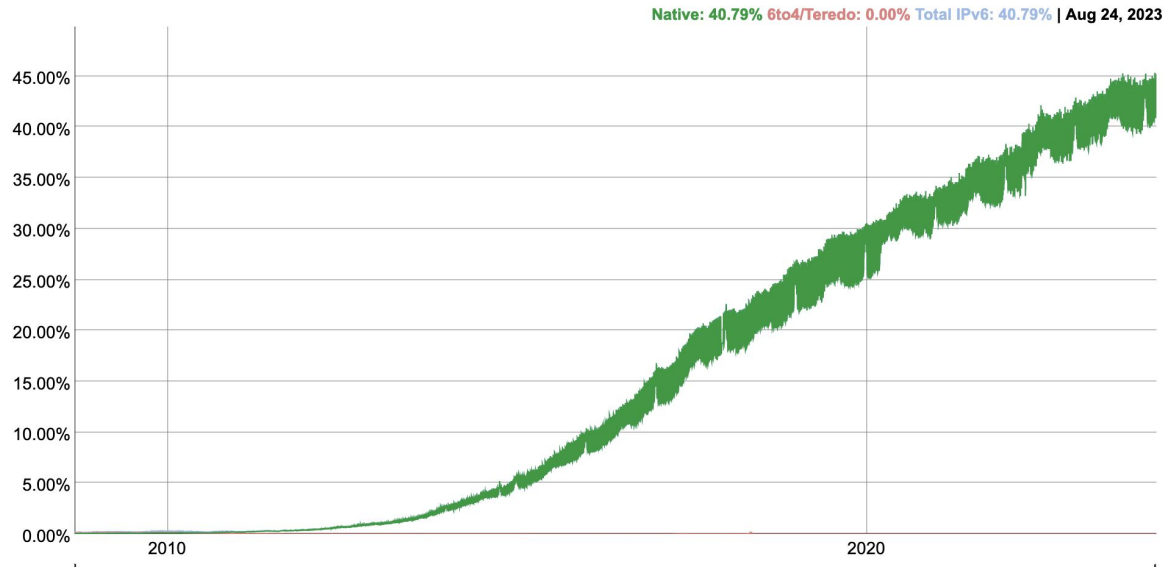
Measuring IPv6 Adoption

IPv6 Adoption - by Prefixes [Potaroo]



Source: https://bgp.potaroo.net/v6/as2.0/index.html

IPv6 Adoption - by Traffic [Google]



Source: https://www.google.com/intl/en/ipv6/statistics.html

Measuring IPv6 Deployment at Internet2

IPv6 at the end-user networks shows

ASN	IPv4 Traffic	IPv6 Traffic
[redacted]	99.97%	0.03%
[redacted]	97.67%	2.33%
[redacted]	99.09%	0.91%
[redacted]	100.00%	0.00%
[redacted]	99.93%	0.07%
[redacted]	100.00%	0.00%
[redacted]	69.50%	30.50%
[redacted]	98.70%	1.30%
[redacted]	38.07%	61.93%
[redacted]	98.55%	1.45%
[redacted]	93.82%	6.18%
[redacted]	99.82%	0.18%
[redacted]	99.85%	0.15%
[redacted]	100.00%	0.00%

IPv6 Adoption - Measurements

- https://bgp.potaroo.net/v6/as2.0/index.html
- https://www.google.com/intl/en/ipv6/statistics.html
- https://radar.cloudflare.com/reports/ipv6
- https://pulse.internetsociety.org/technologies
- https://www.akamai.com/internet-station/cyber-attacks/state-of-the-internet-report/ipv6-adoption-visualization
- https://6lab.cisco.com/stats/

IPv6 Only Networks

Why IPv6-Only?

- IPv6-only is where we really want to be
  - Dual-stack is NOT the end-game
- Operational Simplicity
- Fewer hidden issues [Happy Eyeballs]
- Burden on transition mechanisms

  decreases over time

Supporting IPv6 Only

Emerging standards and techniques to keep IPv6-only networks connected to IPv4-only websites

- **NAT64**
- **DNS64**
- **464XLAT**
- IPv6-RA w/ PREF64
- DHCP option 108 [IPv6 Mostly]

NAT64 - Embedding an IPv6 address

- Choose a prefix to represent the IPv4 Internet
  - 64:ff9b::/96 -- "well known"
  - Allocate /96 from your space -- Will do RFC1918 if you want it to
  - Call this "PREF64" or the "Prefix for 6 to 4 translation"
- End host: Connect to an IPv6 address instead
  - 64:ff9b::**192.0.2.1** -- Special Notation
  - 64:ff9b::**c000:201** -- Hex is OK too, but less convenient
- Send over an IPv6-only network
  - Don't forget to make sure this prefix routes to a NAT64 appliance
- NAT64 appliance translates from IPv6 to IPv4
  - Extracts destination IPv4 from IPv6 DA

DNS64 - Get traffic to use the NAT64

- Acts on AAAA records only
- "Synthesizes" a AAAA record
  - only when an AAAA record does not exist
  - only when an A record exists
- Will break DNSSEC if using a validating resolver
  - In most corp networks, the DNS64 server would be doing the validation anyway

464XLAT - Delivering V4 over V6

- **CLAT** - Customer side translator
  - maps IPv4 traffic into a set of IPv6 traffic
  - IPv4 address is embedded in the destination -- 64:ff9b::192.0.2.1
- Traffic transits an IPv6 only network
- **PLAT** - Provider side translator
  - maps that IPv6 traffic back to IPv4 native
  - Probably close to a network edge somewhere
- Traffic transits IPv4 network

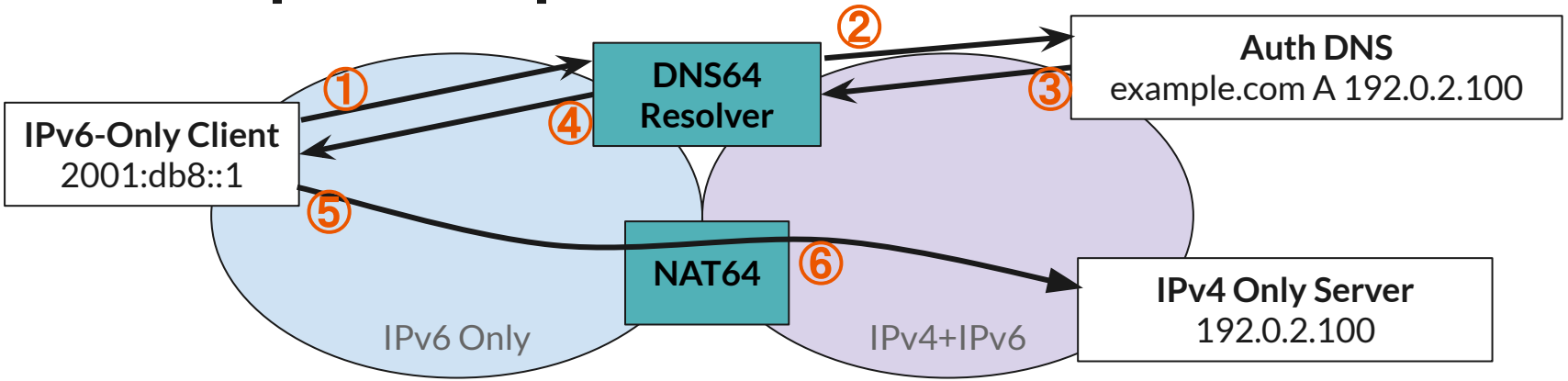
464XLAT - How many configurations?

Oh, Let me count the ways!

Let's just look at one, though.

- The end-device (phone/tablet/laptop) can run the **CLAT**
- **NAT64** appliance works just fine as a **PLAT**

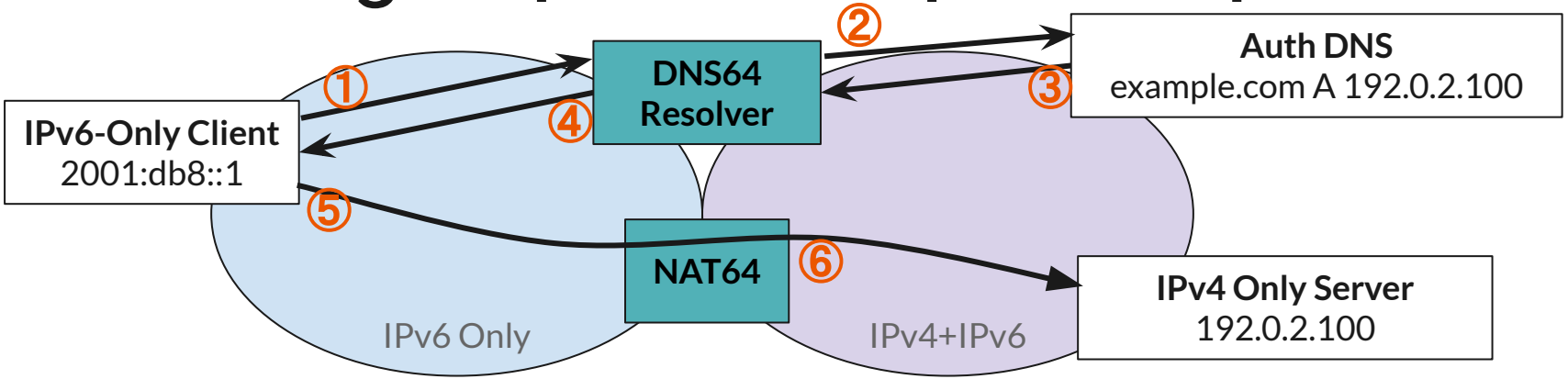
DNS64/NAT64



④ DNS64 synthesizes response -- **example.com AAAA 64:ff9b::192.0.2.100**

⑥ Client traffic to **64:ff9b::192.0.2.100** routed through NAT64 appliance, translated to IPv4

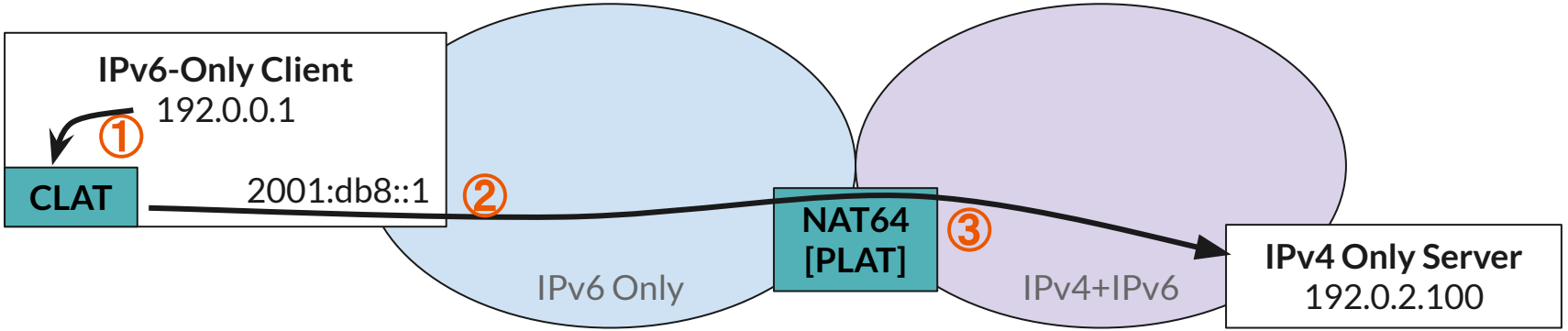
Accessing IPv4 with NAT64 / DNS64



④ DNS64 synthesizes response -- **example.com AAAA 64:ff9b::192.0.2.100**

⑥ Client traffic to **64:ff9b::192.0.2.100** routed through NAT64 appliance, translated to IPv4

Accessing IPv4 with 464XLAT



① Client connects to IPv4-only resource through **CLAT**

② **CLAT** translates to IPv6, connects to **64:ff9b::192.0.2.100**

③ Traffic to **64:ff9b::192.0.2.100** routed through **NAT64 / PLAT** appliance, translated to IPv4

Configuring 464XLAT

RFC 8781 - Discovering PREF64 in Router Advertisements

- Isn't widely supported in most NOS's (yet)
- OS support varies

RFC 8880 - Special Use Domain Name 'ipv4only.arpa'

- **ipv4only.arpa** is a well-known DNS entry with only A records
- If a AAAA record is returned:
  - We know DNS64 is being used
  - We know the NAT64 prefix

Some Typical Problems

	IPv6 Only	DNS64/NAT64	464XLAT
No server-side IPv6	**Problem**	OK	OK
Hard-coded IPv4 literal	**Problem**	**Problem**	OK
Application hard-codes Address Family	**Problem**	**Problem**	OK
Application and Server support IPv6; SSO does not support IPv6	**Problem**	OK	OK
Server IPv6 is listed but broken; **TCP SYN Proxy** breaks Happy Eyeballs	**Problem**	**Problem**	**Problem**

OS Support for 464xlat

iOS	**Supported**	
Android	**Supported**	
macOS	**Supported**	
Windows	**Supported on LTE only**	← Expanded CLAT support expected in Win11
Linux	**Tools exist**, but "assemble yourself"	
FreeBSD / OpenBSD	**Supported in PF**, but "assemble yourself"	

"IPv6 Mostly"

DHCP Option 108 - "IPv6 only Preferred"

- IPv4 is **disabled** if client OS understands this option
- IPv4 is left **enabled** if client OS doesn't understand

Allows a fallback to dual-stack

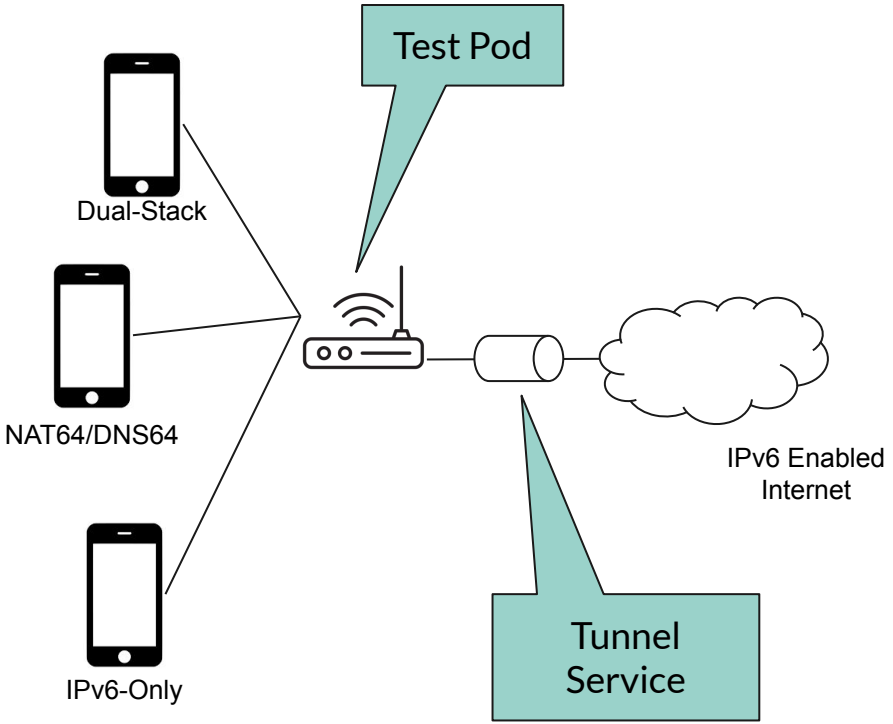
ARIN IPv6 Test Pod Grant

Getting a Lab Set up

1. Understand all the options
2. Get access to IPv6
3. Piece together a solution with a mix of equipment
    a. NAT64 - not well supported in lower end platforms
    b. DNS64 - independent server/container
    c. PREF64 - may not be supported in NOS that supports NAT64
4. Setup multiple test environments
    a. Dual Stack
    b. DNS64 + NAT64
    c. NAT64 + PREF64
    d. IPv6 only
5. Still do your day job

IPv6 Test Pod

- $7,000 ARIN Grant
- Target making client-side testing easy
- Inexpensive device (<$150)
- Creates 3+ wifi+wired networks for testing: dual-stack, nat64, ipv6-only
- Uses an a tunnel for IPv6
- Service includes tunnel termination
- Comes pre-configured, plug-in and go
- Distributed at no-cost to participant
- Inspired by RIPE ATLAS probes



Target Users

- **App Developer** - Wants to test a client-side app in a v6-only environment. The back-end infrastructure is supposed to be configured, but happy eyeballs and a dual-stacked server may be hiding problems.
- **IT Support** - Has a set of applications they want to test for an IPv6-only environment, but the rest of the organization doesn't have time/resources to set up the test bed.
- **Network Engineer** - Who has been asked to research NAT64/DNS64; lab environment setup would take days/weeks

Project Timeline

Month 0-6 – Purchase initial batch of test hardware, Evaluate software

Month 3-9 – Collect applications, Configure & distribute devices,

Month 9-12 – Gather feedback from participants, Summarize in report

Ways to Participate

- jharr@internet2.edu
- ipv6-pod.info
  - Submit an application for a test pod
  - Mail list - https://lists.internet2.edu/sympa/info/ipv6-pod-announce