

IPv6: Kicking and Screaming



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WARNING

- My goal with this talk is to kill your **last vestiges of denial**.
- IPv6 isn't *coming*, it's *here*. **IPv4 is now the legacy protocol**.
- If you are working in a technical field anywhere adjacent to the Internet, **you must know IPv6**.

No exceptions!

What's IPv4?

- Internet addresses like this: 192 . 0 . 2 . 1
- Four ~~bytes~~ *octets*, separated by periods:
dotted quad.
- Sometimes followed by a slash and a **netmask**:
 - 198 . 51 . 100 . 117 / 255 . 255 . 255 . 0
 - 203 . 0 . 113 . 0 / 24

0 . 0 . 0 . 0 / 0

What's wrong with IPv4?—1/5

- We're **running out of it**: IPv4 address exhaustion
- Four-billion-odd addresses isn't enough.
 - Actually, it's even less than that...
 - Documentation ranges, private ranges, multicast...
 - Lots of unrouted space out there (e.g. **US .mil**)...
- Prices for small allocations and even single addresses are **increasing exponentially**.

0 . 0 . 0 . 0 / 0

What's wrong with IPv4?—2/5

- Most homes and businesses in New Zealand have only one “real” public address.
- Each device there has a private ([RFC1918](#)) address.
- To talk to the internet, they **masquerade** as the public address: [Network Address Translation \(NAT\)](#)
- [End-to-end connectivity](#) becomes **difficult...**

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What's wrong with IPv4?—3/5

- Your personal computer on your home network is at 192.168.1.99, a **private address**.
- The webserver for <https://www.plug.org.nz/> is at 139.180.168.151, a **global address**.
- Routers can get your packets directly *there*...
- ...but they can't route directly *back*!
- Workarounds are needed to maintain a connection.

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What's wrong with IPv4?—4/5

- Now ISPs are running out of IPv4 addresses, too...
- So they put *many* customers behind *one* IPv4 address.
- And each of the customers has their own private network behind *that*: **Carrier Grade NAT (CGNAT)**
- End-to-end connectivity becomes **impossible**.

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What's wrong with IPv4?—5/5

- A few other problems:
 - Header format is inefficient...
 - Privacy and security problems...
 - Limited extensibility...
 - Adapts badly to roaming and mobile...
 - Needs a separate network service for assignment (DHCP)...
- But most of these are minor.
- Address space is the big problem staring us down.

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The Sixth Sense

- IPv6 fixes this with a significantly larger address space.
- Addresses are *four times longer*: from **32 bits** to **128 bits**.
- Total theoretical address space is therefore *many millions of times* larger.

(Aside: Why no IPv5?)

- There *was* one...sort of.
- The **Internet Stream Protocol (ST)** was internet protocol number 5.
- Never intended as a replacement for IPv4.
- Not too interesting; just a historical detail.

Address representation—1/2

Network:

2001:0db8:000c:0000:0000:0000:0000:0000/64

Addresses:

2001:0db8:000c:0000:0000:0000:0000:0001

2001:0db8:000c:0000:f64d:30ff:fe61:bd0c

::/0

Address representation—2/2

Network:

2001:db8:c::/64

Addresses:

2001:db8:c::1

2001:db8:c::f64d:30ff:fe61:bd0c

::/0

How many addresses?—1/2

2^{128}

...or...

```
$ python -c 'print("{:,}".format(2**128))'
```

```
340,282,366,920,938,463,463,374,607,431,768,21  
1,456
```

How many addresses?—2/2

- Well...not *really* that many.
- We've only assigned a fraction of all that space to be globally routed.
- The rest is **reserved**, at least at present:
 - by standards (private addresses, multicast...)
 - by IANA (Internet Assigned Numbers Authority)
 - by RIRs (Regional Internet Registries)

Network size—1/2

- The basic building block is the /64:

2001:db8:c::/64

- The first four groups are the **routing prefix** and the **subnet ID**.
- The remaining four are for the hosts, or **interface identifiers**:
 - 2001:db8:c::**1**
 - 2001:db8:c::**256f**
 - 2001:db8:c::**dead:f00d...**

::/0

Network size—2/2

- You can break this up further—/96, /112...
- ...but do you really *need* to?
- Just make another /64.
 - Why not?
 - Break out of the poverty mindset!

Getting routed—1/2

- If your ISP supports IPv6, great!
 - Ask them to route you a /56.
 - 256 enormous /64 networks, just for you!
 - Might require you to swap out your equipment.
 - Might come with some conditions...

Getting routed—2/2

- If your ISP *doesn't* support IPv6...
 - Ask them: “pretty please?”
- However, you still have other options:
 - [WireGuard](#) to a VPS (a few dollars a month)
 - [Hurricane Electric Free IPv6 Tunnel Broker](#)

Getting addressed—1/3

- If there's an IPv6 router on your network, you may get a SLAAC address ([RFC4862](#)) automatically.
- This is derived from your network hardware (MAC) address. These addresses are long:

```
$ ip -brief -family inet6 address show scope global
```

```
enp3s0  UP  2001:0db8:000c:0000:f64d:30ff:fe61:bd0c/64
```

```
::/0
```

Getting addressed—2/3

- You can add a **static address** too, of course.
 - Shorter
 - Fixed
 - Not derived from the hardware
- Probably a good idea for routers and servers.
- SLAAC addresses are generally good enough for clients.

```
$ ip address add 2001:db8:c::1/64 dev enp3s0
```

```
::/0
```

Getting addressed—3/3

- If the address length or complexity still bothers you, don't forget to **use DNS**.
- “Numbers for computers, words for humans!”

2403 : 7000 : 8000 : 700 : : c

↑ ↓

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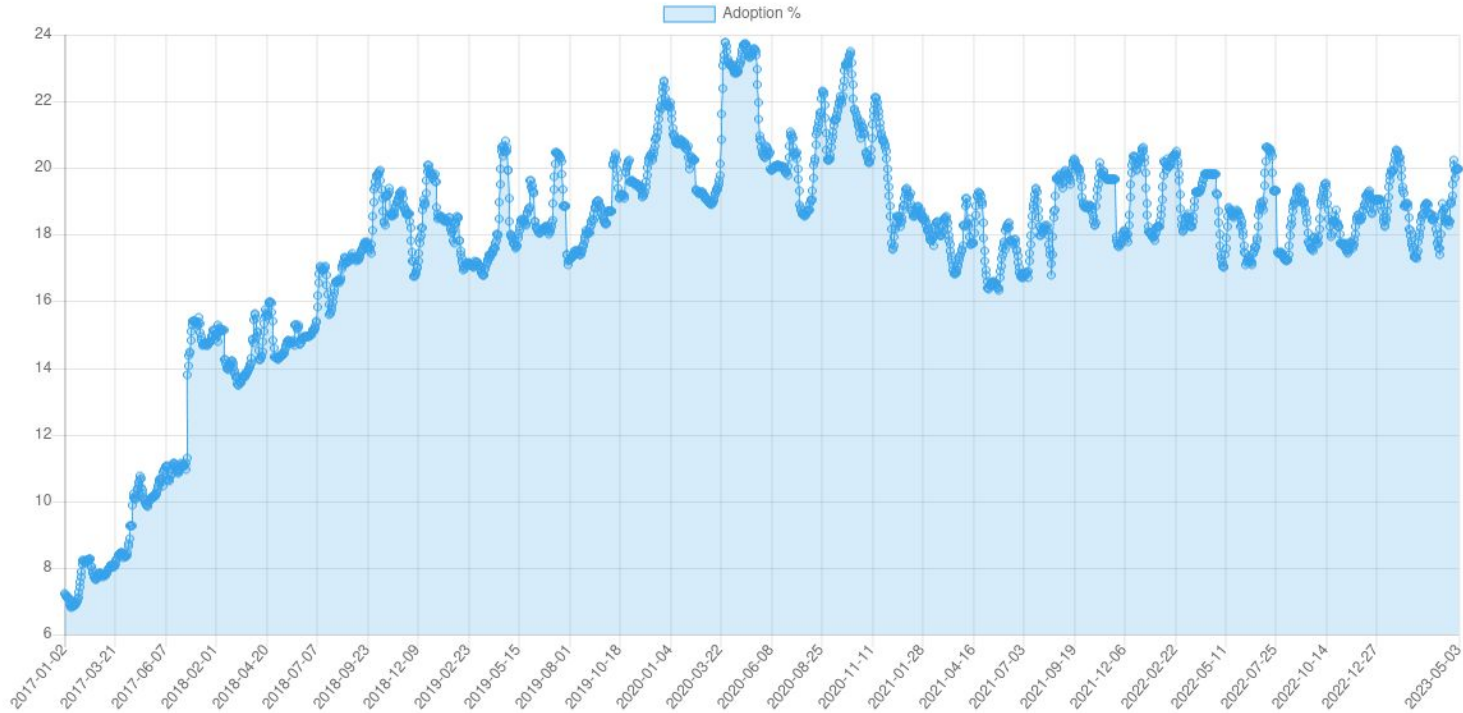
Mindset

- Many years ago now, I first got IPv6 set up on my router for work with the help of our local guru.
- I said to him:
 - “So, how do I do port forwarding in IPv6?”
- He just looked at me for a while, and then said:
 - “...you *don't*.”
- So: it *does* take a while to get used to this...

What's taking so long?—1/6

Google IPv6 Country Adoption - New Zealand

Country adoption graph based on data from [Google IPv6 Statistics](#) page.



[Back to the list of countries.](#)

What's taking so long?—2/6



The Most Popular Websites Without IPv6 In United States



The Most Popular Websites Without IPv6 In New Zealand

Each of the following websites is sorted by Alexa rank and loads over an **IPv4 only** connections.

Alexa Rank	Website	IPv6	NS IPv6
12	twitter.com	✗	✓
26	twitch.tv	✗	✓
30	<i>WHOOPS!</i> Can't show that in a Christian manga!	✗	✓
42	ebay.com	✗	✓
43	t.co	✗	✓
51	imdb.com	✗	✓

Each of the following websites is sorted by Alexa rank and loads over an **IPv4 only** connections.

Alexa Rank	Website	IPv6	NS IPv6
2737	trademe.co.nz	✗	✓
8903	auckland.ac.nz	✗	✓
10033	kmart.com.au	✗	✓
13137	davidjones.com.au	✗	✓
13429	metSERVICE.com	✗	✓
14033	tvnz.co.nz	✗	✓

What's taking so long?—3/6

- Lack of **public interest**.
 - In the 90s, everyone wanted to get on the Internet, so we all learned IPv4 to get our customers online.
 - But for end-users now, they're *already* online, and for most people, it *already* works.
 - So: why would they care?

What's taking so long?—4/6



GNU/r000t

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and I swear to you, if zoomers could only watch their dance videos on IPv6, there would be 100% saturation (at least in the US) within two weeks. It'd be considered an emergency. ISPs would be hauled in front of congress and asked why the dance videos went away.

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What's taking so long?—5/6

- Lack of **infrastructure**.
 - IPv6 is not a new standard ([RFC 2460](#), December 1998), but there's a *lot* of legacy network gear out there.
 - A lot of it does *support* IPv6, but the support is incomplete or buggy.

What's taking so long?—6/6

- Lack of **resources**.
 - Maintaining and securing IPv4 networks is already very difficult.
 - Adding IPv6 analogues to all that configuration means a lot more **training**, a lot more **time**...
 - ...and a lot more **mistakes**.

What to do?—1/3

- **Wait it out**, fundamentally.
- IPv6 is inevitable. CGNAT is awful, and nobody wants it. But it does slow adoption down.
- The required incentives can't really be artificially created in a free market economy.
- If you're the **CCP**, however...

What to do?—2/3

- *Eventually*, we will get to the point where new networks are IPv6 only...
 - ...because you can't *get* any IPv4 anymore...
 - ...and there's stuff on those networks that **people want**.
- That's when we'll hit critical mass and people will start demanding IPv6, if they don't already have it.
- That's still a way off.

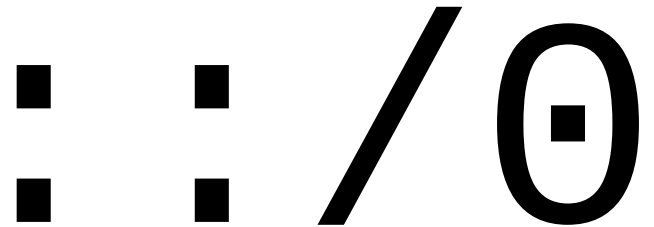
What to do?—3/3

- The best thing you can do is get IPv6 going yourself.
- Support IPv6 on the services you run.
- Ask other services to support it.
- Tell your technical friends.
- ...and the adoption graph will keep creeping up, even for us here in slow New Zealand.



Questions?

- IPv6 (Wikipedia)
- IETF—RFC8200
- IANA—IPv6 Address Space
- APNIC—IPv4 post-exhaustion



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