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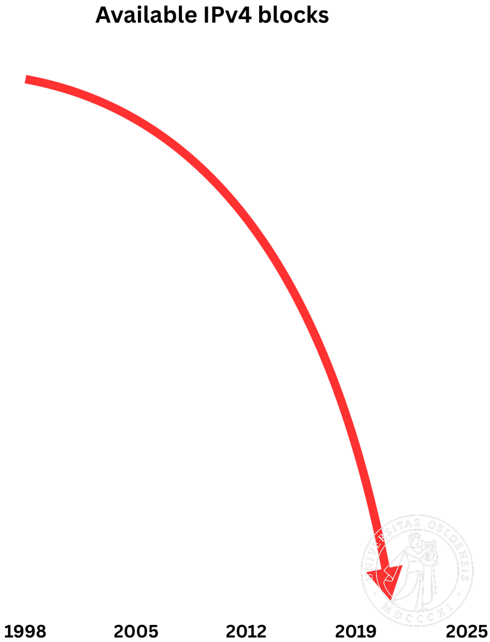

Protocol Racing

Is it really an advancement?

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October 18, 2025

Agenda

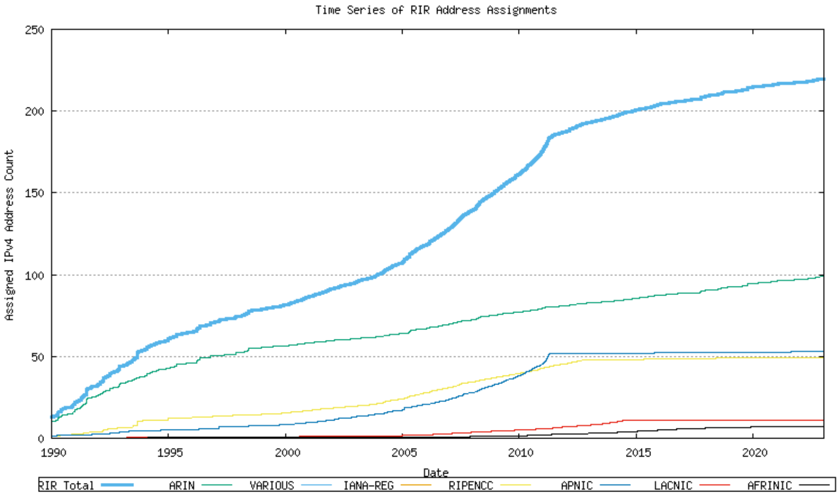
1. A bit of history
2. The issue with Dual-Stacking
3. The solution
4. Issues with Happy Eyeballs
5. Happy Eyeballs version 2
6. Wrap-up

IPv4

- **RFC 791** – *Internet Protocol*
- Written for DARPA in 1981 (before the IETF existed)
- Designed to interconnect different packet-switched networks (ARPANET, SATNET, university nets)
- Created under the assumption that every device would have its own globally unique, routable address
- 32-bit address space — $2^{32} = 4\,294\,967\,296$ possible addresses
- Sounds like a lot… until you remember that there are 8 billion people alive

Source: (*Internet Protocol* 1981)

The problem with IPv4



Source: (*IPv4 Address Report* 2025)

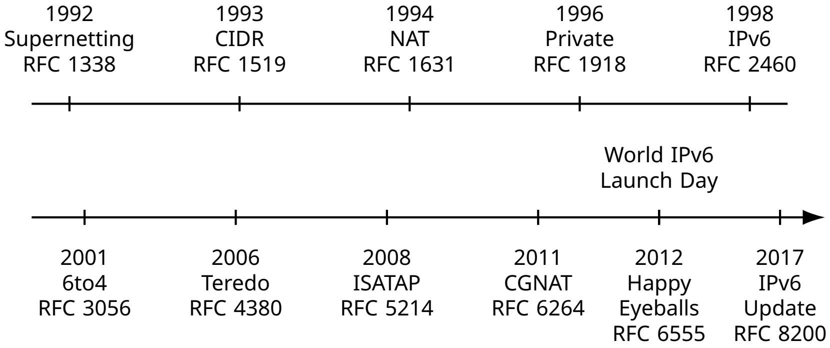
RFC 1338 — Supernetting: an Address Assignment and Aggregation Strategy

It does not attempt to solve the third problem, which is of a more long-term nature, but instead endeavors to ease enough of the short to mid-term difficulties to allow the Internet to continue to function efficiently while progress is made on a longer- term solution.

(The third problem being IPv4 exhaustion)

Source: (Fuller **andothers** 1992)

Timeline of stopgap measures



Timeline of measures from Supernetting to IPv6 ’v2’

IPv6

- **RFC 2460** – *Internet Protocol, Version 6*
- Finished in 1998 later updated in 2017
- Designed to fix the issues of IPv4
- Increases the address space from 32-bit to 128-bit
- 340 282 366 920 938 463 463 374 607 431 768 211 456 addresses
- Allows for some cool things like NAT64

Source: (Hinden **and** Deering 1998), (Deering **and** Hinden 2017)

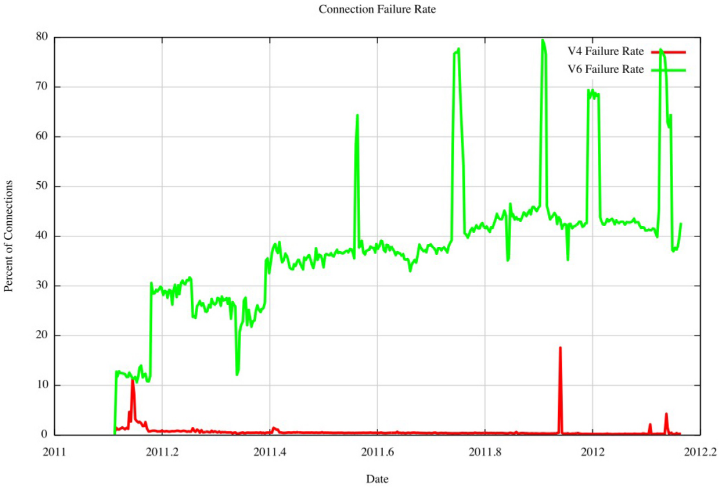
Dual-stack

RFC 1933 — Transition Mechanisms for IPv6 Hosts and Routers

The most straightforward way for IPv6 nodes to remain compatible with IPv4-only nodes is by providing a complete IPv4 implementation. IPv6 nodes that provide a complete IPv4 implementation in addition to their IPv6 implementation are called "IPv6/IPv4 nodes." IPv6/IPv4 nodes have the ability to send and receive both IPv4 and IPv6 packets. They can directly interoperate with IPv4 nodes using IPv4 packets, and also directly interoperate with IPv6 nodes using IPv6 packets.

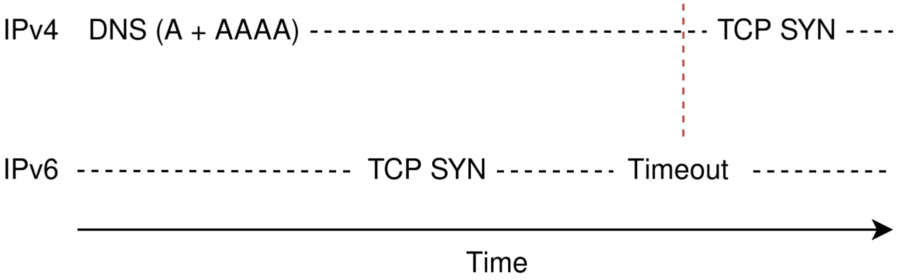
Source: (Nordmark **and** Gilligan 1996)

IPv6 and IPv4 failure rate



Source: (*ISP Column - November 2015* 2025)

Dual-Stacking with IPv6 failure



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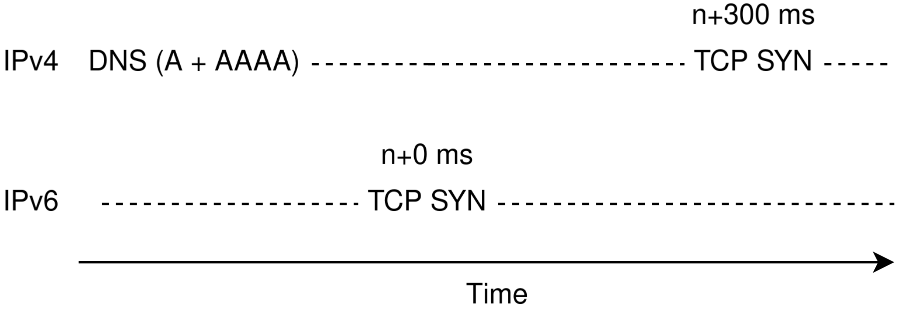
Happy Eyeballs

- **RFC 6555** – *Happy Eyeballs: Success with Dual-Stack Hosts*
- "Races" IPv4 and IPv6 in order to solve blocking behavior
- Applicable to connection oriented transport protocols
- Tries to define a set of standard practices around AAAA DNS records
- No multi-record AAAA responses within the same namespace
- No AAAA specific namespaces e.g. *ipv6.example.com*
- Specifies a head start of 150-250 ms but, all browsers use 300 ms

Source: (Wing **and** Yourtchenko 2012)

Dual-stacking with Happy Eyeballs



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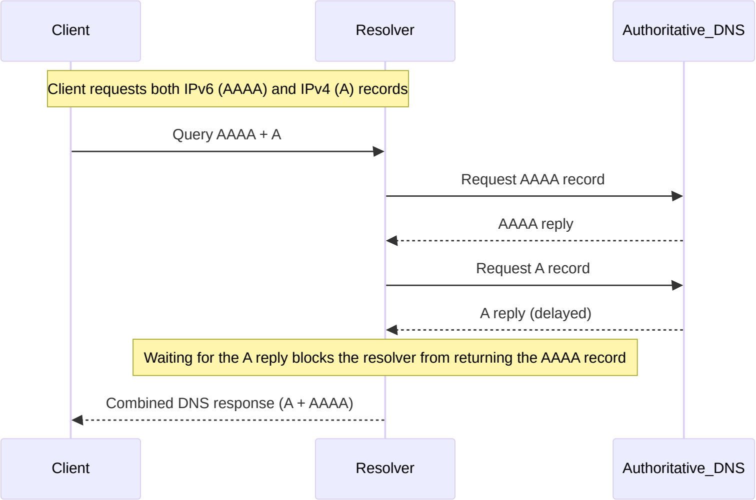
DNS slow family blocking



Slower Connections

Measuring the Effects of Happy Eyeballs

In 90% of these cases, HE tends to prefer slower IPv6 connection. This shows that the timer value (300 ms) used by the HE algorithm has past its time and is not suitable in today's landscape.

Source: (Bajpai **and** Schönwälder 2016)

Happy Eyeballs version 2

- **RFC 8305** – *Happy Eyeballs: Better Connectivity Using Concurrency*
- Races DNS families to avoid blocking
- Races multiple records in multi record DNS responses
- Implements a set of 10 rules for sorting the records (Functionally replacing old IPv6 address selection policy defined in **RFC 3484**)
- Prefers DNS over IPv6 but, won’t race them if both IPv4 and IPv6 addresses are available
- Implements a ’resolution delay’ to give AAAA records a head start

Source: (Schinazi **and** Pauly 2017)

Questions?

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