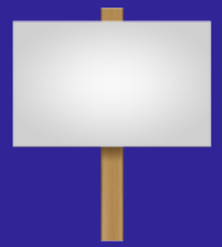
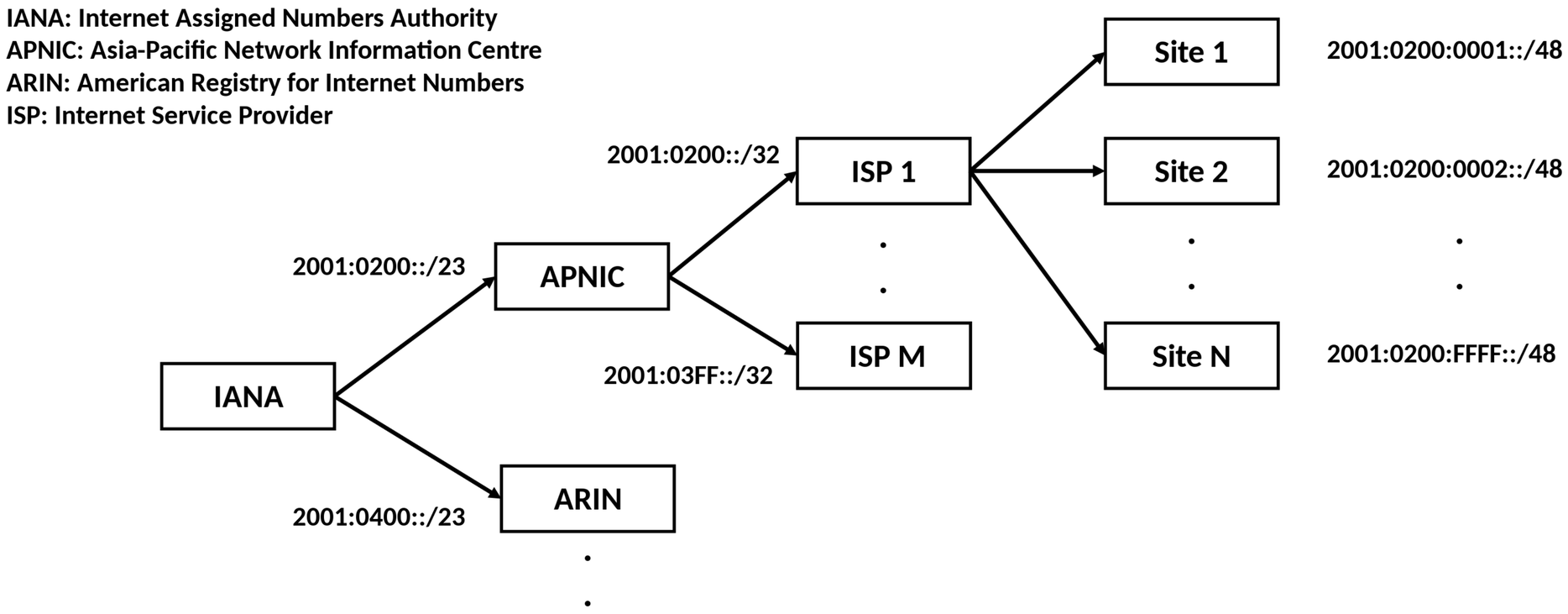


IP Addresses

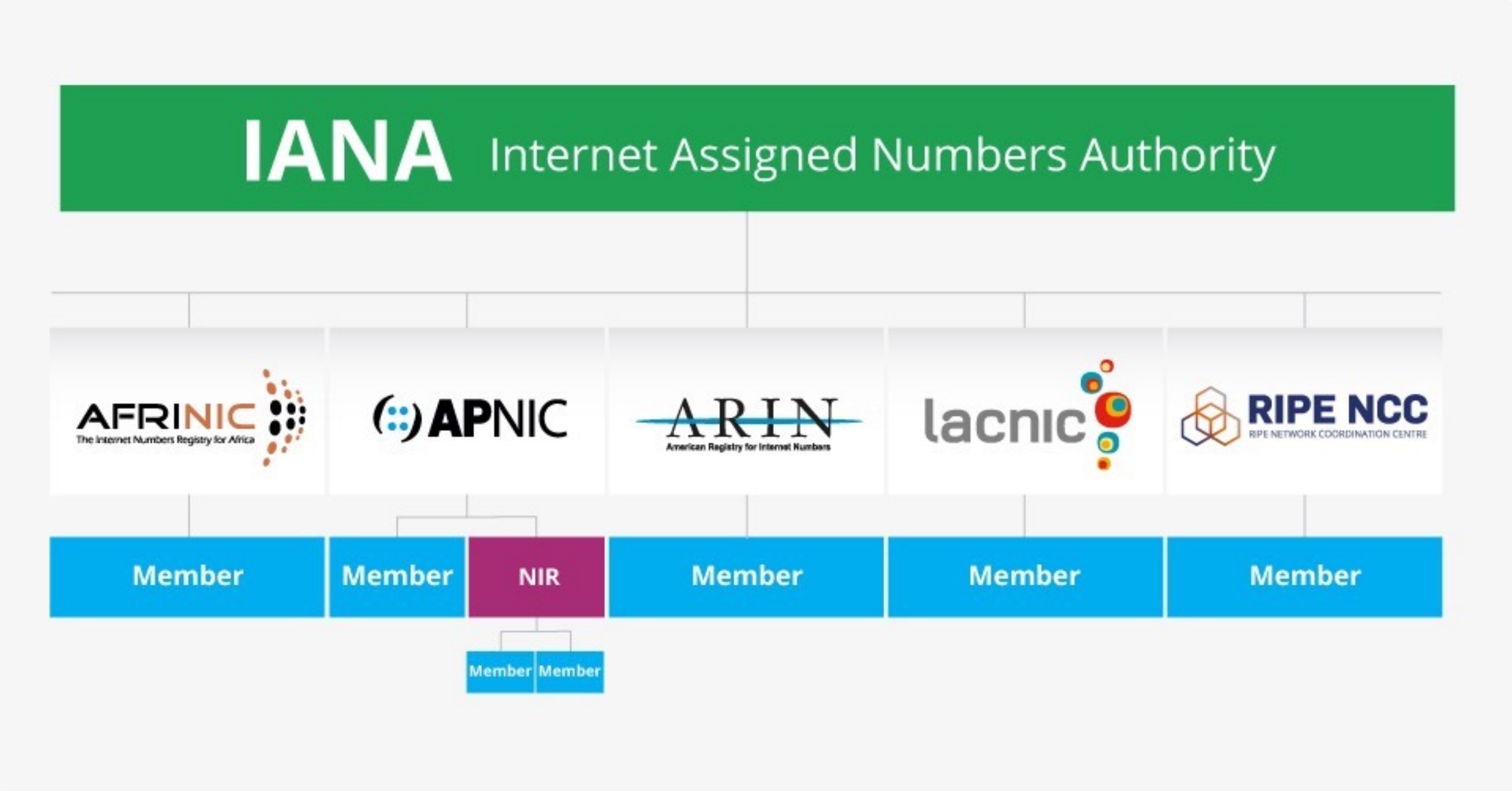
IP Address Allocation

IANA allocates blocks of IP addresses to regional Internet registries (RIRs).

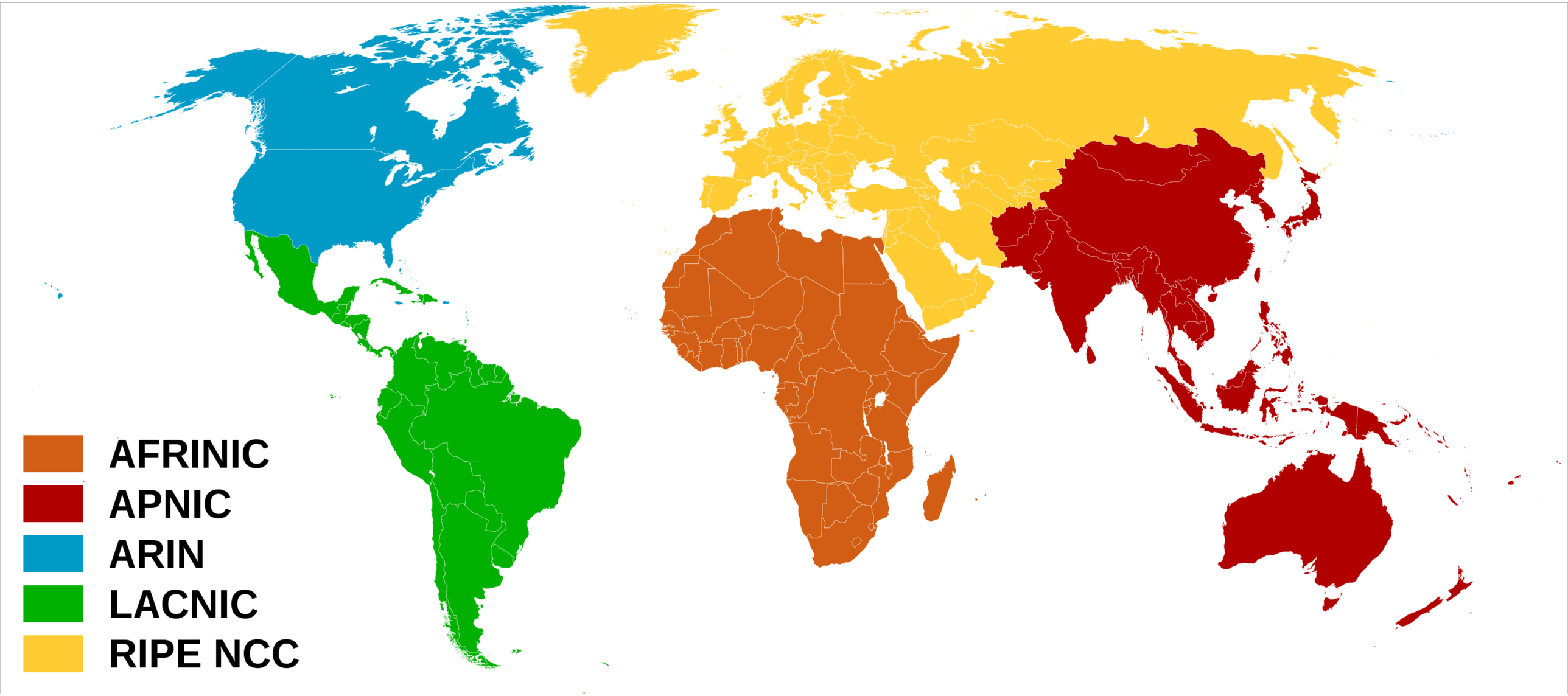


The 5 RIRs are informally liaised through an independent non-profit *Number Resource Organization (NRO)*

Regional Internet Registries

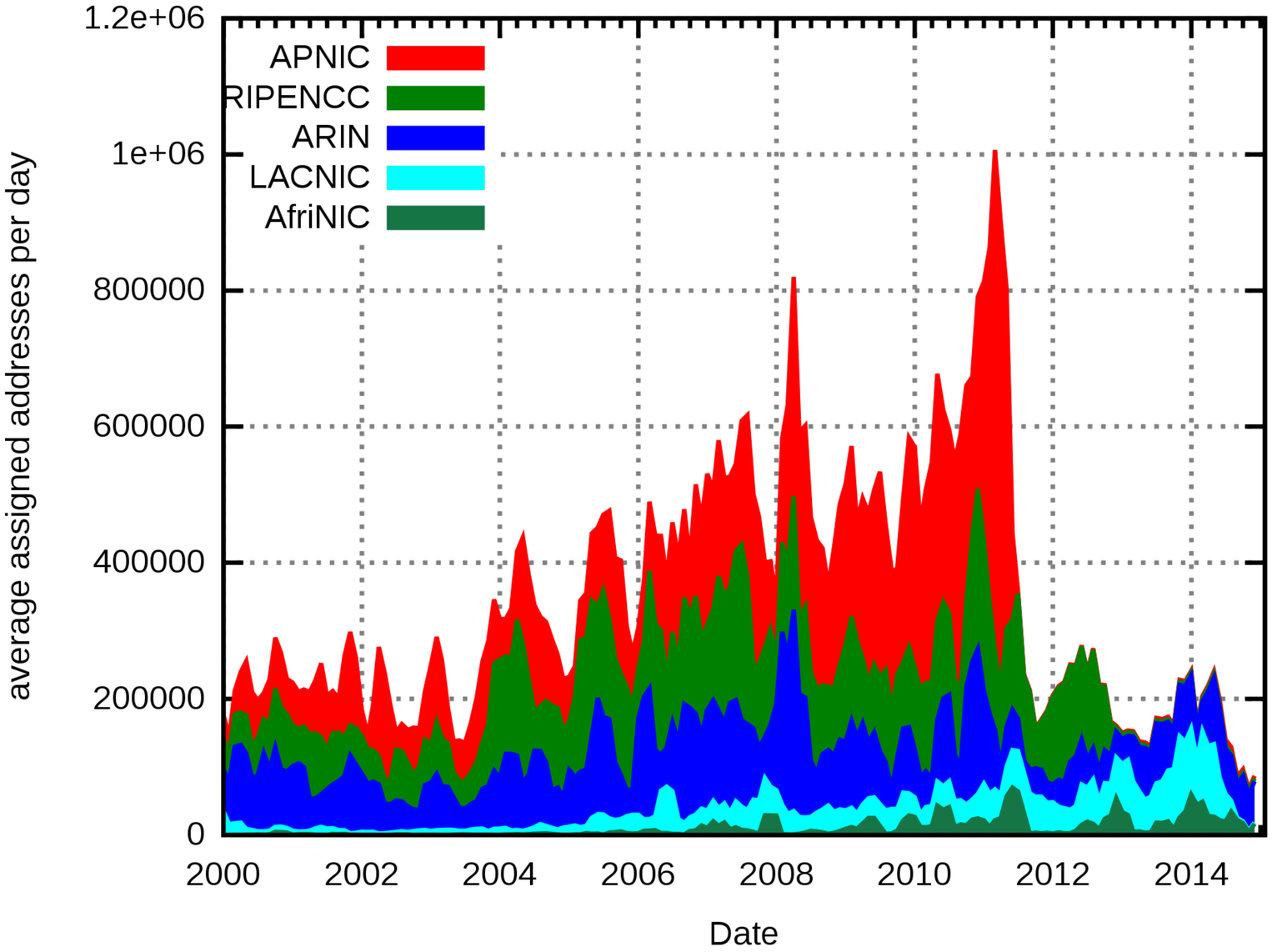


Regional Internet Registries



RIR IPv4 Allocation Rates

RIRs were allocating IPs at tremendous rate — especially in Asia

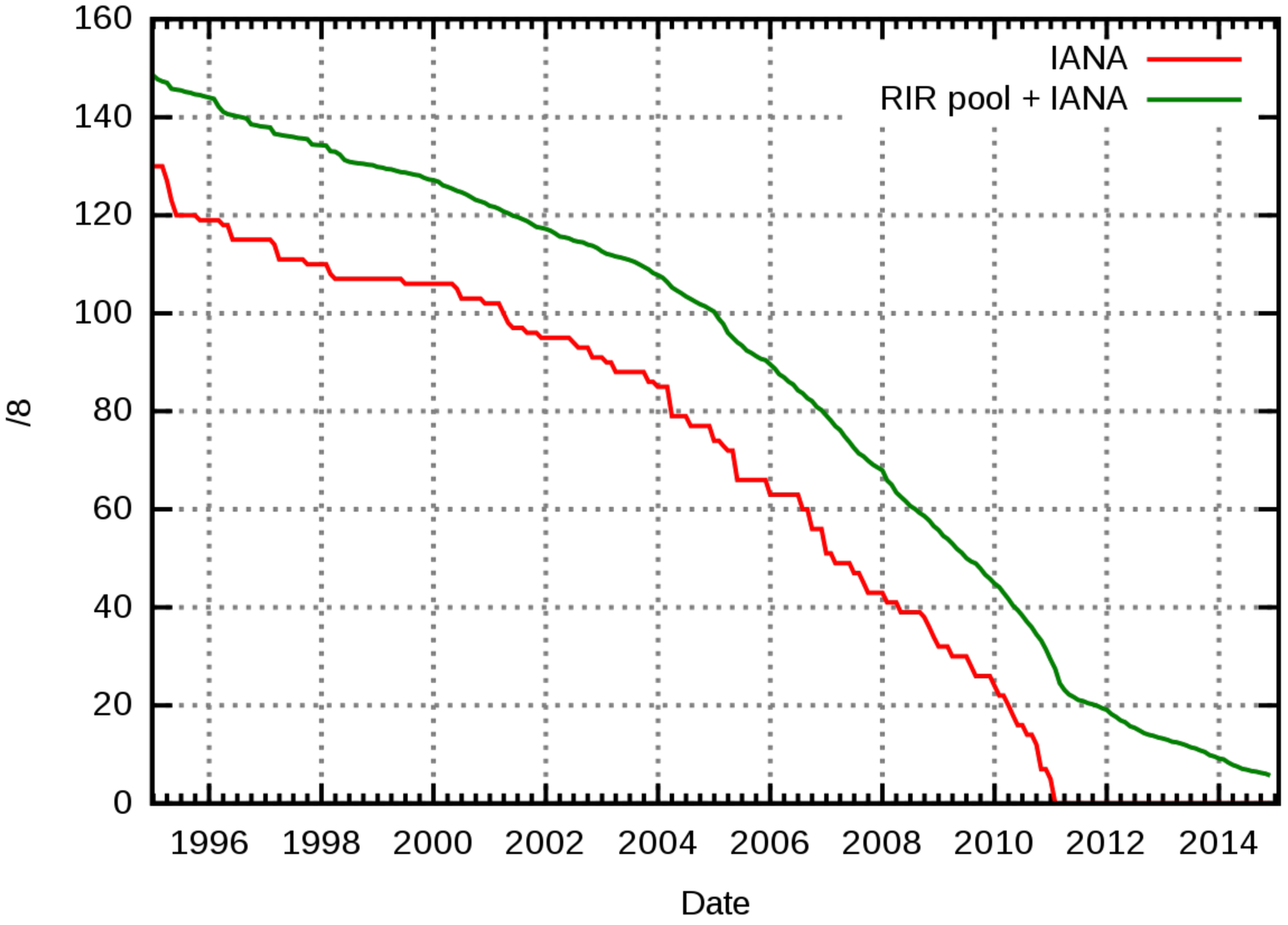


IPv4 Allocations

IANA ran out out unallocated IP blocks in January 2011

RIRs ran out soon after:

- APNIC — April 2011
- LACNIC — June 2014
- ARIN — Sept 2015
- AFRINIC — April 2017
- RIPE — Nov 2019



Reclaiming Unused IPv4 Address Space

Some organizations have returned unused address space

- Stanford returned 36.0.0.0/8 and kept only 5 x /16s by 2000

- MIT sold half of 18.0.0.0/8 to Amazon in 2017.
  Had only ever used 2 of the 16 million IPs they owned

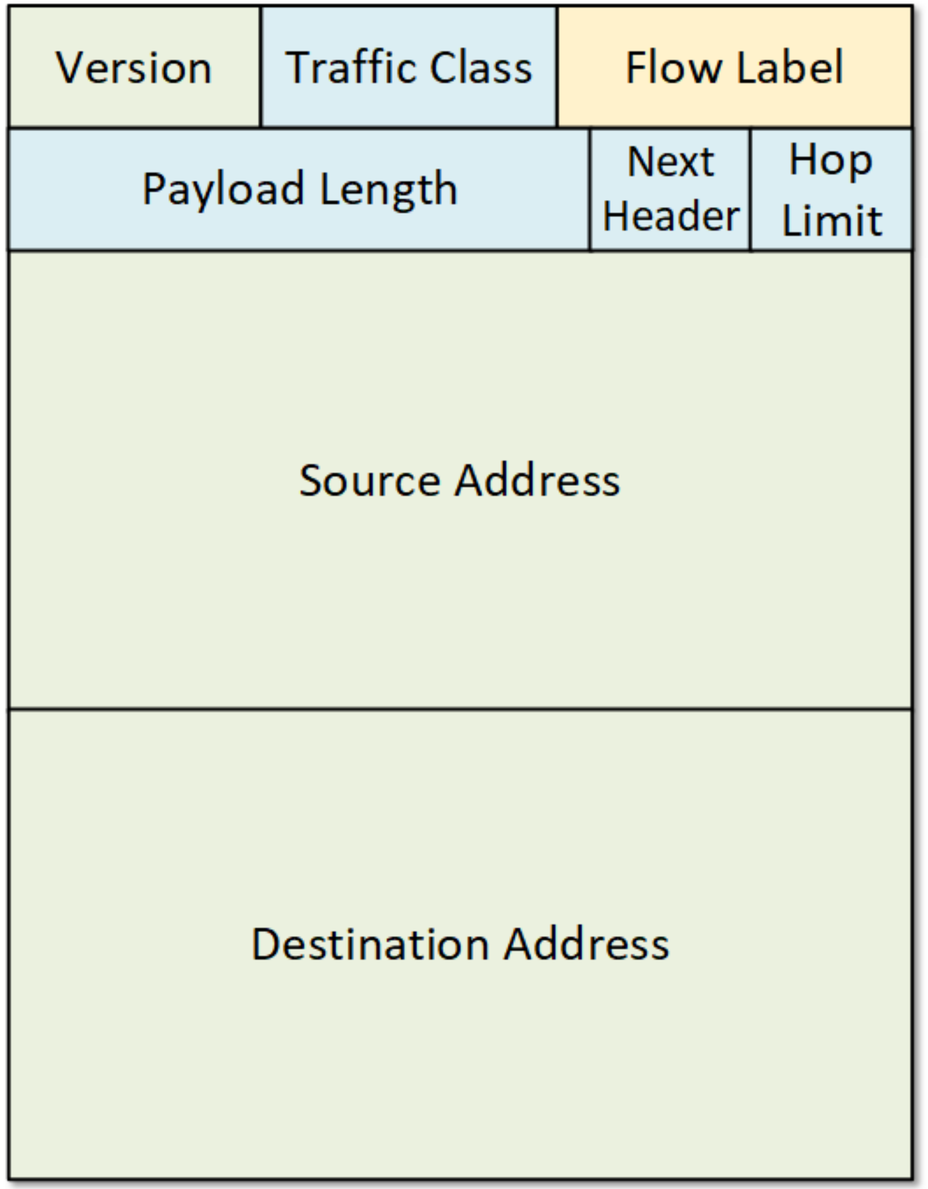
? How much of IPv4 is advertised? You can check your routing table.

IPv6 Addresses

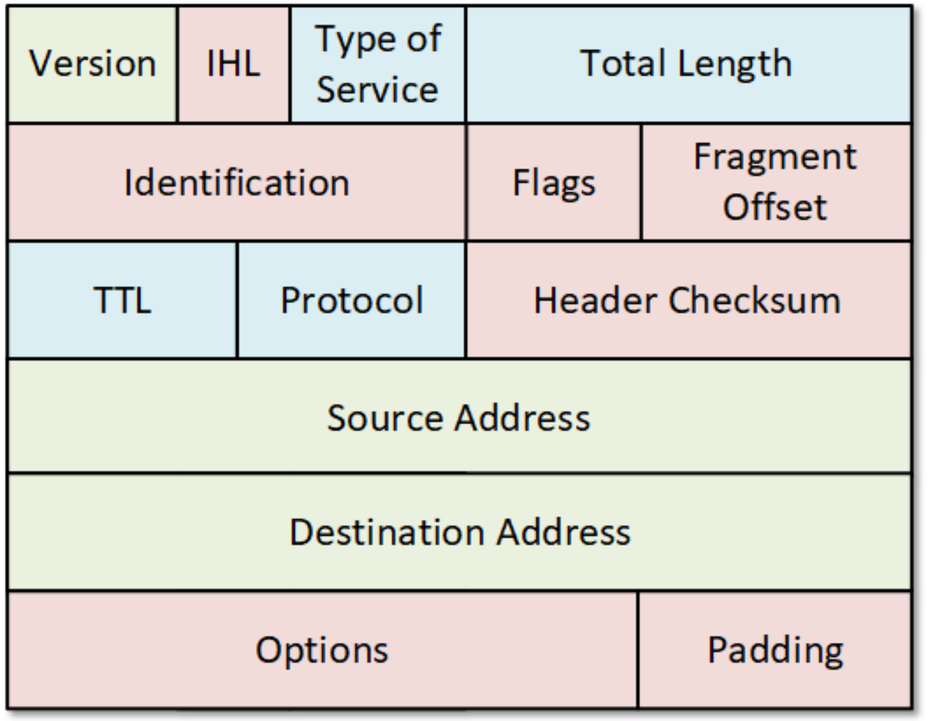
IPv4 → IPv6

	IPv4	IPv6
Address Size	32-bit	128-bit
Header Size	20 bytes	40 bytes
Header Fields	12 fields	8 fields
Checksum	IP + TCP, Sometimes UDP	TCP + UDP
Flow Labeling	—	Flow ID
Fragmentation	Host + Router	Host Only
Host Addressing	DHCP, ARP, IRDP	SLAC, ICMP, DHCPv6
Broadcast	Yes!	No!

IPv6 Header



IPv4 Header



Legend

- Fields **kept** in IPv6
- Fields **kept** in IPv6, but name and position changed
- Fields **not kept** in IPv6
- Fields that are **new** in IPv6

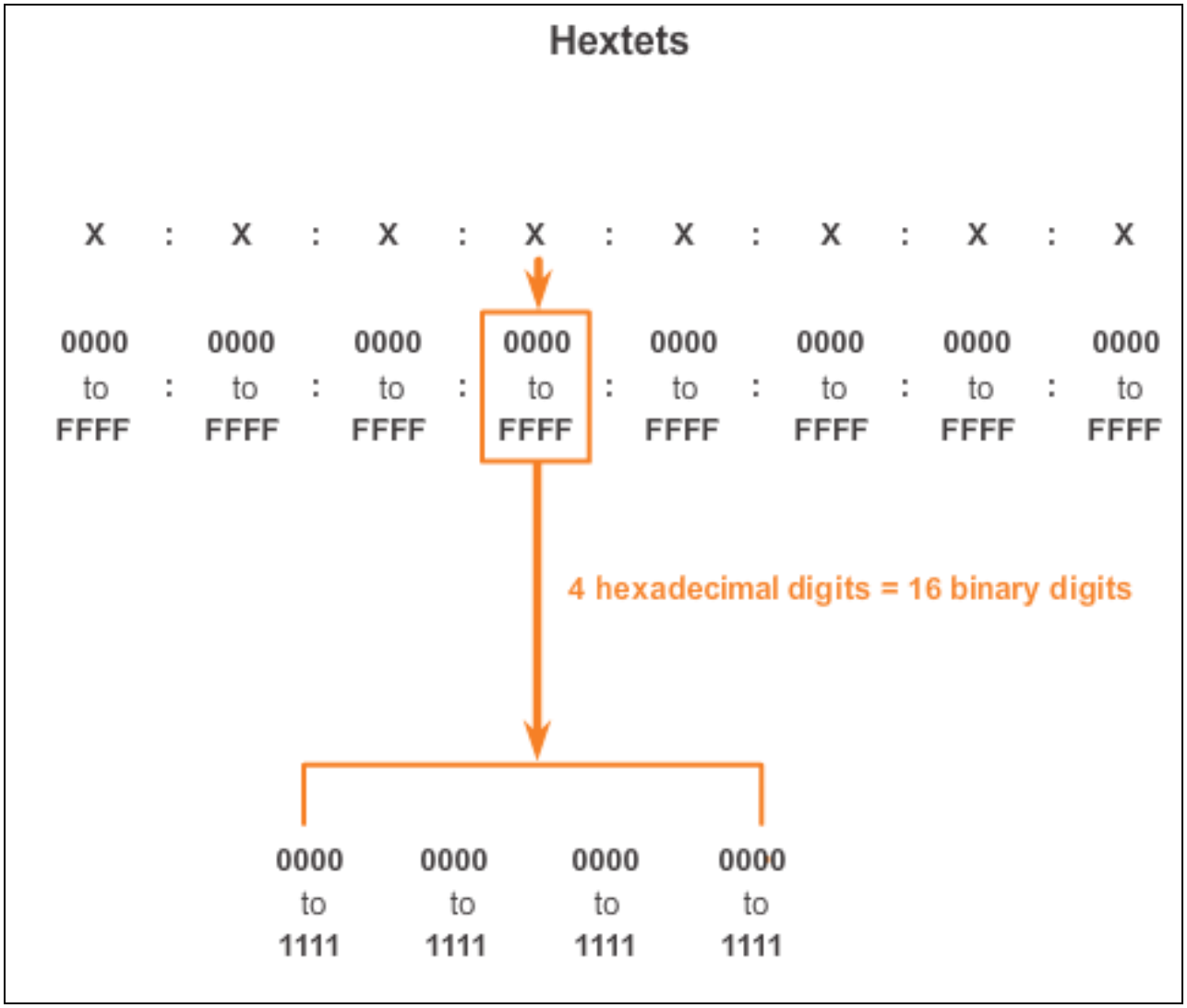
IPv6 Address Representation

- 128 bits in length and written as a string of hexadecimal values
- In IPv6, 4 bits represents a single hexadecimal digit, 32 hexadecimal value = IPv6 address

```
2001:0DB8:0000:1111:0000:0000:0000:0200
FE80:0000:0000:0000:0123:4567:89AB:CDEF
```

- Hextet used to refer to a segment of 16 bits or four hexadecimals
- Can be written in either lowercase or uppercase

IPv6 Address Representation (cont.)



Rule 2 - Omitting All 0 Segments

- A double colon (::) can replace any single, contiguous string of one or more 16-bit segments (hextets) consisting of all 0's.
- Double colon (::) can only be used once within an address otherwise the address will be ambiguous.
- Known as the *compressed format.*
- Incorrect address - 2001:0DB8::ABCD::1234.

Rule 1- Omitting Leading 0s

- The first rule to help reduce the notation of IPv6 addresses is any leading 0s (zeros) in any 16-bit section or hextet can be omitted.
- 01AB can be represented as 1AB.
- 09F0 can be represented as 9F0.
- 0A00 can be represented as A00.
- 00AB can be represented as AB.

Preferred	2001:0DB8:000A:1000:0000:0000:0000:0100
No leading 0s	2001: DB8: A:1000: 0: 0: 0: 100
Compressed	2001:DB8:A:1000:0:0:0:100

Rule 2 - Omitting All 0 Segments (cont.)

Example #1

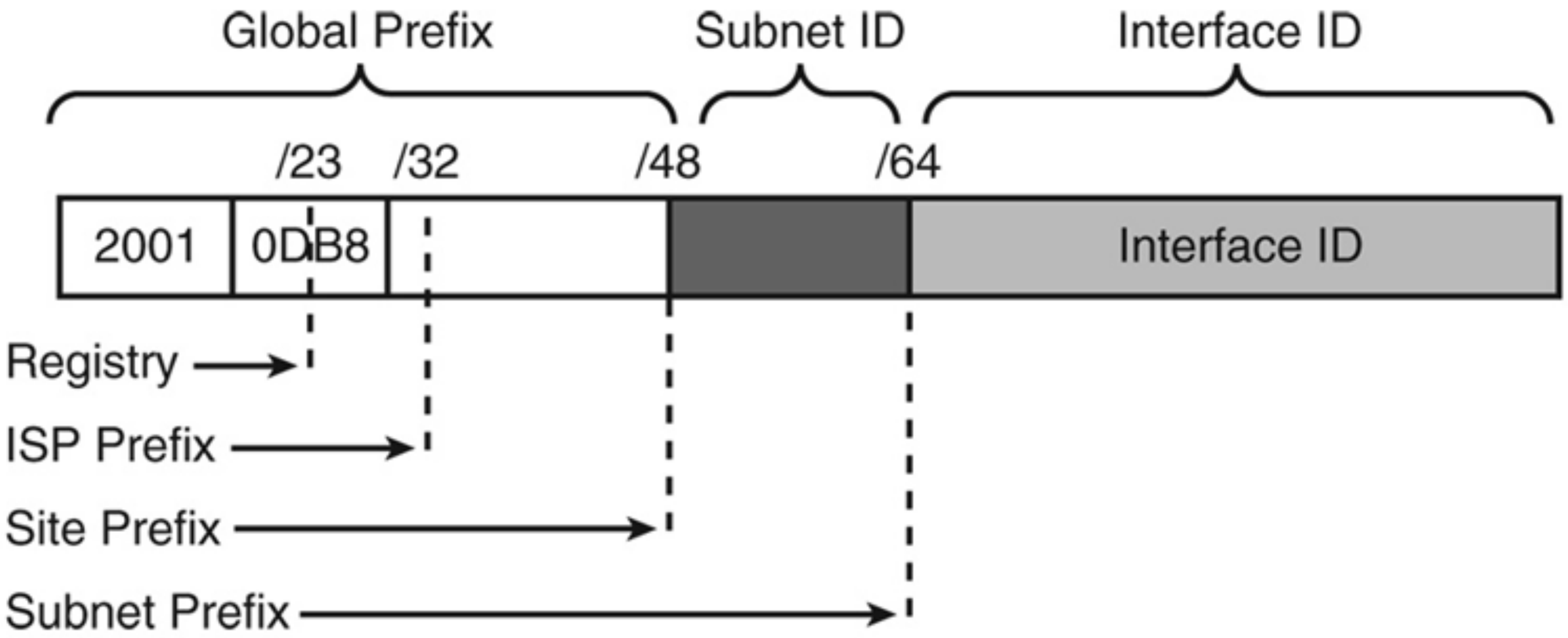
Preferred	2001:0DB8:0000:0000:ABCD:0000:0000:0100
Omit leading 0s	2001: DB8: 0: 0:ABCD: 0: 0: 100
Compressed	2001:DB8::ABCD:0:0:100
OR	
Compressed	2001:DB8:0:0:ABCD::100

Only one : : may be used.

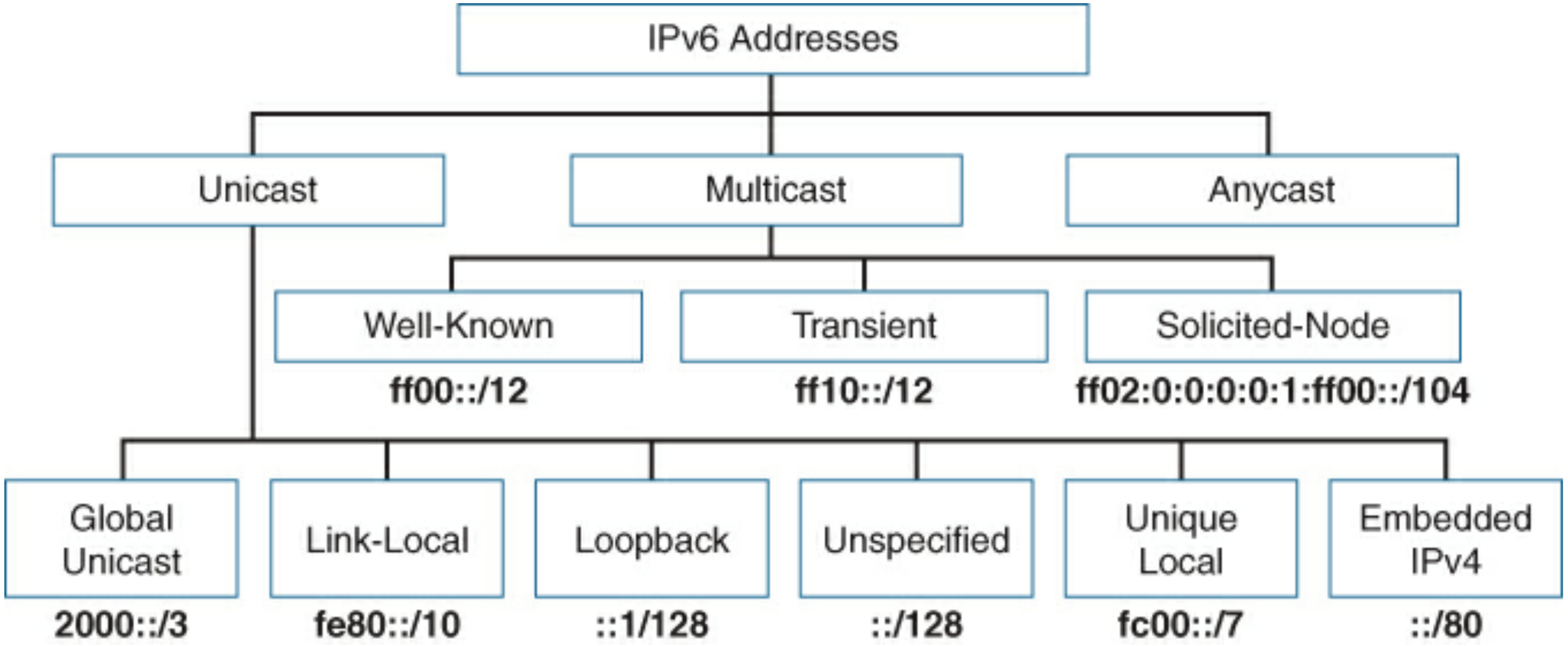
Example #2

Preferred	FE80:0000:0000:0000:0123:4567:89AB:CDEF
Omit leading 0s	FE80: 0: 0: 0: 123:4567:89AB:CDEF
Compressed	FE80::123:4567:89AB:CDEF

128 Bit Addresses



128 Bit Addresses

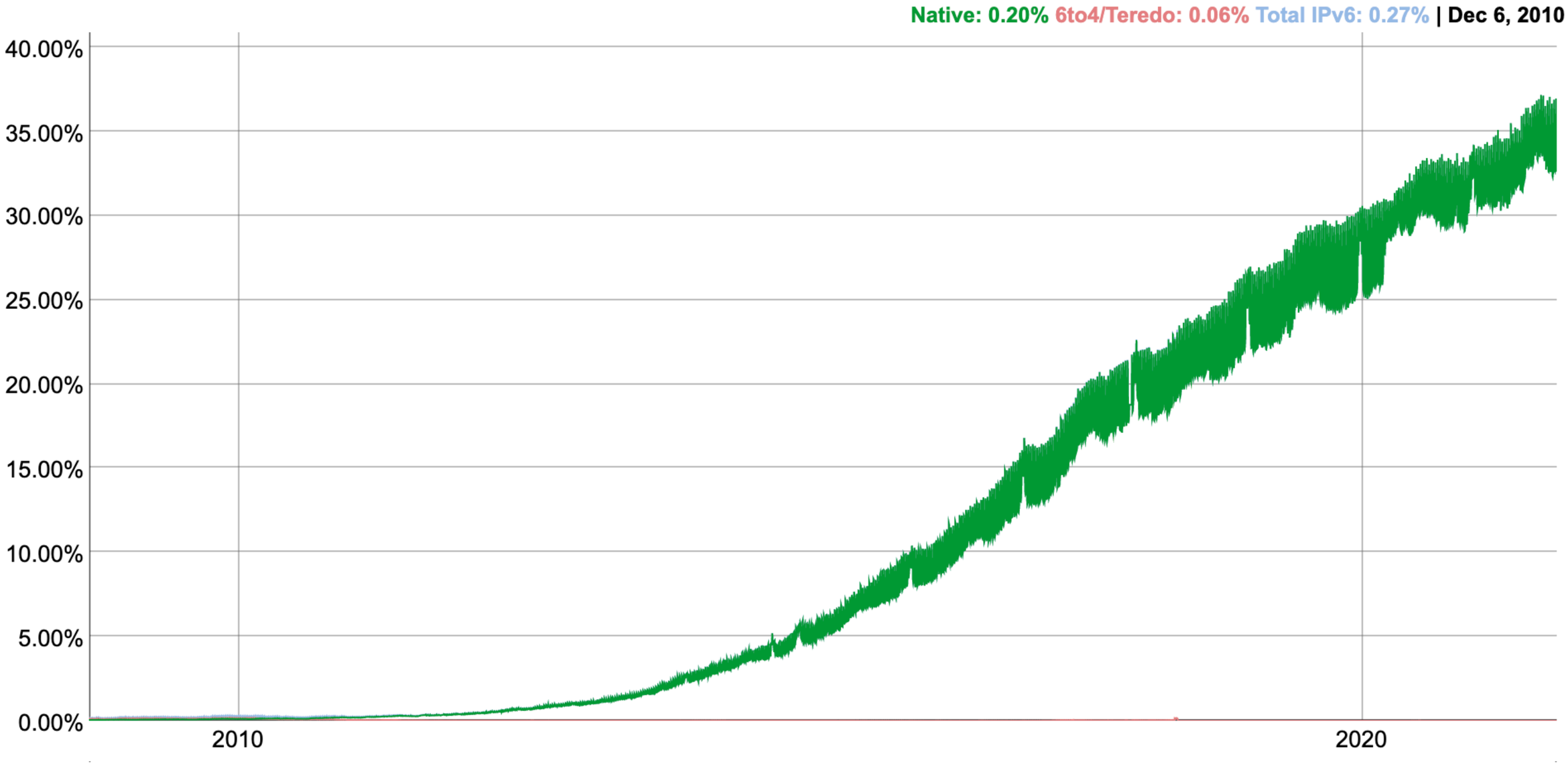


Interfaces have Multiple IPs

```
48: vlan50@bridge: <BROADCAST,MULTICAST,UP,LOWER_UP
    link/ether a8:1e:84:ce:64:5f brd ff:ff:ff:ff:ff
    inet 171.67.70.1/23 scope global vlan50
       valid_lft forever preferred_lft forever
    inet6 2607:f6d0:ec50:100::1/56 scope global
       valid_lft forever preferred_lft forever
    inet6 fe80::aa1e:84ff:fece:645f/64 scope link
       valid_lft forever preferred_lft forever
```

IPv6 Usage

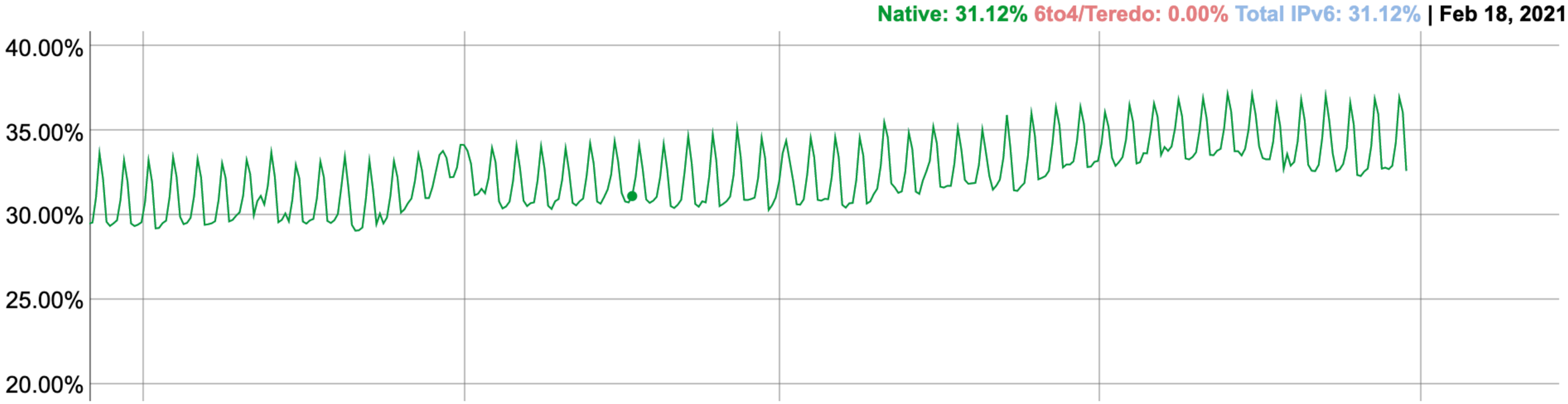
Google Observed Users



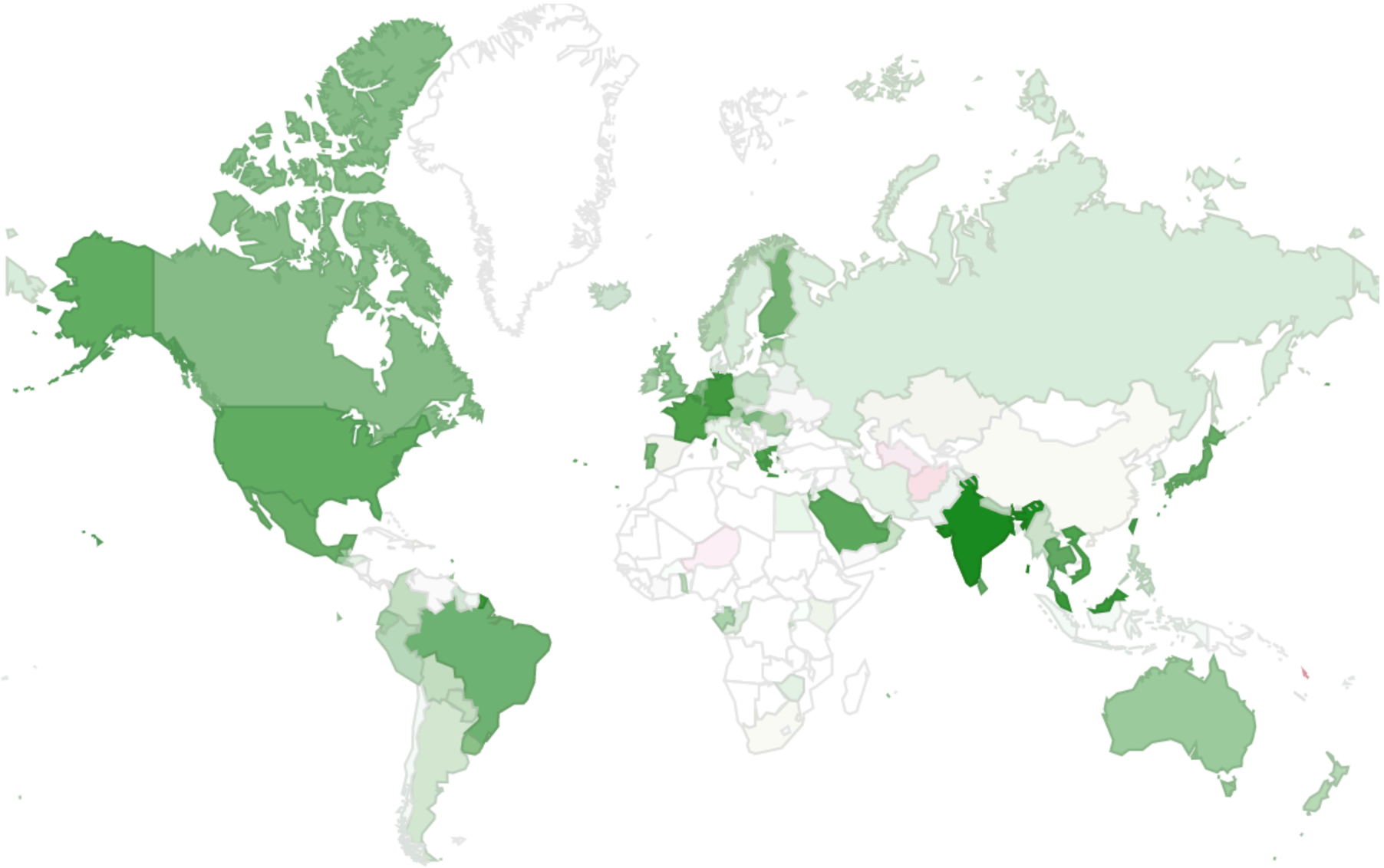
Higher Weekend Usage

IPv6 Adoption

We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.



Geographic Biases



Alexa Top 1K Support

Alexa Rank	Website	AAAA Record	AAAA Record for www. Site	Site returns IPv6 source address	www. Site returns IPv6 source address
1	Google.com	✓	✓	✓	✓
2	YouTube.com	✓	✓	✓	✓
3	Facebook.com	✓	✓	✓	✓
4	Baidu.com	x	x	–	–
5	Wikipedia.org	✓	✓	✓*	✓*
6	Qq.com	x	✓	–	✓*
7	Tmall.com	x	x	–	–
8	Taobao.com	x	x	–	–
9	Yahoo.com	✓	✓	✓	✓
10	Amazon.com	x	x	–	–
11	Twitter.com	x	x	–	–
12	Sohu.com	x	x	–	–
13	Instagram.com	✓	✓	✓	✓
14	Reddit.com	x	x	–	–
15	Jd.com	x	x	–	–

Lots of Traffic != Lots of Deployment