HiLCoE
School of Computer Science & Technology

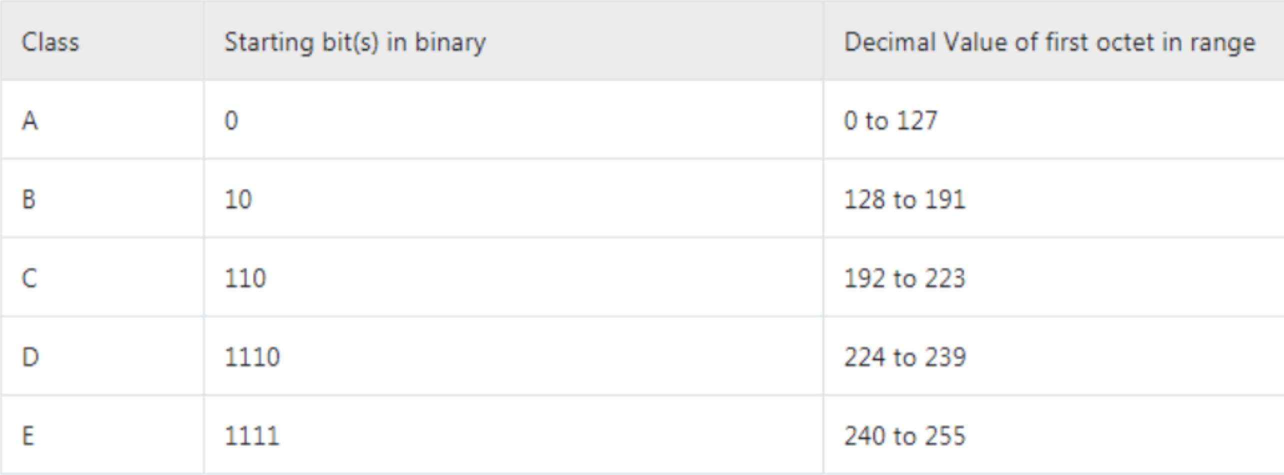
Autumn 2025

Computer Networks
SE321

Subnetting (fixed-size and VLSM) + IPv6 Adoption 2025

IP addresses

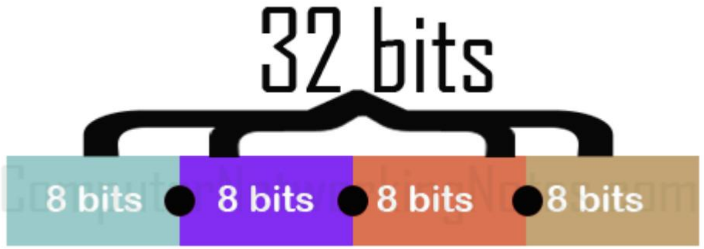
- IP address Classes



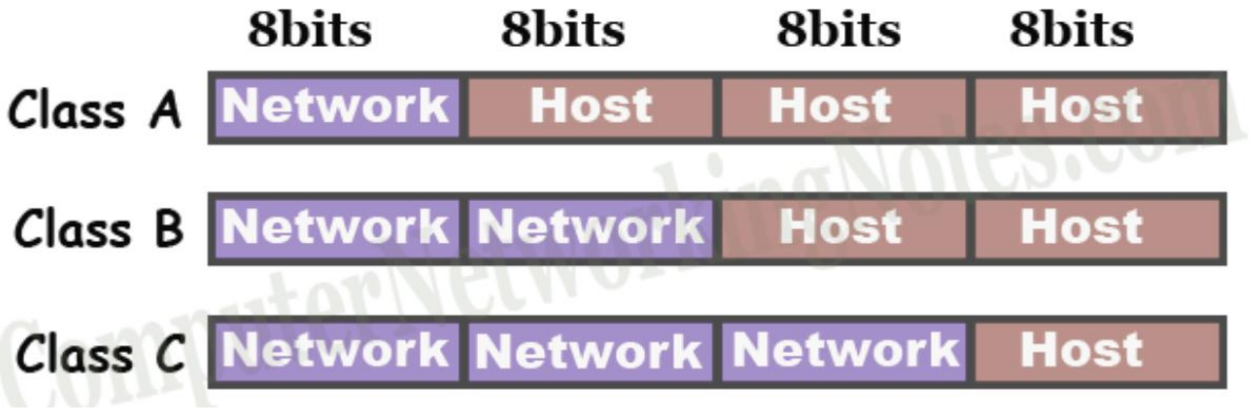
Class	Starting bit(s) in binary	Decimal Value of first octet in range
A	0	0 to 127
B	10	128 to 191
C	110	192 to 223
D	1110	224 to 239
E	1111	240 to 255

IP addresses

- IP address consists of 32 bits



- Network and Host portion of Class A, B, and C



	8bits	8bits	8bits	8bits
Class A	Network	Host	Host	Host
Class B	Network	Network	Host	Host
Class C	Network	Network	Network	Host

ComputerNetworkingNotes.com

IP addresses

- Nearly 4.3 billion IPv4 addresses, BUT not all are available for end devices.
- From these addresses, the following addresses are reserved and cannot be assigned to end devices.
  - 0.0.0.0: this address represents all networks.
  - 127.0.0.0 to 127.255.255.255: this IP range is reserved for loopback testing.
  - 224.0.0.0 to 239.255.255.255 (Class D): this IP class is reserved for multicast.
  - 240.0.0.0 to 255.255.255.254 (Class E): this IP class is reserved for future use.
  - 255.255.255.255: this address represents all hosts.
- Besides these reserved address, we cannot use the first and the last IP address of each network.
  - First IP address is reserved for the network address
  - Last IP address is reserved for the broadcast address
- Thus, we can only use the addresses available between the network address and the broadcast address for end devices.

Subnetting

- Subnetting is the process of dividing a large network into smaller networks known as subnetworks (subnets)
- A subnet is
  - like a smaller group within a large network.
  - a way to split a large network into smaller networks so that devices present in one network can transmit data more easily.
  - For instance, in a University campus, different faculties (departments) can each have their own subnet, keeping their data traffic separate from others.
- Subnets provide each group of devices with their own space to communicate, which ultimately helps the network to work easily.
  - This also improves the security of the network, makes the network faster and easier to manage, as each subnet can be monitored and controlled separately.

Subnetting

Fixed Size Subnetting versus Variable Length Subnet Masking (VLSM)

- Fixed Size Subnetting divides a network into equal-sized subnets, regardless of the number of hosts required per subnet.
  - All subnets have the same number of IP addresses.
  - It is simpler but can waste IPs if host needs vary.
  - Suitable when each subnet requires roughly the same size.
  - For example, let's take the Class C network address of 192.168.1.0/24, with a default subnet mask of 255.255.255.0, and total IPs: 256 (254 valid IPs)
  - Let's divide this network into 4 equal subnets.
  - Step 1: Determine how many bits to borrow
    - We need 4 subnets → $2^2 = 4$ → so we borrow 2 bits from the host portion.
    - New subnet mask: /24 + 2 = /26
      - Subnet mask: 255.255.255.192
  - Step 2: Calculate hosts per subnet
    - 2^(32-26) = 64 IPs per subnet
    - Valid (Usable) hosts: 64 - 2 = 62 hosts per subnet

Subnetting

- Fixed Size Subnetting …
  - As seen from the table, all subnets have the same size (fixed length), i.e., 62 hosts per subnet.
  - It is easier to plan BUT not efficient if departments need different (variable) sizes.

Subnet number	Network Address	First Valid Host Address	Last Valid Host address	Broadcast Address
Subnet 0	192.168.1.0 /26	192.168.1.1	192.168.1.62	192.168.1.63
Subnet 1	192.168.1.64/26	192.168.1.65	192.168.1.126	192.168.1.127
Subnet 2	192.168.1.128 /26	192.168.1.129	192.168.1.190	192.168.1.191
Subnet 3	192.168.1.192 /26	192.168.1.193	192.168.1.254	192.168.1.255

Subnetting

Fixed Size Subnetting versus Variable Length Subnet Masking (VLSM)

- Variable Length Subnet Masking (VLSM) is a subnetting technique that allows you to divide an IP network into subnets of different sizes, depending on the specific number of required hosts per subnet.
  - It is subnetting based on actual need, not uniform size.
  - It is suitable to create subnets of varying sizes for different departments or networks.
  - It improves IP address efficiency and reduces wasted IPs compared to fixed-size subnetting.
  - It is more flexible and scalable.
  - It is an efficient IP planning technique in large networks.
  - When employing VLSM, it’s better to allocate IPs to the largest subnet first, then move to the smaller ones using leftover IP blocks.
  - Example of VLSM: see subnetting the HiLCoE Class C network, on next page .

Why Subnetting?

- Assume that HiLCoE is a university having a Class C network address of 194.170.1.0/24 with 256 IP addresses
- HiLCoE has 3 faculties with each faculty having the following number of devices (computers)
  - Artificial Intelligence (AI): 50 devices
  - Computer Science (CS): 28 devices
  - Software Engineering (SE): 12 devices
- Without subnetting
  - All 256 addresses belong to one big network (194.170.1.0/24), which may be inefficient or insecure if we have multiple faculties/ departments or different levels of access.

HiLCoE	Total IP Addresses	Subnet Mask	Network Identifier (Address)	Valid IP address Ranges	Broadcast Address
One Big Network	256	255.255.255.0	194.170.1.0	194.170.1.1 - 194.170.1.254	194.170.1.255

Subnetting

- Without subnetting, all the three faculties will share the same network, and all 256 IP addresses of HiLCoE will be available to everyone in the faculties, which leads to
  - Wastage of IP addresses: Only 90 devices (computers) are available (28 + 12 + 50), but all 256 addresses are allocated to the network, wasting 166 IP addresses.
  - Performance Issues: Since all faculties are on the same network, any data sent between computers floods the entire network, slowing communication for everyone.
    - For example, heavy data transfer in AI faculty can impact the CS and SE faculties.
  - Security Risks: Without subnets, anyone in AI faculty can access CS or SE devices, exposing sensitive data like student grading systems.
- With subnetting: we can use Variable Length Subnet Masking (VLSM) subnetting technique and split the HiLCoE network into three subnetworks, allocating just enough IP addresses for each faculty while minimizing wastage of IP addresses:
  - AI: 194.170.1.0/26 → for 50 devices, we needs at least 2^6 = 64 host IPs (14 IPs left)
  - CS:194.170.1.64/27 → for 28 devices, we needs at least 2^5 = 32 host IPs (4 IPs left)
  - SE: 194.170.1.96/28 → for 12 devices, we needs at least 2^4 = 16 host IPs (4 IPs left)

Subnetting

- In general, the subnet identifiers, subnet masks, valid host IP address ranges and broadcast addresses of the three HiLCoE faculties (subnetworks) is shown in the following table.

HiLCoE Faculties	Required Devices (Hosts)	Subnet Mask	Subnet Identifier (Address)	Valid IP address Ranges	Broadcast Address
AI	50	/26	194.170.1.0	194.170.1.1 - 194.170.1.62	194.170.1.63
CS	28	/27	194.170.1.64	194.170.1.65 - 194.170.1.94	194.170.1.95
SE	12	/28	194.170.1.96	194.170.1.97 - 194.170.1.110	194.170.1.111

Subnetting

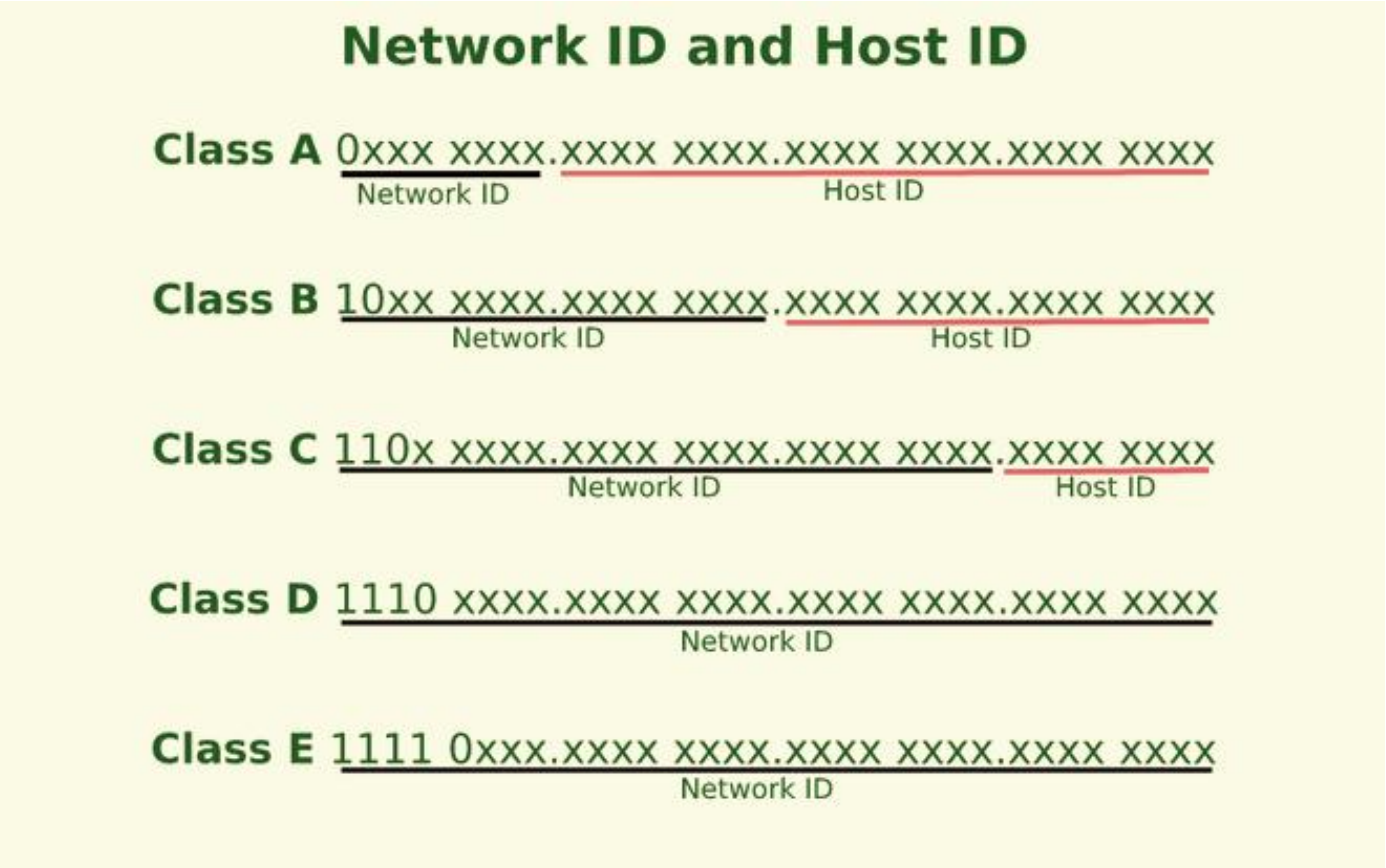
- By implementing the subnetting, we can get the following benefits:
  - Better efficiency - Save many IP addresses:
    - Out of the 256 IP addresses of HiLCoE, the three faculties used 112 addresses (50+28+12+14+4+4), by leaving the remaining 144 addresses unused (to be used for future expansion of HiLCoE faculties).
    - So, when the need arises, the unused address space will start from 194.170.1.112.
  - Better performance - Keep networks faster:
    - Data communication within each faculty stays in its subnetwork. For instance, CS faculty traffic stays in CS, reducing network congestion for SE and AI faculties.
  - Improved security - Protect sensitive data:
    - Each faculty is independent, and if someone in SE faculty tries to access CS computer systems, the subnetwork restrictions block him.

Basic concepts in Subnetting: IP addressing

- An IP address is made up of different parts, each serving a specific purpose in identifying a device on a network.
- An IPv4 address consists of four parts called “octets”, separated by dots (for example, 194.170.1.1).
- IPv4 has two main sections:
  - Network Portion: Identifies the network the device belongs to.
  - Host Portion: Uniquely identifies a device within the network.
- IPv4 addresses are divided into classes based on the length of the network and host portions:
  - Class A: 8-bit network ID, 24-bit host ID.
  - Class B: 16-bit network ID, 16-bit host ID.
  - Class C: 24-bit network ID, 8-bit host ID

Basic concepts in Subnetting

- IPv4 Address classes



Network ID and Host ID

Class A 0xxx xxxx.xxxx xxxx.xxxx xxxx.xxxx xxxx

Class B 10xx xxxx.xxxx xxxx.xxxx xxxx.xxxx xxxx

Class C 110x xxxx.xxxx xxxx.xxxx xxxx.xxxx xxxx

Class D 1110 xxxx.xxxx xxxx.xxxx xxxx.xxxx xxxx

Class E 1111 0xxx.xxxx xxxx.xxxx xxxx.xxxx xxxx

What is subnet mask?

- A subnet mask is a 32-bit number used in IP addressing to separate the network portion of an IP address from the host portion.
  - helps computers and devices determine which part of an IP address refers to the network they are present, and which part refers to their specific location or address within that network.
- CIDR Notation: A Simplified Approach to Subnetting
  - Instead of using a long subnet mask (e.g., 255.255.255.0), CIDR uses a simple format like /24.
  - The number after the slash (/n) represents the number of bits used for the network portion of the IP address.

Working logic of subnetting

- First, subnetting divides the network into smaller subnets (subnetworks).
- Routers, switches and hubs are used for the communication between the subnets.
- Each subnet allows its linked devices (computers) to communicate with each other.
- Subnetting of a network should be done without affecting the network portion bits.
- For instance, in class C the first 3 octets belongs to the network portion bits, and hence it remains as it is.
- To divide a network into two subnets, you need to choose one bit from the host ID part for each subnet, i.e, (0, 1).

Working logic of subnetting

- For Subnet-1: The first bit which is chosen from the host ID part is zero and the subnet address range will be from (194.1.2.00000000 till you get all 1’s in the host ID part, i.e, 194.1.2.01111111) except for the first bit which is chosen zero for subnet id part.
  - The range of subnet-1: 194.1.2.0 to 194.1.2.127
  - Subnet id of subnet-1: 194.1.2.0
  - Direct Broadcast id of subnet-1: 194.1.2.127
  - Total number of possible hosts: 126 (out of 128 (2^7) hosts, 2 ids are used for Subnet id and Direct Broadcast id)
  - Subnet mask of Subnet-1: 255.255.255.128

Working logic of subnetting

- For Subnet-2: The first bit which is chosen from the host ID part is one and the subnet address range will be from (194.1.2.10000000 till you get all 1's in the host ID part, i.e, 194.1.2.11111111).
  - The range of subnet-1: 194.1.2.128 to 194.1.2.255
  - Subnet id of subnet-1: 194.1.2.128
  - Direct Broadcast id of subnet-1: 194.1.2.255
  - Total number of possible hosts: 126 (out of 128 (2^7) hosts, 2 ids are used for Subnet id and Direct Broadcast id)
  - Subnet mask of Subnet-1: 255.255.255.128
- The best way to find out the subnet mask of a subnet is to set the fixed bit of host-id to 1 and the rest to 0.
- Eventually, after implementing the subnetting , the total number of usable hosts for the wo subnets becomes 252 out of 256.

Working logic of subnetting

- In general, the network can be divided into different parts (subnets)

For instance,

- To divide a network into two (2^1) parts (subnets), you need to choose one bit from the host ID part for each subnet, i.e, (0, 1).
- To divide a network into four (2^2) parts (subnets), you need to choose two bits from the host ID part for each subnet, i.e, (00, 01, 10, 11).
- To divide a network into eight (2^3) parts (subnets), you need to choose three bits from the host ID part for each subnet, i.e, (000 , 001, 010, 011, 100, 101, 110, 111) and so on.
- If the total number of subnets in a network increases, the total number of usable hosts decreases.

More examples on subnetting

- 1. Assume that an X-University has assigned a class C network address of 198.35.2.0. It uses a subnet mask of 255.255.255.192 to divide this network into subnetworks (subnets). Which of the following is/are valid host IP addresses?
  - (A) 198.35.2.63
  - (B) 198.35.2.191
  - (C) 198.35.2.255
  - (D) 198.35.2.127
  - (E) 198.35.2.130
  - (F) both (B) and (D)

More examples on subnetting

- A class C network address of 198.35.2.0. with subnet mask of 255.255.255.192
  - (A) 198.35.2.63 (B) 198.35.2.191 (C) 198.35.2.255
  - (D) 198.35.2.127 (E) 198.35.2.130 (F) both (B) and (D)

Solution:

- When converting the last octet of:
  - the subnet mask into the binary form, it becomes: 255.255.255.11000000
  - Option A into the binary form, it becomes:198.35.2.00111111
  - Option B into the binary form, it becomes:198.35.2.10111111
  - Option C into the binary form, it becomes:198.35.2.11111111
  - Option D into the binary form, it becomes:198.35.2.01111111
  - Option E into the binary form, it becomes:198.35.2.10000010
- We can see that Options A, B and C are not valid host IP addresses because they are broadcast addresses of subnetworks.
- Hence, Option E is a valid host IP address because the last 6 bits of the host address are not 1.

More examples on subnetting

- 2. Assume that a Y-University has assigned a class C network address of 198.32.64.0. It uses a subnet mask of 255.255.255.248 to divide this network into subnetworks (subnets). Which of the following is not a valid Broadcast address for any subnetworks?
  - (A) 198.32.64.135
  - (B) 198.32.64.207
  - (C) 198.32.64.231
  - (D) 198.32.64.241

More examples on subnetting

- 2. A class C network address of 198.32.64.0 , a subnet mask of 255.255.255.248. Which of the following is not a valid Broadcast address for any subnetworks?
  - (A) 198.32.64.135 (B) 198.32.64.207
  - (C) 198.32.64.231 (D) 198.32.64.241

Solution:

- When converting the last octet of:
  - the subnet mask into the binary form, it becomes: 255.255.255.11111000
  - Option A into the binary form, it becomes: 198.32.64.10000111
  - Option B into the binary form, it becomes: 198.32.64.11001111
  - Option C into the binary form, it becomes: 198.32.64.11100111
  - Option D into the binary form, it becomes: 198.32.64.11110001
- We can see that Options A, B and C are valid Broadcast addresses of the subnetworks because all the host bits are 1.
- Option D is not valid broadcast address as the last 3 bits of host address are not 1

More examples on subnetting

- 3. Assume that a Y-University has assigned a class C network address of 198.32.64.0. It uses a subnet mask of 255.255.255.240 to divide this network into subnetworks (subnets). Which of the following is not a valid Broadcast address for any subnetworks?
  - ❑ (A) 198.32.64.225
  - ❑ (B) 198.32.64.207
  - ❑ (C) 198.32.64.239
  - ❑ (D) 198.32.64.143

More examples on subnetting

- 3. A class C network address of 198.32.64.0 , a subnet mask of 255.255.255.240 Which of the following is not a valid Broadcast address for any subnetworks?
  - (A) 198.32.64.225	(B) 198.32.64.207
  - (C) 198.32.64.239	(D) 198.32.64.143

Solution:

- When converting the last octet of:
  - the subnet mask into the binary form, it becomes: 255.255.255.11110000
  - Option A into the binary form, it becomes: 198.32.64.11100001
  - Option B into the binary form, it becomes: 198.32.64.11001111
  - Option C into the binary form, it becomes: 198.32.64.11101111
  - Option D into the binary form, it becomes: 198.32.64.10001111
- We can see that Options B, C and D are valid Broadcast addresses of the subnetworks because all the host bits are 1.
- Option A is not valid broadcast address as the last 4 bits of host address are not 1

More examples on subnetting (Class B address)

Class B address subnetting

- A class B network address of 186.32.0.0/24 , a subnet mask of 255.255.255.0.

- The binary representation of the 1st octet is 10111100 and 2nd Octet is 00100000
- The binary representation of the 3rd octet is 11111111 and 4th Octet is 00000000.
- Using mask /24, the subnet mask becomes 255.255.255.0.
- Number of subnets (for the /24 mask) = 2^N, where N = 8 (indicates all the 8 host bits of 3rd Octet that are borrowed and converted into network bits)
  - => #of subnets = 2^8 = 256
- Number of hosts for each subnet = $(2^H) - 2$, where H = 8 (indicates all the 8 host bits from 4th octet that are set to zero)
  - => #of hosts per subnet = $2^8 - 2 = 256 – 2 = 254$.

More examples on subnetting (Class B address)

- Block size of each subnet = 256 - 255, where 255 is the decimal representation of the 3rd octet with all values set to 1.
  - => Block size = 256 - 255 = 1.
- Therefore, for /24 mask, you get 256 subnets, with each subnet having 254 hosts, and a block size of 1.
- IP address of all the 256 subnets becomes:
  - 1st subnet = 186.32.0.0/24
  - 2nd subnet = 186.32.1.0/24
  - 3rd subnet = 186.32.2.0/24
  - 4th subnet = 186.32.3.0/24
  - 5th subnet = 186.32.4.0/24
  - 255th subnet=186.32.254.0/24
  - 256th subnet=186.32.255.0/24

More examples on subnetting (Class B address)

IP address ranges of the 256 subnets: the 1st and last valid IP addresses, the broadcast IP address.

- 1st subnet
  - 1st valid IP is 186.32.0.1/24
  - last valid IP is 186.32.0.254/24
  - broadcast IP is 186.32.0.255/24
- 2nd subnet
  - 1st valid IP is 186.32.1.1/24
  - last valid IP is 186.32.1.254/24
  - broadcast IP is 186.32.1.255/24
- 3rd Subnet
  - 1st valid IP is 186.32.2.1/24
  - last valid IP is 186.32.2.254/24
  - broadcast IP is 186.32.2.255/24

More examples on subnetting (Class B address)

IP address ranges of the 256 subnets: the 1st and last valid IP addresses, the broadcast IP address.

- 4th subnet
  - 1st valid IP is 186.32.3.1/24
  - last valid IP is 186.32.3.254/24
  - broadcast IP is 186.32.3.255/24
- 255th subnet
  - 1st valid IP is 186.32.254.1/24,
  - last valid IP is 186.32.254.254/24
  - broadcast IP is 186.32.254.255/24
- 256th subnet,
  - 1st valid IP is 186.32.255.1/24
  - last valid IP is 186.32.255.254/24
  - broadcast IP is 186.32.255.255/24

More examples on subnetting (Class B address)

- 4. A class B network address of 186.32.0.0/24, a subnet mask of 255.255.255.0. Which of the following is not a valid Broadcast address for any subnetworks?
    - (A) 186.32.0.255 /24 (B) 186.32.255.255 /24
    - (C) 186.32.255.254 /24 (D) 186.32.254.255 /24

More examples on subnetting (Class B address)

- 4. A class B network address of 186.32.0.0/24, a subnet mask of 255.255.255.0. Which of the following is not a valid Broadcast address for any subnetworks?
  - (A) 186.32.0.255 /24
  - (B) 186.32.255.255 /24
  - (C) 186.32.255.254 /24
  - (D) 186.32.254.255 /24

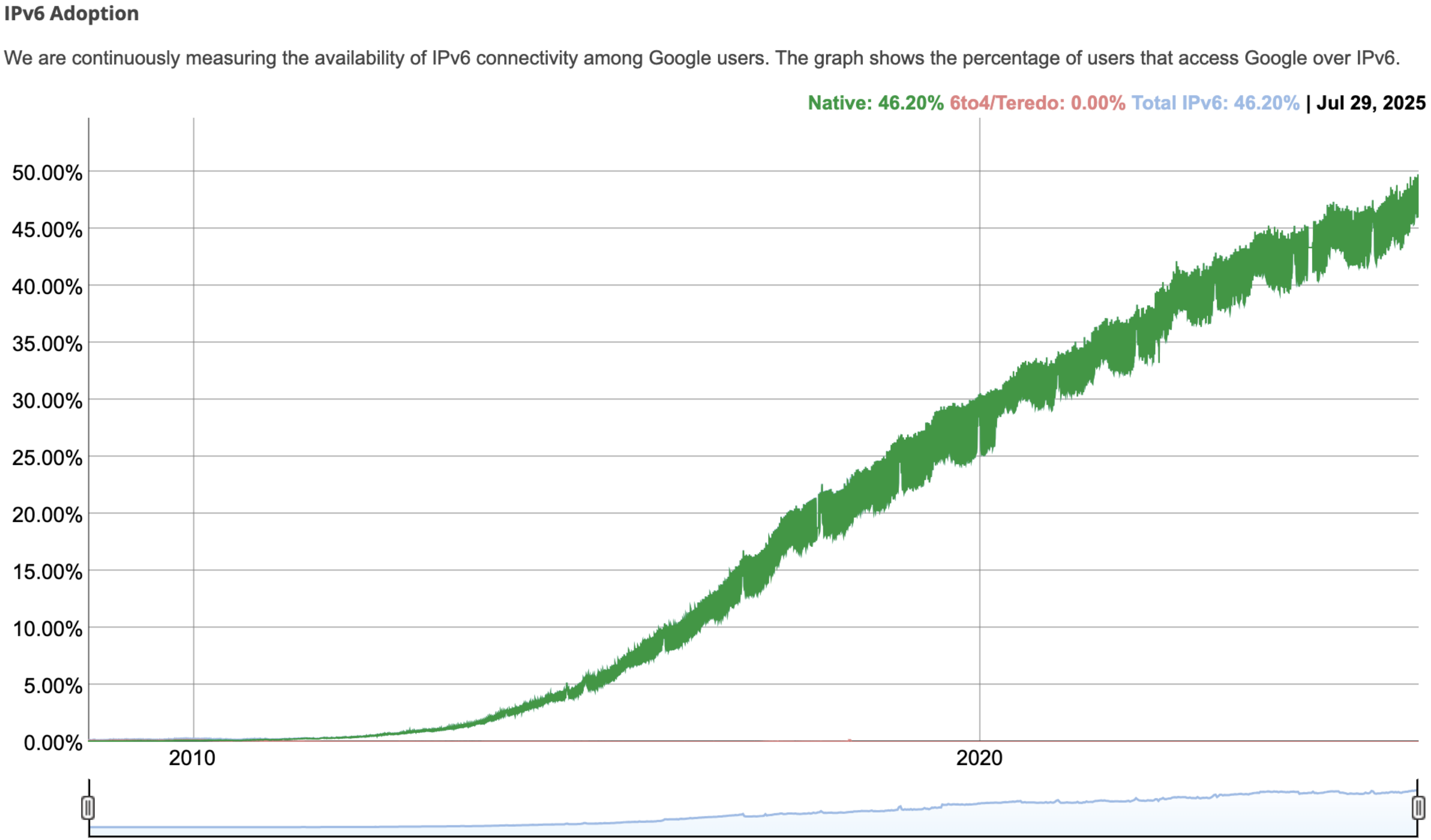
Solution:

- When converting:
  - the subnet mask into the binary form, it becomes: 11111111.11111111.11111111.00000000
  - option A into the binary form, it becomes: 10111100.00100000.00000000.11111111
  - option B into the binary form, it becomes: 10111100.00100000.11111111.11111111
  - option C into the binary form, it becomes: 10111100.00100000.11111111.11111110
  - option D into the binary form, it becomes: 10111100.00100000.11111110.11111111
- Option C is not valid broadcast address as the last 8 bits of host address are not 1.
- Hence, we can see that Options A, B and D are valid Broadcast addresses of the subnetworks because all the host bits are 1.

Subnetting

- IP addressing is a method used to identify and locate devices on a network, allowing them to communicate with each other over the Internet.
- IPv6 subnetting
  - is the process of dividing an IPv6 address space into smaller, manageable subnets.
  - allows organizations to efficiently allocate and manage their IP addresses within the larger IPv6 framework.
- A public subnet allows devices to communicate directly with the Internet, while a private subnet is isolated from the Internet and typically used for internal communication within an organization
- Disadvantage
  - Costly – subnetting requires very costly internal routers, switches, hubs and so on
  - For each subnetwork, two IP addresses are wasted

IPv6 Adoption

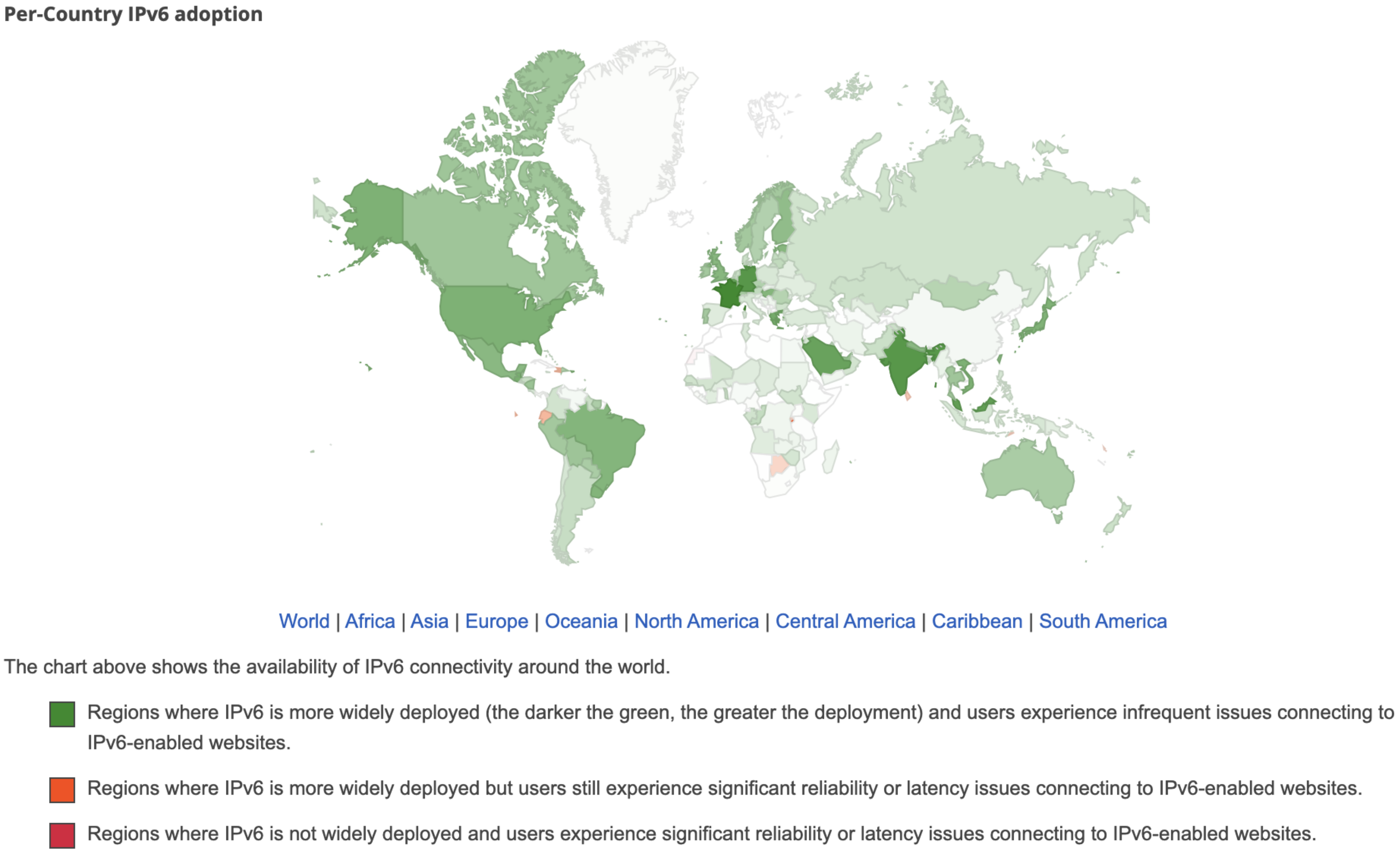


IPv6 Adoption

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

Native: 46.20% 6to4/Teredo: 0.00% Total IPv6: 46.20% | Jul 29, 2025

IPv6 Adoption by Country



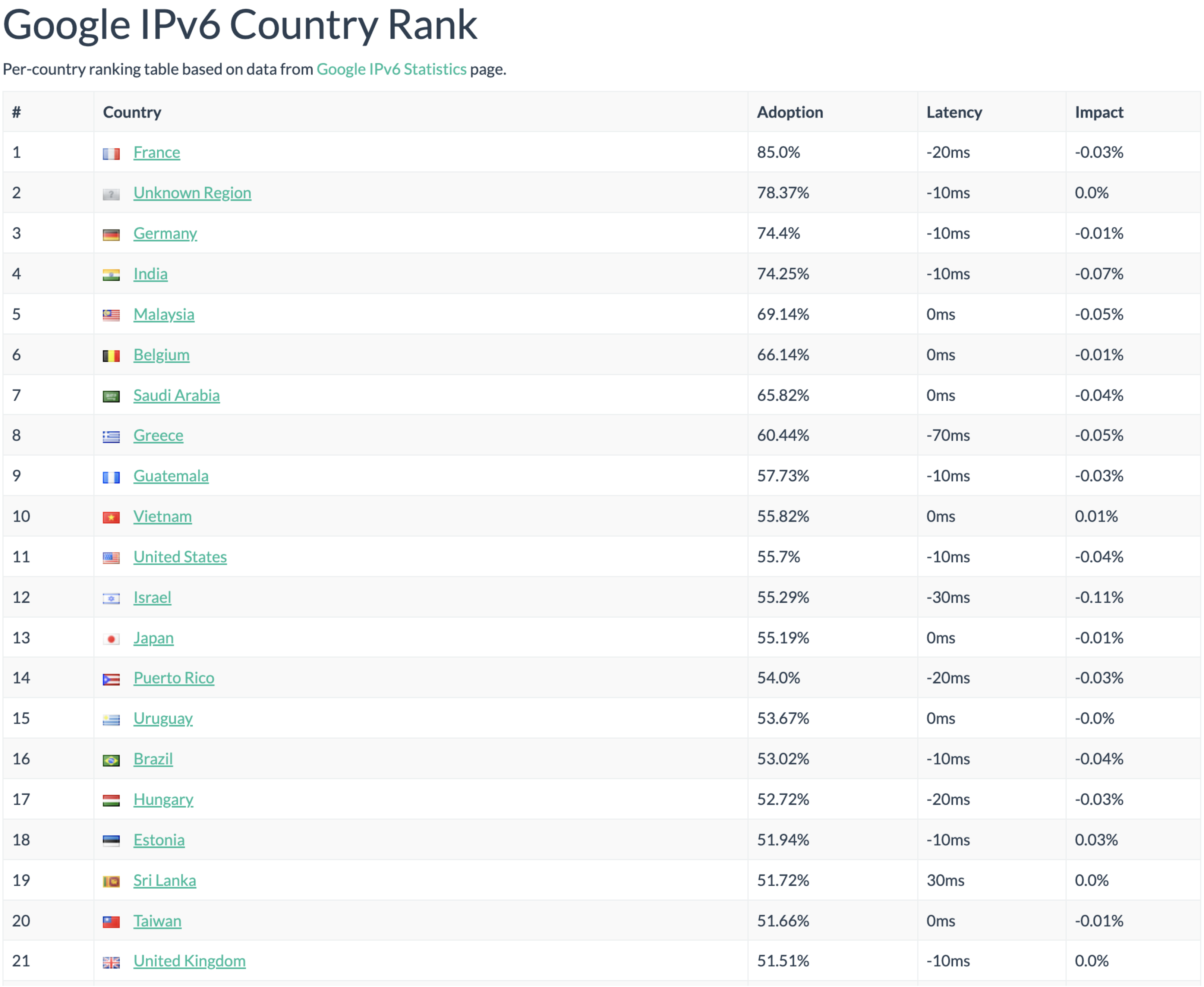
Per-Country IPv6 adoption

World | Africa | Asia | Europe | Oceania | North America | Central America | Caribbean | South America

The chart above shows the availability of IPv6 connectivity around the world.

- 🟩 Regions where IPv6 is more widely deployed (the darker the green, the greater the deployment) and users experience infrequent issues connecting to IPv6-enabled websites.
- 🟧 Regions where IPv6 is more widely deployed but users still experience significant reliability or latency issues connecting to IPv6-enabled websites.
- 🟥 Regions where IPv6 is not widely deployed and users experience significant reliability or latency issues connecting to IPv6-enabled websites.

IPv6 Adoption Rank by Country

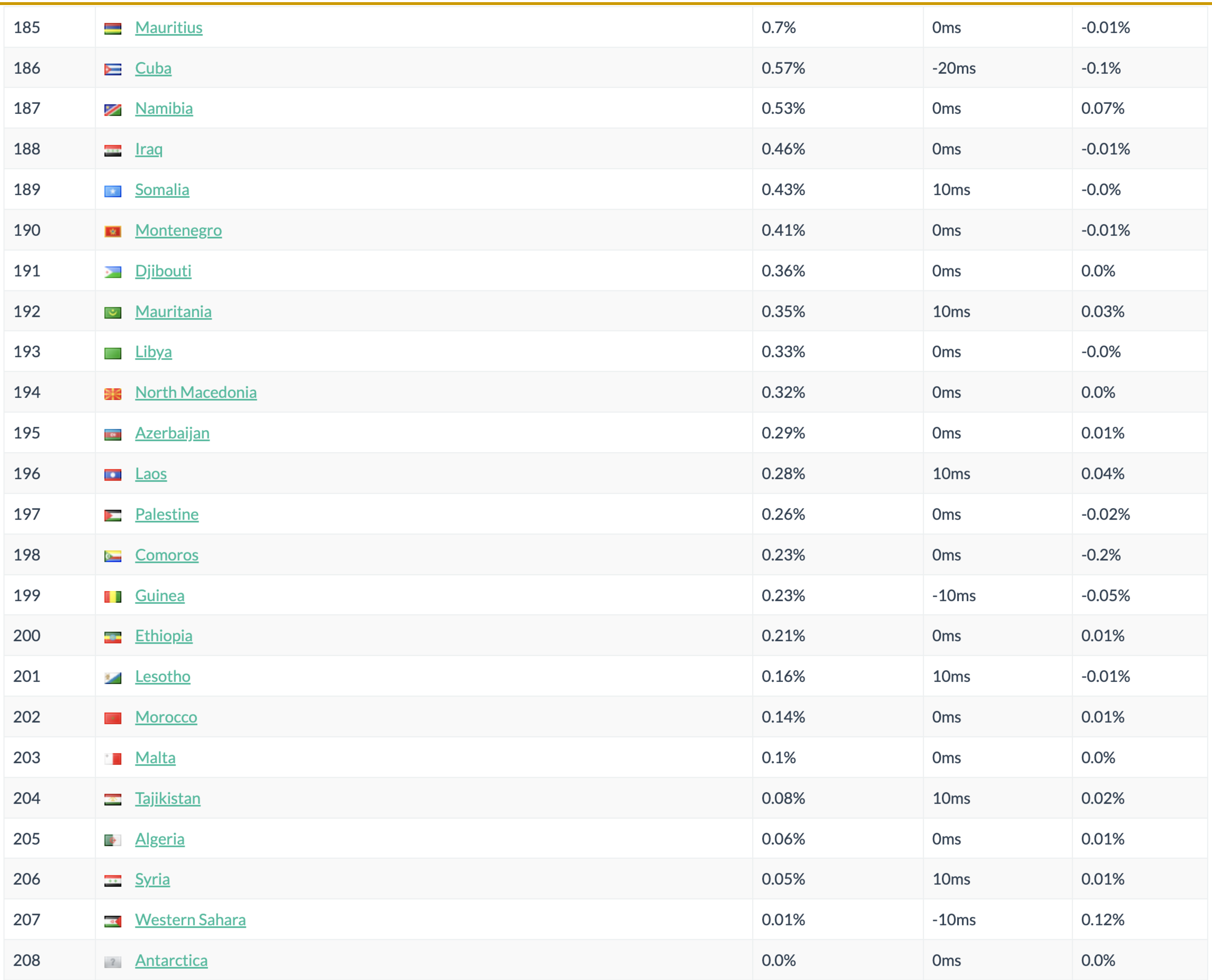


Google IPv6 Country Rank

Per-country ranking table based on data from Google IPv6 Statistics page.

#	Country	Adoption	Latency	Impact
1	France	85.0%	-20ms	-0.03%
2	Unknown Region	78.37%	-10ms	0.0%
3	Germany	74.4%	-10ms	-0.01%
4	India	74.25%	-10ms	-0.07%
5	Malaysia	69.14%	0ms	-0.05%
6	Belgium	66.14%	0ms	-0.01%
7	Saudi Arabia	65.82%	0ms	-0.04%
8	Greece	60.44%	-70ms	-0.05%
9	Guatemala	57.73%	-10ms	-0.03%
10	Vietnam	55.82%	0ms	0.01%
11	United States	55.7%	-10ms	-0.04%
12	Israel	55.29%	-30ms	-0.11%
13	Japan	55.19%	0ms	-0.01%
14	Puerto Rico	54.0%	-20ms	-0.03%
15	Uruguay	53.67%	0ms	-0.0%
16	Brazil	53.02%	-10ms	-0.04%
17	Hungary	52.72%	-20ms	-0.03%
18	Estonia	51.94%	-10ms	0.03%
19	Sri Lanka	51.72%	30ms	0.0%
20	Taiwan	51.66%	0ms	-0.01%
21	United Kingdom	51.51%	-10ms	0.0%

IPv6 Adoption Rank by Country



185	Mauritius	0.7%	0ms	-0.01%
186	Cuba	0.57%	-20ms	-0.1%
187	Namibia	0.53%	0ms	0.07%
188	Iraq	0.46%	0ms	-0.01%
189	Somalia	0.43%	10ms	-0.0%
190	Montenegro	0.41%	0ms	-0.01%
191	Djibouti	0.36%	0ms	0.0%
192	Mauritania	0.35%	10ms	0.03%
193	Libya	0.33%	0ms	-0.0%
194	North Macedonia	0.32%	0ms	0.0%
195	Azerbaijan	0.29%	0ms	0.01%
196	Laos	0.28%	10ms	0.04%
197	Palestine	0.26%	0ms	-0.02%
198	Comoros	0.23%	0ms	-0.2%
199	Guinea	0.23%	-10ms	-0.05%
200	Ethiopia	0.21%	0ms	0.01%
201	Lesotho	0.16%	10ms	-0.01%
202	Morocco	0.14%	0ms	0.01%
203	Malta	0.1%	0ms	0.0%
204	Tajikistan	0.08%	10ms	0.02%
205	Algeria	0.06%	0ms	0.01%
206	Syria	0.05%	10ms	0.01%
207	Western Sahara	0.01%	-10ms	0.12%
208	Antarctica	0.0%	0ms	0.0%