1. Six Benefits of IPv6

Address Abundance

IPv6 has 3.4 x 10^{38} addresses – 340 trillion trillion trillion – vs IPv4 with only 4.3 billion.

Easier Network Management

Networks are simpler, flatter, more easily managed. Addresses can be autoconfigured.

Faster Routing

Address header fixed at 40 bytes, means faster, more efficient packet forwarding.

Improved Security & Mobility

Support is mandated for authentication and encryption. Mobility connectivity is improved.

End-to-End Transparency

Vast address space means direct connectivity, no NATs, improves performance and security.

Innovation Space

Huge address space allows billions of devices, necessary for IoT, cloud, mobiles, wearables.

See more at: *6now.net/whyipv6.php*

2. IPv6 Address Formats

IPv6 format is hexadecimal. Here is 0 to 15 in binary (machine) format, decimal (IPv4) and hex (IPv6):

Binary	Dec.	Hex	Binary	Dec.	Hex
0000	0	0	1000	8	8
0001	1	1	1001	9	9
0010	2	2	1010	10	a
0011	3	3	1011	11	b
0100	4	4	1100	12	c
0101	5	5	1101	13	d
0110	6	6	1110	14	e
0111	7	7	1111	15	f

Addresses in IPv4

Bit = **0** or **1**, **Byte** = 8 bits, e.g. `00010110`

IPv4 is written as **32** bits in **4** bytes, e.g.

`11000000 10101000 00000001 00000000`

In decimal format = `192.168.1.0`

Addresses in IPv6

IPv6 is written as **128** bits in **16** bytes, e.g.

```
00100000 00000001 00001101 10111000
00000000 00000000 00000000 00000000
00010010 00110100 00000000 00000000
00000000 00000000 00000000 00000001
```

In hex format = `2001:db8:0:0:1234:0:0:1`

From Binary to Hex

How to convert a binary IPv6 address to hex:

1. Address written in 128 bits –

```
00100000000000010000110110111000000000000000
00000000000000000000000100100011010000000000
00000000000000000000000000000000000000000001
```

2. Convert the binary to hex –
   `20010db800000000123400000000001`
3. Put into 8 groups of 4 separated by colons –
   `2001:0db8:0000:0000:1234:0000:0000:0001`
4. (*Optional*) Drop the leading zeros –
   `2001:db8:0:0:1234:0:0:1`
5. (*Optional*) Collapse ONE ONLY group of zeros to double colons –
   `2001:db8::1234:0:0:1` *or*
   `2001:db8:0:0:1234::1`

3. Prefixes and Subnets

The bits on the left side of an IPv6 address specify the network *prefix*, and all of the addresses in a network have the same prefix.

/N (slash-N) is shorthand for a prefix N bits long, e.g. shorthand for all addresses in the 32-bit network with the prefix `2001:0db8` is `2001:db8::/32`

A typical IPv6 address might have 48 bits of prefix and 16 bits of subnet:

`2001:db8:0:`	`abcd:`	`1234:0:0:7`

48 bit prefix + 16 bit subnet + 64 bit host

Network `2001:db8:0::/48`
Subnet `2001:db8:0:abcd::/64`
Host `2001:db8:0:abcd:1234::7`

Sizes of Subnets

A standard small IPv6 subnet will usually be assigned a /64 prefix, *which is 4.3 billion times the size of the current IPv4 Internet.*

Type of network	Prefix	No. of addresses
Standard small	/64	1.8 x 10^{19}
Enterprise network	/48	65,536 subnets, each of /64 size
Service provider	/32	65,536 subnets, each of /48 size

To calculate the number of subnets in a network prefix, take the difference between the network and subnet sizes, and raise to the power of 2.

e.g. How many /48 subnets in a /32?
48 - 32 = 16 and 2^{16} = 65,536

See more: *6now.net/primers/IPv6PrefixPrimer.php*

Prefixes and Numbers of Addresses

Prefix	Number of Addresses	Equivalent Quantity
/0	3.4 x 10^{38}	All possible IPv6 addresses
/8	1.3 x 10^{36}	1/3 of watts luminosity of Milky Way
/16	5.2 x 10^{33}	Sun's energy in joules in 6 months
/24	2.0 x 10^{31}	20 times the no. of bacteria on Earth
/32	7.9 x 10^{28}	42 times mass of Jupiter in kilograms
/40	3.1 x 10^{26}	3 x diameter of Universe in metres
/48	1.2 x 10^{24}	20 x number of stars in the Universe
/56	4.7 x 10^{21}	2 x number of grains of sand on Earth
/64	1.8 x 10^{19}	18 x number of insects on Earth
/72	7.2 x 10^{16}	Earth to closest star & back in metres
/80	2.8 x 10^{14}	No. of leaves on all trees on Earth
/88	1.1 x 10^{12}	3 x number of stars in the Milky Way
/96	4.3 x 10^{9}	All possible IPv4 addresses
/104	16,777,216	
/112	65,536	
/120	256	
/128	1	

Even a /96 prefix network, miniscule in IPv6 terms, is the size of the *entire* IPv4 Internet.

Maximum number of IPv4 addresses possible: 4,294,967,296

Maximum no. of IPv6 addresses possible:
340,282,366,920,938,463,463,374,607,431,768,211,456

4. IPv6 Address Types

Unicast – single address, uniquely receives traffic.

Anycast – unicast address on multiple interfaces, *any one* receives traffic.

Multicast – address for multiple interfaces, *all of which* receive traffic. Listeners join multicast group and hosts send only to that group.

Defined Address Prefixes

Default route	`::/0`
Unspecified address	`::/128`
Loopback/localhost	`::1/128`
IPv4-mapped IPv6	`::ffff:0:0/96`
Unique Local unicast	`fc00::/7`
Link-Local unicast	`fe80::/10`
Multicast	`ff00::/8`
Global unicast	`2000::/3`
Documentation	`2001:db8::/32`
Benchmarking	`2001:0002::/48`
Teredo	`2001:0000::/32`
6to4 space	`2002::/16`
Well-Known translated IPv4	`64:ff9b::/96`

5. Host Address Allocation

Static IPv6 Addresses

IPv6 addresses can simply be assigned as in IPv4.

Stateless Address Autoconfiguration (SLAAC)

Plug in, switch on, globally routable. With SLAAC, a host configures its own address: the address is *generated*, not allocated.

Benefits: low cost, huge scalability, fast, no host configuration, universally supported, no servers required, can assign globally routable addresses.

Drawbacks: less secure, fails rapidly and completely on error, no policy hooks, no event logging, little address control, little extra information.

Dynamic Host Configuration (DHCPv6)

Stateful Autoconfiguration: with DHCPv6, a server supplies addresses to hosts in a network: the address is *allocated*, not generated.

Benefits: Allows address control. Fails more gracefully, has policy hooks and event logging.

Drawbacks: snooping possible, doesn't have boot server, dual-stack issues with information from two sources, DUID is tied to host, not an interface.

6. Commands for Windows and Unix

Unix Commands for IPv6

mtr -6 – host and network route and reachability
ping6 – host and network reachability
traceroute6 – traces route to a host
tracepath6 – traces route with MTU along path
ifconfig -a – see all network interfaces on host
route -6 – the current routing table
netstat – routing tables, interface stats etc.

Windows Commands for IPv6

ping [-4 -6 -i -R -S]
tracert [-4 -6 -R -S]
pathping [-4 -6]
netstat
ipconfig /all
netsh interface ipv6 show

IPv6 Testing, Security, Address Tools

Ping, trace, connectivity – *6now.net/tools.php*
Security tools – *6now.net/security.php*
Address management – *6now.net/addresses.php*
IPv6 tutorials – *6now.net/resources.php*

