Introduction to IPv6

Structure and function of IPv6 addresses

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Vision

- There is a federal mandate for IPv6.
- Let's get the training we need!
- Please put in the chat window (or email to me / Fred) any IPv6 terms or concepts which you find confusing, anywhere you find yourself stuck in implementation, or what information you feel would help you! This will allow us to think about follow-on activities / webinars.

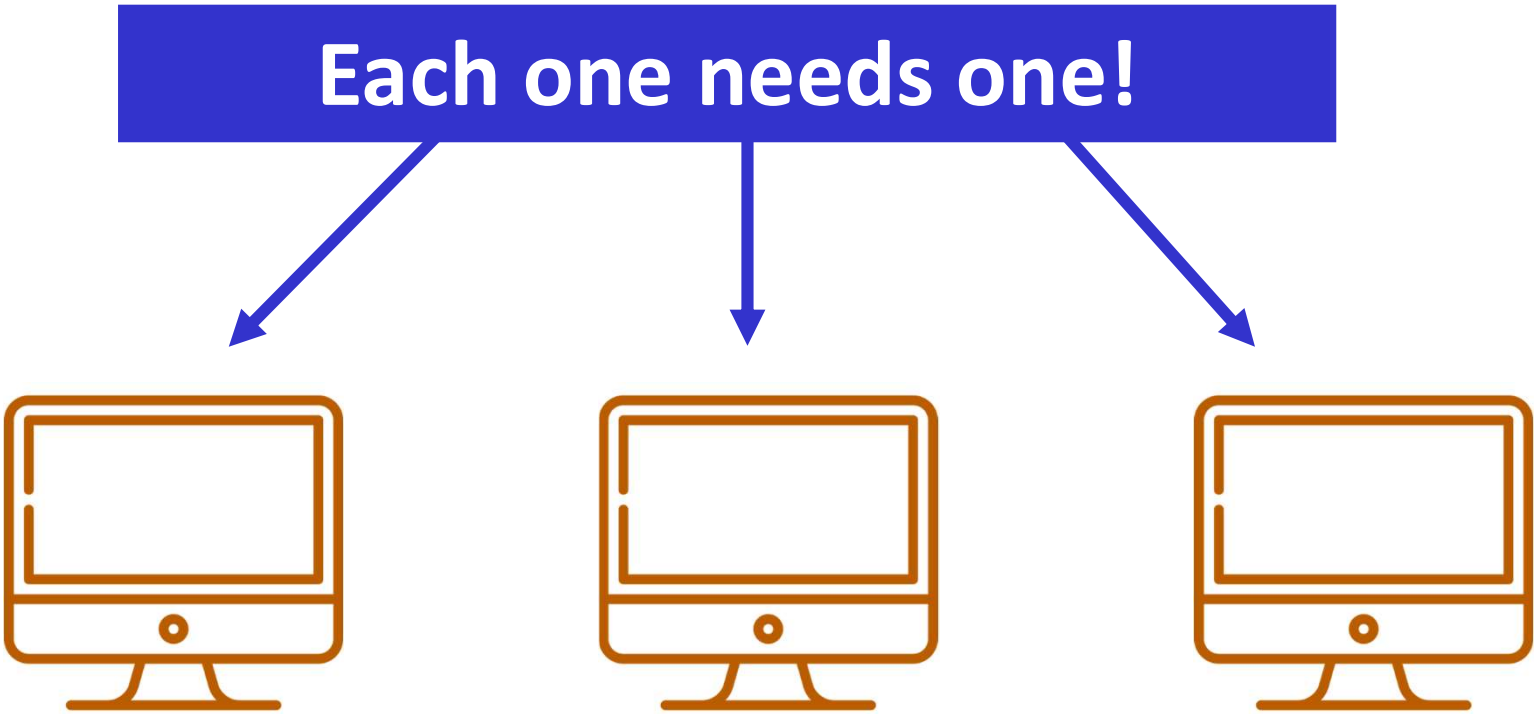
A few words about me

- President: Industry Network Technology Council (https://industrynetcouncil.org/)
- Founder & CEO: Outside the Stacks, Inc. (https://www.outsidethestack.net/)
- Co-Founder & Advisory Board: India Internet Engineering Society (https://www.iiesoc.in/)
- RFCs: RFC8250 (Embedded performance and diagnostics for IPv6) and others
- Active in TLS and MLS IETF groups
- Product developer (OEMed by IBM and others)
- Working with IPv6 for 20 years
- Working with network management, diagnostic, performance issues at large brick-and-mortar enterprises for over 30 years

Agenda

- Introduction to addressing
- Overview of Binary, Hexadecimal, decimal addressing concepts
- Zero compression
- Address changes from IPv4 to IPv6
- Public and private addresses
- IPv6 Prefixes
- IPv6 Address Structure
- IPv6 Interface ID
- IPv6 Addressing and Address Allocation Methods (stateless, stateful)
- Address types, unicast, multicast, anycast
- Address categories: global, site local, link local
- Unique Local Unicast addresses
- Special addresses (loopback, unspecified, IPv4 mapped IPv6)
- Broadcast address elimination

Network Addresses



Let's look at an address

What is this?

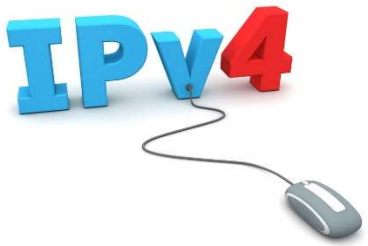
1600 Pennsylvania Ave NW
Washington, DC 20500

Private vs. Public Addresses

Public:
1600 Pennsylvania Ave
NW, Washington, DC 20500

Private:
P.O. Box 27624
Washington, D.C. 20500

Sample IPv4 Addresses

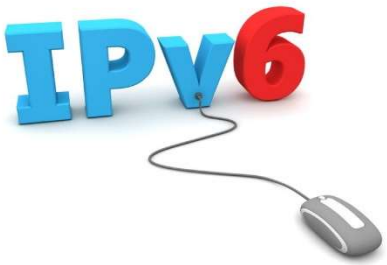


192.168.1.1

10.12.15.201

201.23.5.104

Sample IPv6 Addresses



3FFE:52AB:2:ABC:123:56:DE:1
2001::2:ABC:123
FE80::1234:1
FF01::2
::

Sample Private Addresses

192.168.1.1

- IPv4
- Private

FE80::1234:1

- IPv6
- Private (limited)

Sample Public Addresses

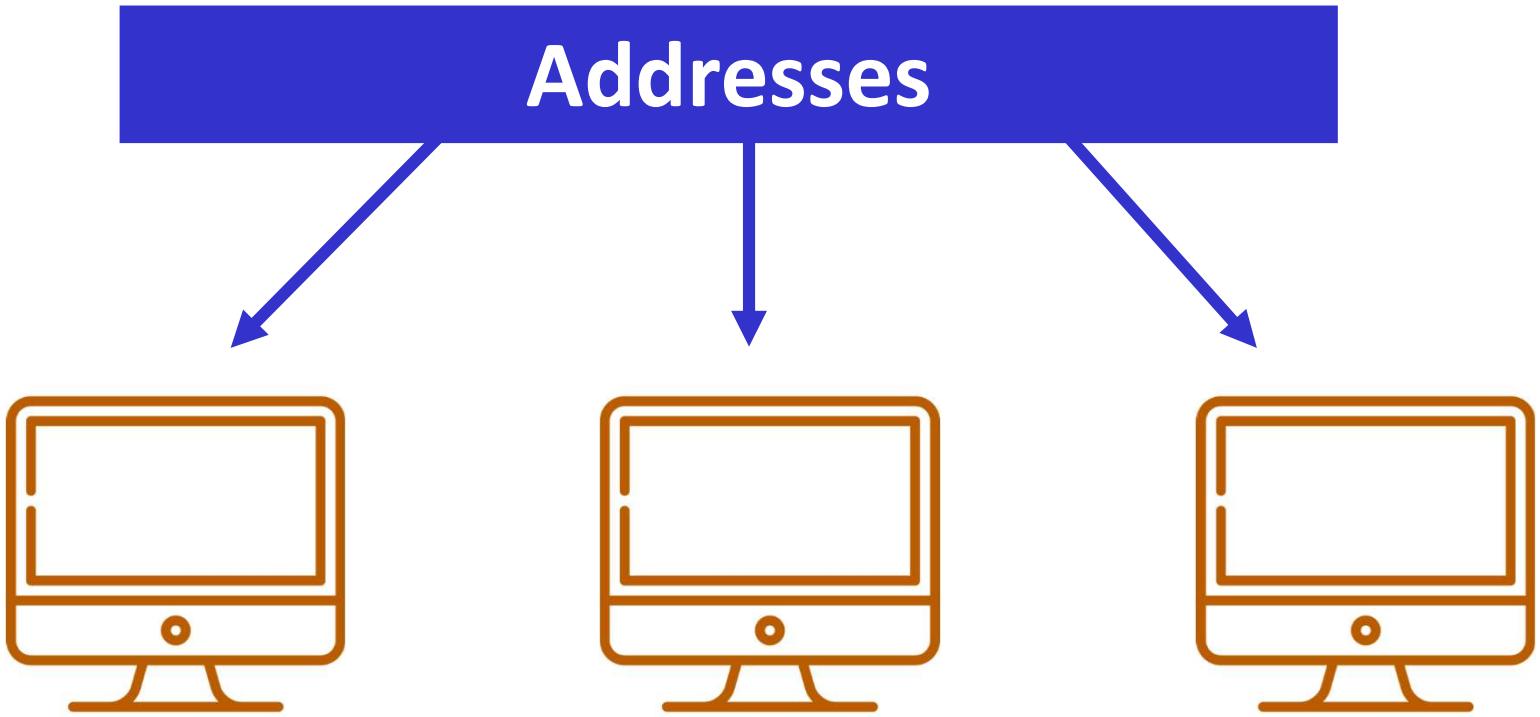
201.23.5.104

- IPv4
- Public

2001::2:ABC:123

- IPv6
- Public

TCP/IP Network



192.168.1.100

2001:5c0:8fff:3::100

192.168.1.101

2001:5c0:8fff:3::101

192.168.1.102

2001:5c0:8fff:3::102

Addressing Concepts

Decimal notation (IPv4)

1.2.3.4

Hexadecimal notation (IPv6)

00 - FF

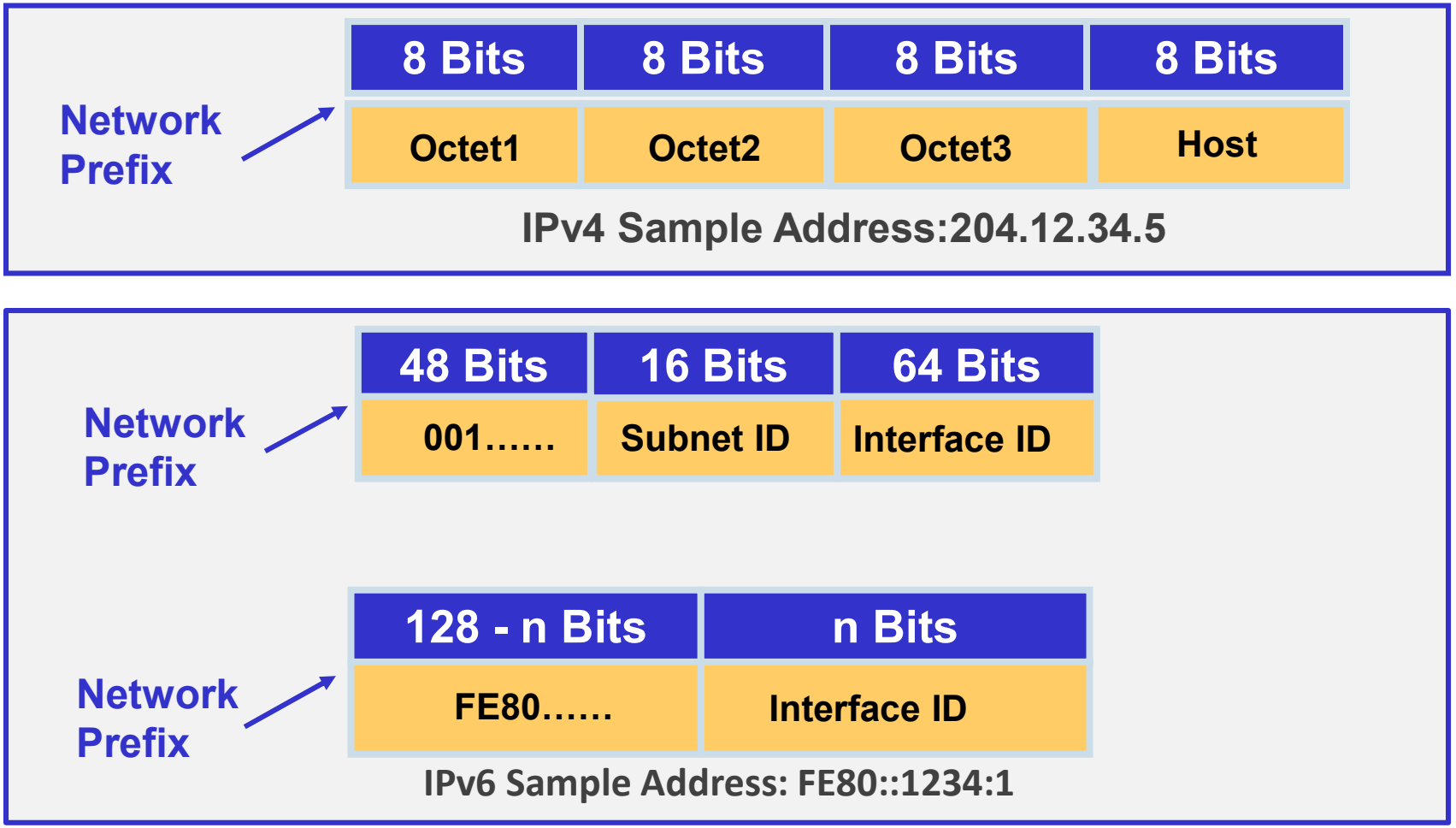
Binary

1 byte = 8 bits

Important IPv6 Prefix Notations

/8	11111111xxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	00xx:: FFxx::
/16	1111111111111111.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:: FFFF::
/32	1111111111111111.1111111111111111. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:: FFFF:FFFF::
/48	1111111111111111.1111111111111111. 1111111111111111.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:: FFFF:FFFF:FFFF::
/56	1111111111111111.1111111111111111. 1111111111111111.11111111xxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:00xx:: FFFF:FFFF:FFFF:FFxx::
/64	1111111111111111.1111111111111111. 1111111111111111.1111111111111111. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:0000:: FFFF:FFFF:FFFF:FFFF::

IPv4 / IPv6 Address Structure



IPv6 Address Representation

IPv4 Address : 32 bits – IPv6 address : 128 bits

- IPv6 address : 8 sections of 4 hex digits (16 bits)
  - 1111:2222:3333:4444:5555:6666:7777:8888

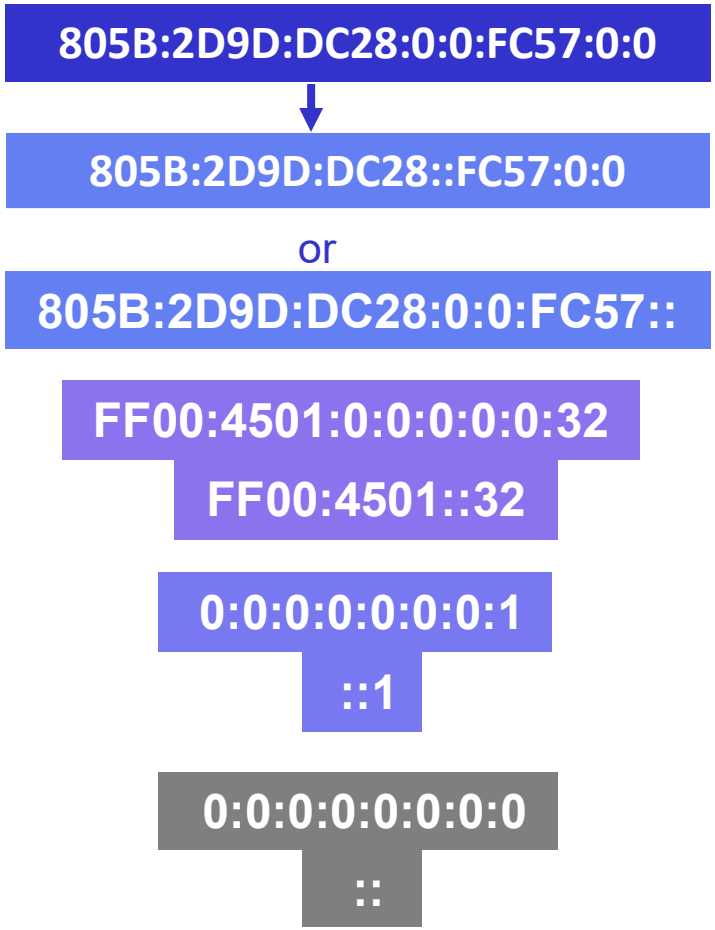
- Zero-compression
  - 1111:2222:**0:0**:5555:6666:7777:8888
  - 1111:2222**::**5555:6666:7777:8888

- Prefix length
  - 1111:2222::5555:6666:7777:8888 /64

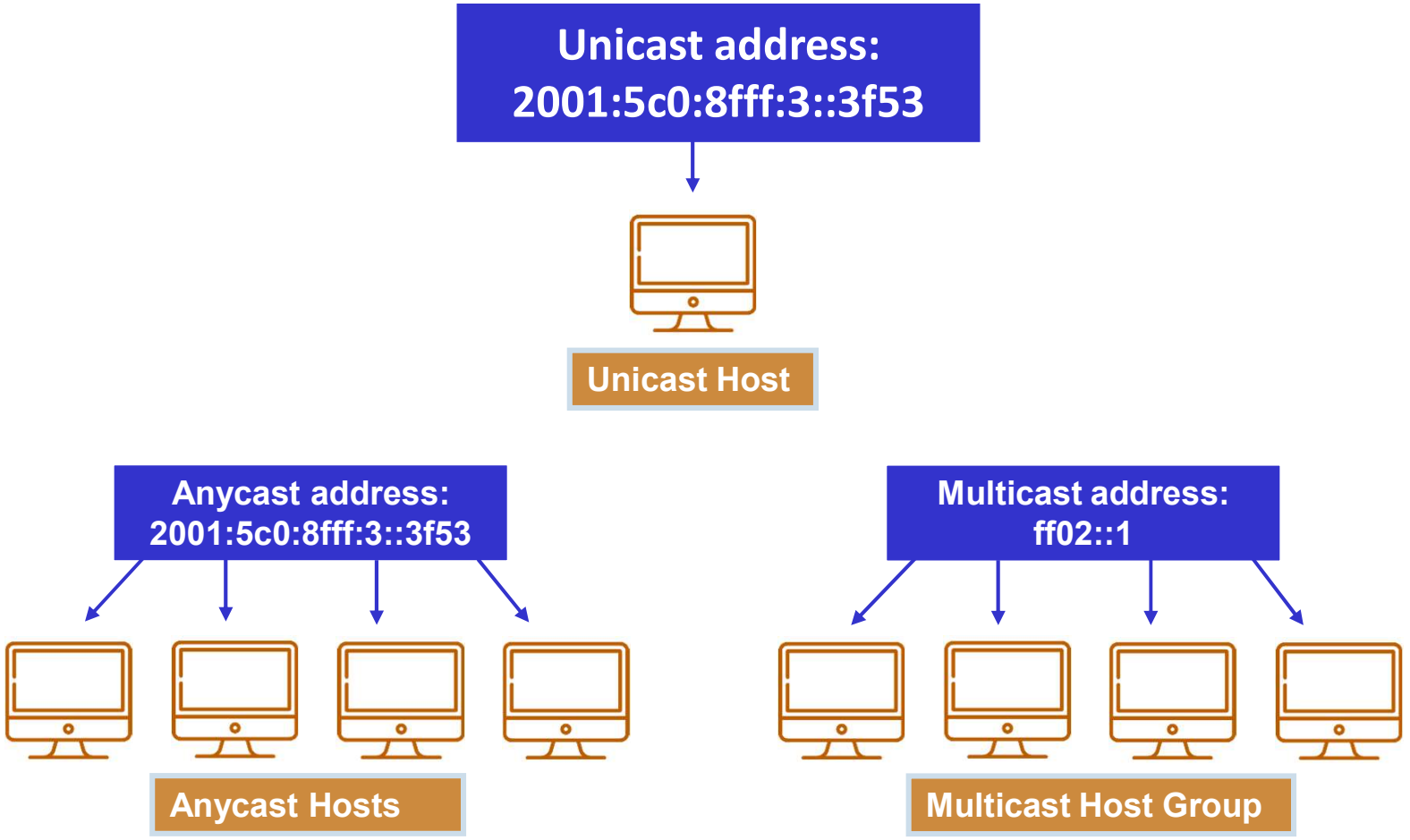
- Prefix alone
  - 1111:2222:: /64

Zero Compression

- IPv6 addresses are zero compressed.
- Double colon can appear only once.
- Zero compression of special addresses.



IPv6 Address Types



Anycast addresses appear the same as unicast addresses

Importance of IPv6 Network Prefix

- First part of network prefix important!
- Example: **2001:5c0:8fff:3::3f53**
- Learn:
  - Can you go out on the internet with it,
  - What devices can you talk to,
  - Is it for special function.

FE80 = Link Local

FFxx = Multicast

2001 = Global Unicast

0000 = Special

Addressing Changes

- No broadcast addressing in IPv6
- IPv6 multicast addressing used

IPv4 Broadcast Addresses

192.168.1.255

255.255.255.255

Addressing Planning

- IPv6 address planning is different from IPv4
- IPv4: final octet 0 address is network, 1 address is gateway, 255 is broadcast (generally)
- IPv4 and IPv6 subnet structure is different
- Basically, you do not lose three addresses per subnet

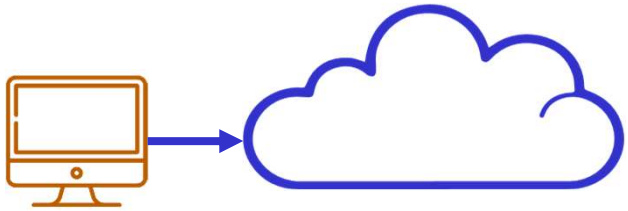
IPv4 Subnet

192.168.1.1 (network)

192.168.1.255 (broadcast)

No need for these in IPv6.

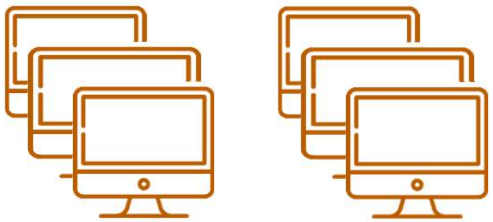
Types of Unicast Addresses



- global unicast

FE8n - FEBn = Link Local

- link-local unicast

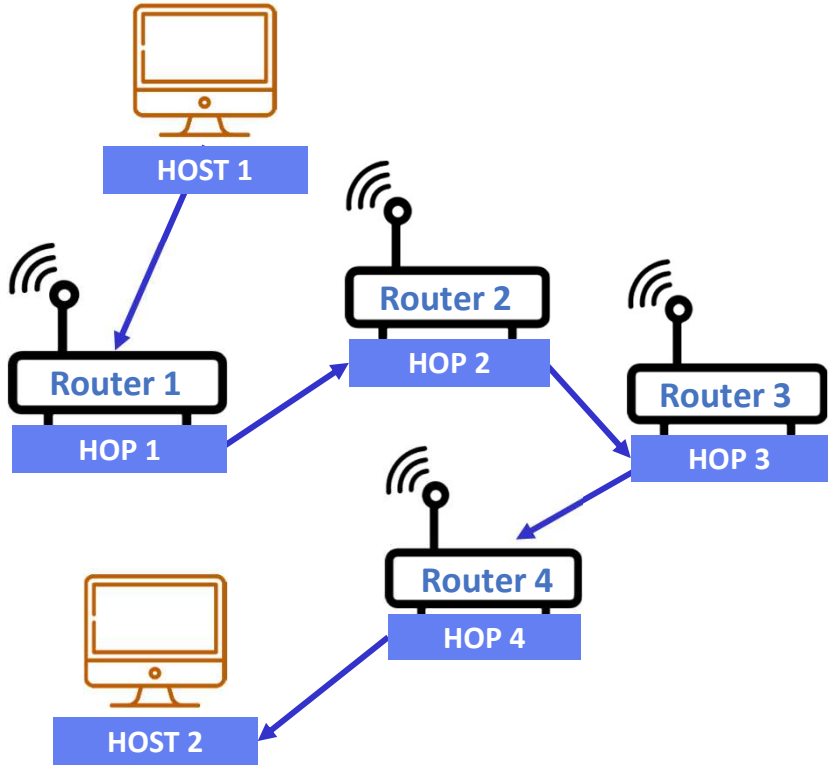


FECn - FEFn = Site Local

- site-local unicast.

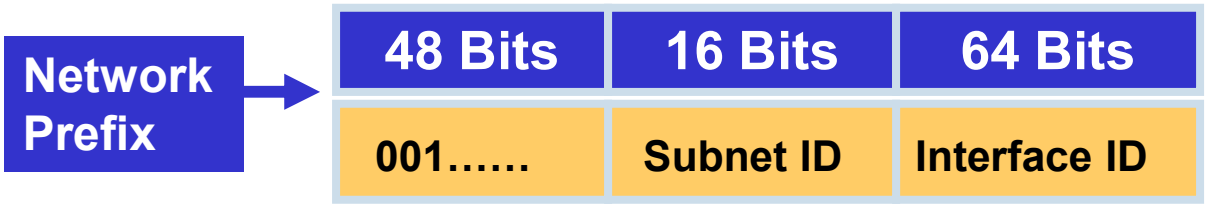
IPv6 Global Unicast Address

- IPv6 global unicast address (like) IPv4 global unicast address
- Current global unicast address allocation: 2000::/3 (binary 001)
- Plan network in hierarchy
- Limit routing table entries



```
Windows IP Configuration


Ethernet adapter Ethernet:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Local Area Connection* 2:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Local Area Connection* 13:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . :
   IPv6 Address. . . . . . . . . . . : 2601:642:c201:bd::478d
   IPv6 Address. . . . . . . . . . . : 2601:642:c201:bd:fced:f576:4c8d:11f7
   Temporary IPv6 Address. . . . . . : 2601:642:c201:bd:c5f4:62a3:c9cd:500b
   Link-local IPv6 Address . . . . . : fe80::fced:f576:4c8d:11f7%9
   IPv4 Address. . . . . . . . . . . : 10.0.0.118
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : fe80::5a19:f8ff:fef4:a74e%9
                                       10.0.0.1

Ethernet adapter Bluetooth Network Connection:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
```

Global Unicast Network Prefix



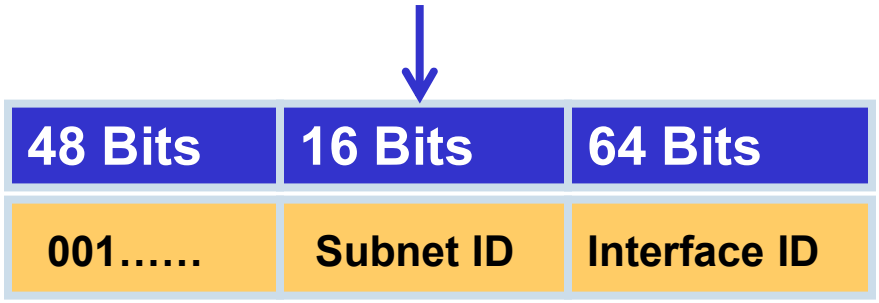
Global Unicast Address

2001:5c0:8fff:3::3f53

- Network Prefix: First part of an IPv6 address.
- Best practices: 48 bits

Global Unicast Subnet Prefix

- Subnet prefix: standard is 16 bits
- 65,535 subnets

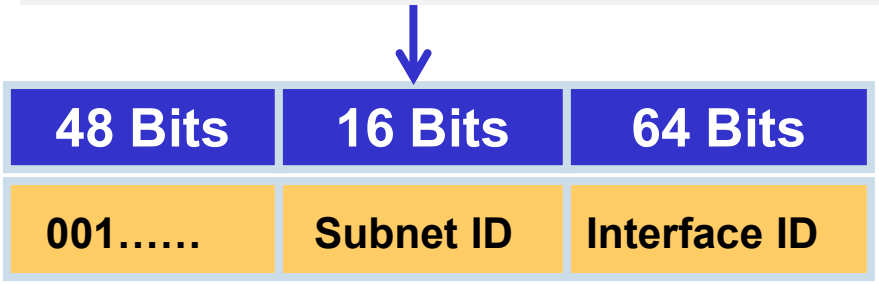


Global Unicast Address

2001:5c0:8fff:0003::35f3

Global Unicast Interface ID (IID)

- IID is for an interface
- IID must be unique
- IID: standard is 64 bits



Global Unicast Address

2001:5c0:8fff:3::3f53

EUI-64 Format

- IID: based on the link-layer (MAC) address
- EUI-64 format : OUI field + FFFE + Serial Number

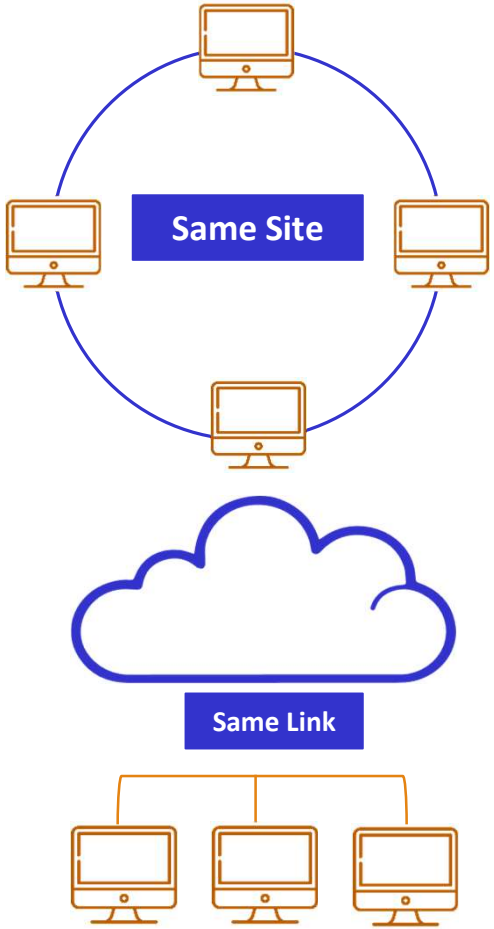
Example on Windows PC: result of IPConfig

Ethernet adapter Local Area Connection:
Description : Realtek Family Fast Ethernet NIC
Physical Address : 00-11-D8-39-29-2B
Autoconfiguration Enabled . : Yes
IP Address : fe80::211:d8ff:fe39:292b%4

IPv6 Private Addresses

- Link-local or site-local
- Never routed outside an organization or link
- Start with hex FE then 8 to F (1111 1110 1)
- Most common: FE80 (link-local).
- Range is FE80::/10

FE8n – FEFn = Private Addresses



Link-Local Unicast Address

- IPv6 devices always have link-local address
- IPv6 devices use link-local to communicate with ‘on-link’ devices
- IPv6 routers must not forward link-local packets

10 Bits	54 Bits	64 Bits
1111111010	zeroes	Interface ID

Sample Link-Local Address

fe80::211:d8ff:fe39:292b

Link-Local Address Explained

- Why do you need link-local addresses?
- How do you get a link-local address?

Who am I? IPv6 Stateless autoconfiguration

FE8n - FEBn = Link Local

Site-Local Unicast Addresses

- IPv4 site-local private addresses = 10.0.0.0/80.0/12 or 192.168.0.0/16
- Site-local address + NAT used for topology hiding
- **IPv6 site-local unicast deprecated**
- Site scope multicast still available

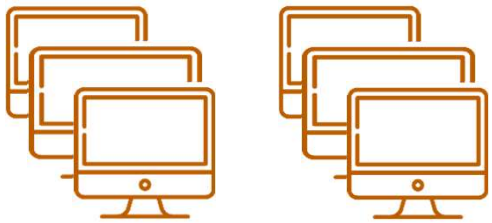
FECn - FEFn = Site Local

IPv6 Prefix	Allocation	Reference
0000::/8	Reserved by IETF	[RFC3513]
0100::/8	Reserved by IETF	[RFC3513]
0200::/7	Reserved by IETF	[RFC4048]
0400::/6	Reserved by IETF	[RFC3513]
0800::/5	Reserved by IETF	[RFC3513]
1000::/4	Reserved by IETF	[RFC3513]
2000::/3	Global Unicast	[RFC3513]
4000::/3	Reserved by IETF	[RFC3513]
6000::/3	Reserved by IETF	[RFC3513]
8000::/3	Reserved by IETF	[RFC3513]
A000::/3	Reserved by IETF	[RFC3513]
C000::/3	Reserved by IETF	[RFC3513]
E000::/4	Reserved by IETF	[RFC3513]
F000::/5	Reserved by IETF	[RFC3513]
F800::/6	Reserved by IETF	[RFC3513]
FC00::/7	Unique Local Unicast	[RFC4193]
FE00::/9	Reserved by IETF	[RFC3513]
FE80::/10	Link Local Unicast	[RFC3513]
FEC0::/10	Reserved by IETF	[RFC3879]
FF00::/8	Multicast	[RFC3513]

IPv6 Address Space Allocations

De facto Site-Local Unicast

- ULA (Unique Local Unicast) addresses
- Large address space!
- Conflicts?



FC00:: /7 = ULA

An IPConfig from London

1. IPv6 Address. . . . . :2a02:c7d:500e:f900:f5:8404:5e0:430e
Global Unicast IPv6 : routable over the Internet
2. IPv6 Address. . . . :fd4f:f7d8:2459:0:f5:8404:5e0:430e
Unique Local Unicast (ULA) IPv6 :not routable over Internet
3. Temporary IPv6 Address:2a02:c7d:500e:f900:a53a:5a06:130b:a2ff
Privacy Global Unicast IPv6 :routable over the Internet
4. Temporary IPv6 Address:fd4f:f7d8:2459:0:a53a:5a06:130b:a2ff
Privacy ULA IPv6 :not routable over the Internet
5. Link-local IPv6 Address:fe80::f5:8404:5e0:430e%13
Private Interface IPv6: not routable over the Internet
6. IPv4 Address. . . . . :192.168.0.6
Site Local GUA IPv4 : not routable over the Internet

IPv6 Reserved Addresses

- Defined by the IETF

Includes:

- Unspecified,
- Loopback and
- IPv4 Embedded addresses

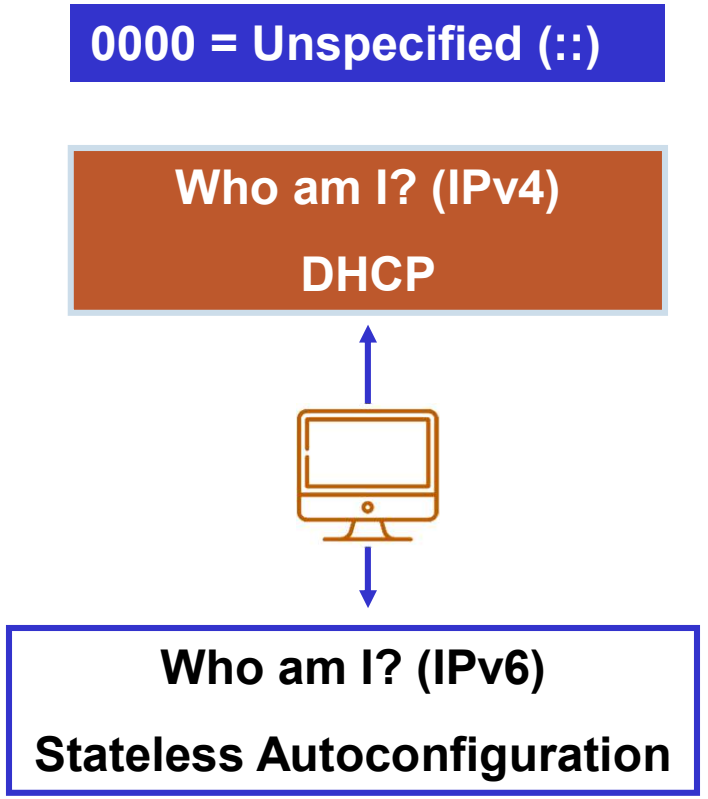
:: /8 = Reserved

See:

http://www.iana.org/assignments/ipv6-address-space/ipv6-address-space.xml

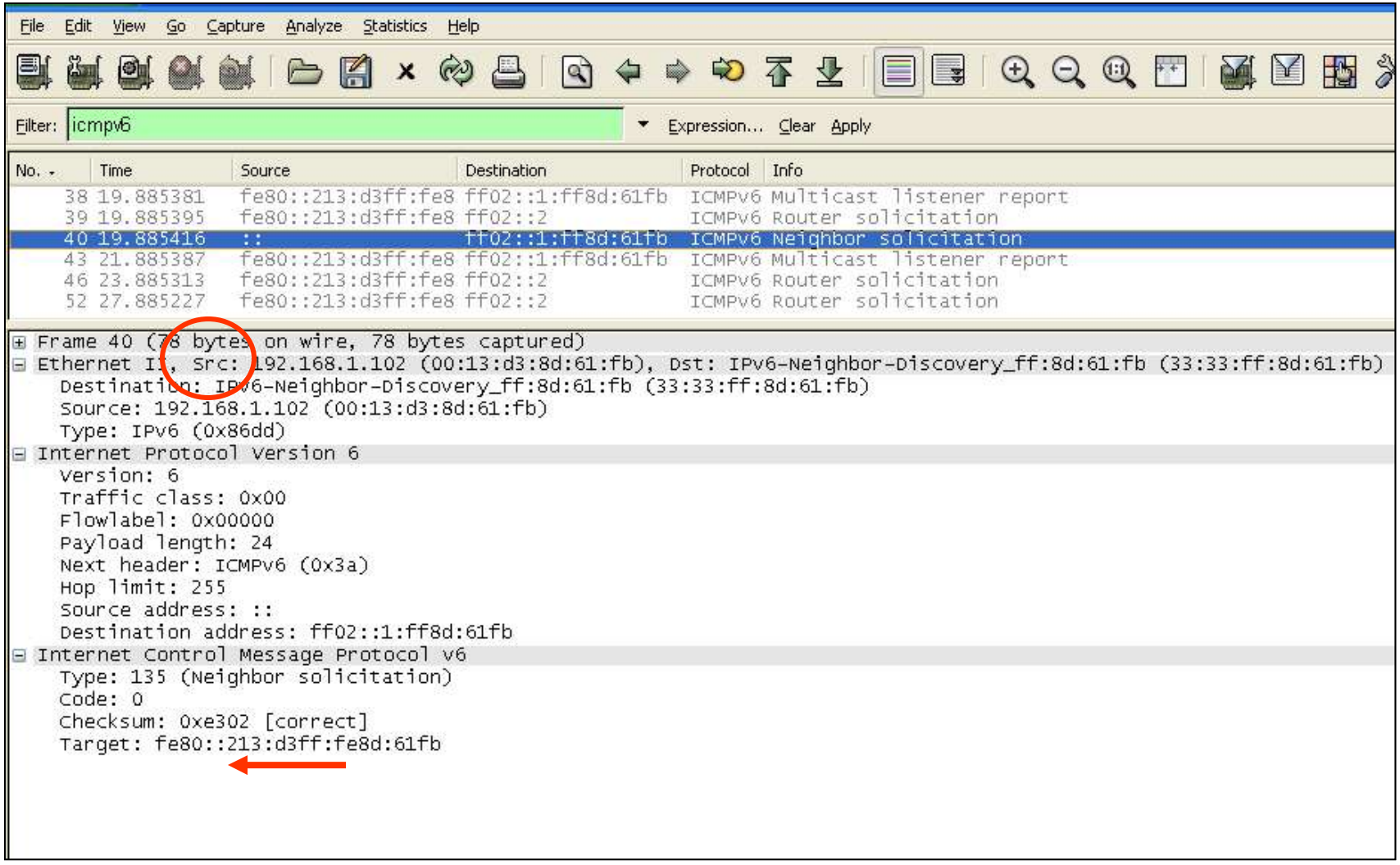
IPv6 Unspecified Address

- Who am I?
- IPv6 *unspecified address*.
- Stateless Autoconfiguration
- Represented as ::



```
164 ADCD     PACKET   00000004 08:14:04.416323 Packet Trace
  From Interface    : ETH1              Device: LCS Ethernet     Full=342
   Tod Clock        : 2006/01/06 08:14:04.416317                 Intfx: 4
   Sequence #       : 0                 Flags: Pkt
  IpHeader: Version : 4                 Header Length: 20
   Tos              : 00                QOS: Routine Normal Service
   Packet Length    : 342               ID Number: 0000
   Fragment         :                   Offset: 0
   TTL              : 128               Protocol: UDP            CheckSum: 3998 FFFF
   Source           : 0.0.0.0
   Destination      : 255.255.255.255

  UDP
   Source Port      : 68    (bootpc)    Destination Port:  67    (bootps)
   Datagram Length  : 322               CheckSum: 93B0 FFFF
   BOOTP Opcode     : REQUEST           HW Type: ETHERNET 10M  HW Length: 6
    HOP Count       : 0                 Trans ID: 1047706584   Seconds: 0
    Client IP       : 0.0.0.0           Your IP: 0.0.0.0
    Server IP       : 0.0.0.0           Gateway: 0.0.0.0
    Client HW Addr  : 0013D38D61FB00000000000000000000 Flags: 0
    Server Host Name:
    Boot FileName   :
    Vendor Info     : 638253633501033D07010013D38D61FB3204C0A801650C0C42617272792D636F
    Vendor Info     : 6D706171511000000042617272792D636F6D7061712E3C084D53465420352E30
     DHCPMSG        : DhcpREQUEST
     CLIENTID       : 7 010013D38D61FB
     REQIPADDR      : 192.168.1.101
     HOSTNAME       : Barry-compaq
     DHCPDDNS       : 16 00000042617272792D636F6D7061712E
     CLASSID        : MSFT 5.0
     PARMLIST       : 11 options
```

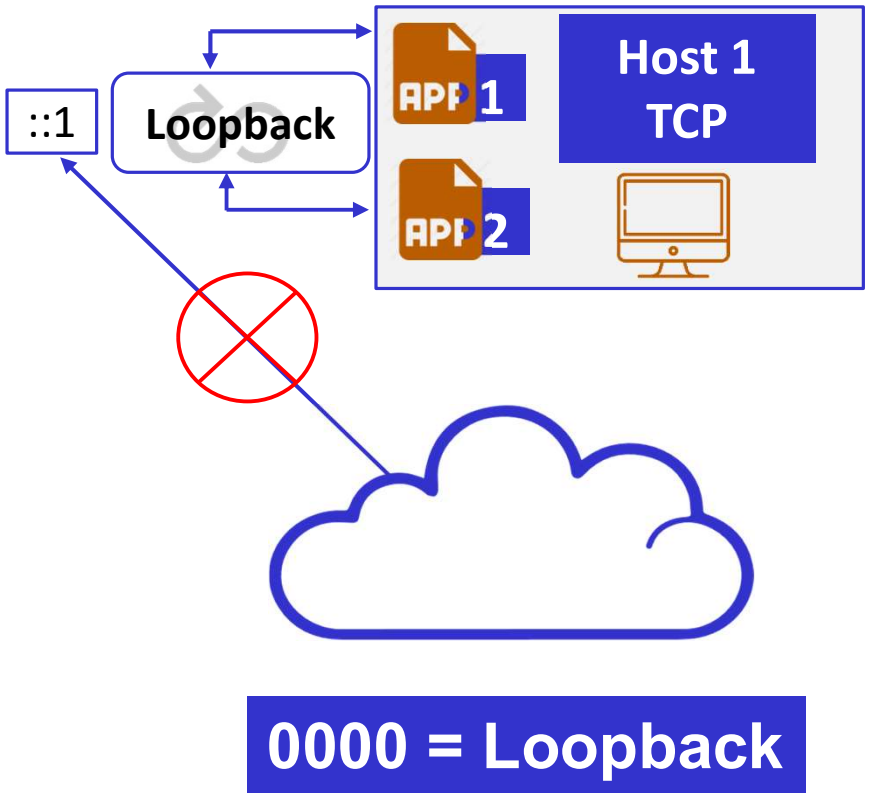
IPv6 Stateless Autoconfiguration



Loopback Address

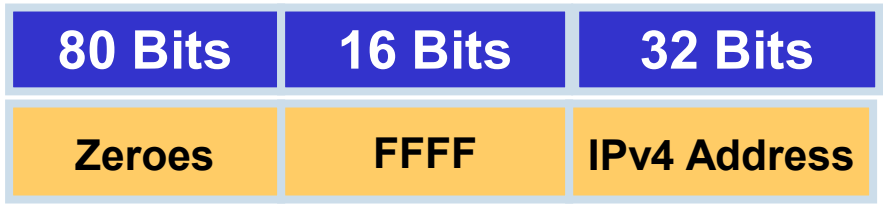
- IPv6 loopback address is 0:0:0:0:0:0:0:1 (::1)

- Acts like IPv4 loopback.
  - Can't be assigned to physical interface.
  - Used by local applications
  - Can't travel outside node
  - Can't be forwarded by router



IPv4 Addresses in IPv6

- From reserved space (0000::/8)
- IPv4 Mapped (Embedded) IPv6 Addresses.
- Last 32 bits = IPv4 address
- Shown in IPv4 notation



IPv4 Mapped IPv6 Address

::ffff:192.168.0.1

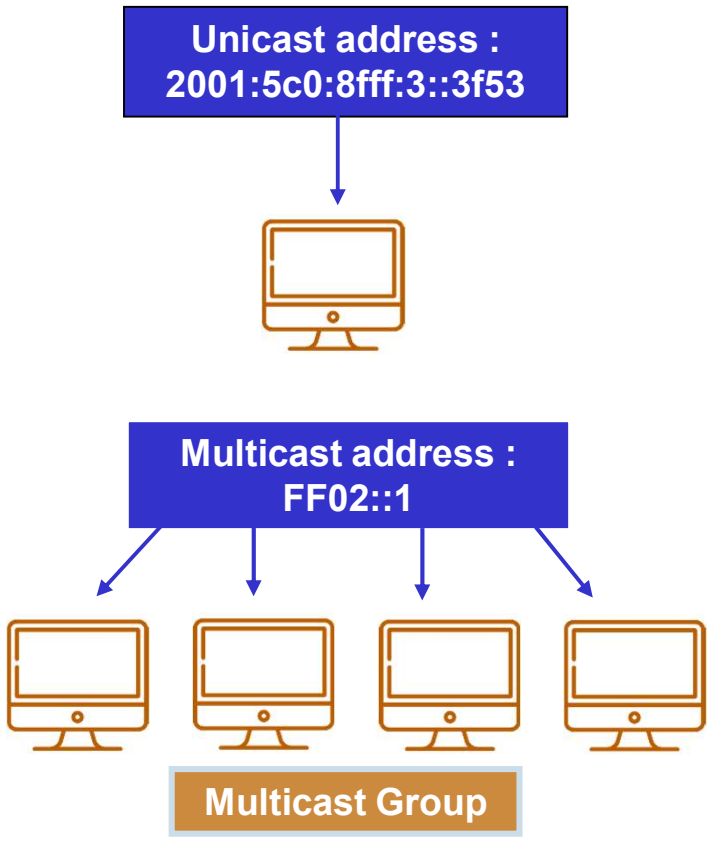
IPv4 Compatible IPv6 Address

::192.168.0.1

Should not be used.

IPv6 Multicast

- In IPv6, multicasting used widely
- Multicast is like a newsletter subscription.
- Devices belong to a multicast group
- IPv4 multicast uses Class D range: (224.xx.xx.xx – 239.xx.xx.xx)



IPv6 Multicast Scope

- IPv6 multicast addresses start with FF.
- Last 4 bits is scope. (Ex. FF01, FF02, etc).
- FF01:: means on same interface
- FF02:: means on same link
- FF05:: means in the same site
- FF0E:: means in the Internet.

(From RFC 4291)

Common IPv6 Multicast Groups

- Multicast addresses are registered with the Internet Assigned Numbers Authority (IANA).

See:

http://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicast-addresses.xml

IPv6 multicast address	Description
FF02::1	**The all-nodes address**
FF02::2	**The all-routers address**
FF02::5	**The all-Open Shortest Path First (OSPF) routers address**
FF02::6	**The all-OSPF designated routers address**

IPv6 Address Summary

- IPv6 is more than a bigger address!
- Many changes to protocol.

2001:5c0:8fff:fffe::1

2001::11:22:33:44

ff02::1

fe80::211:d8ff:fe39:292b

fe80::192:168:1:100

fe80::169.254.1.100

Winston Churchill famously said:

Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.

For us, as far as IPv6:

Now this is not the end. It is not even the end of the beginning. It is only the beginning of the beginning.

Things Yet to Learn

- IPv6 Neighbor Discovery
- IPv6 address planning
- IPv6 security
- DHCPv6
- DNSv6
- IPv6 migration planning
- Setting up an IPv6 lab
- Application migration
- How to segment your network
- Getting an IPv6 address range

In no particular order and off the top of my head.

Next Steps

- Join INTC Enterprise Advisory Council
  - Email: **president@industrynetcouncil.org** or mackermann@bcbsm.com
  - More information at: https://industrynetcouncil.org/eac/

- Join INTC to get more on other webinars
  - https://industrynetcouncil.org/supporters/

- Please email to me / Fred any IPv6 terms or concepts which you find confusing, where you find yourself stuck in implementation, or what you feel would help you! This will allow us to think about follow-on activities / webinars. Or comments about this class!

Questions?

Contact:

president@industrynetcouncil.org

Or

Nalini.Elkins@outsidethestack.net